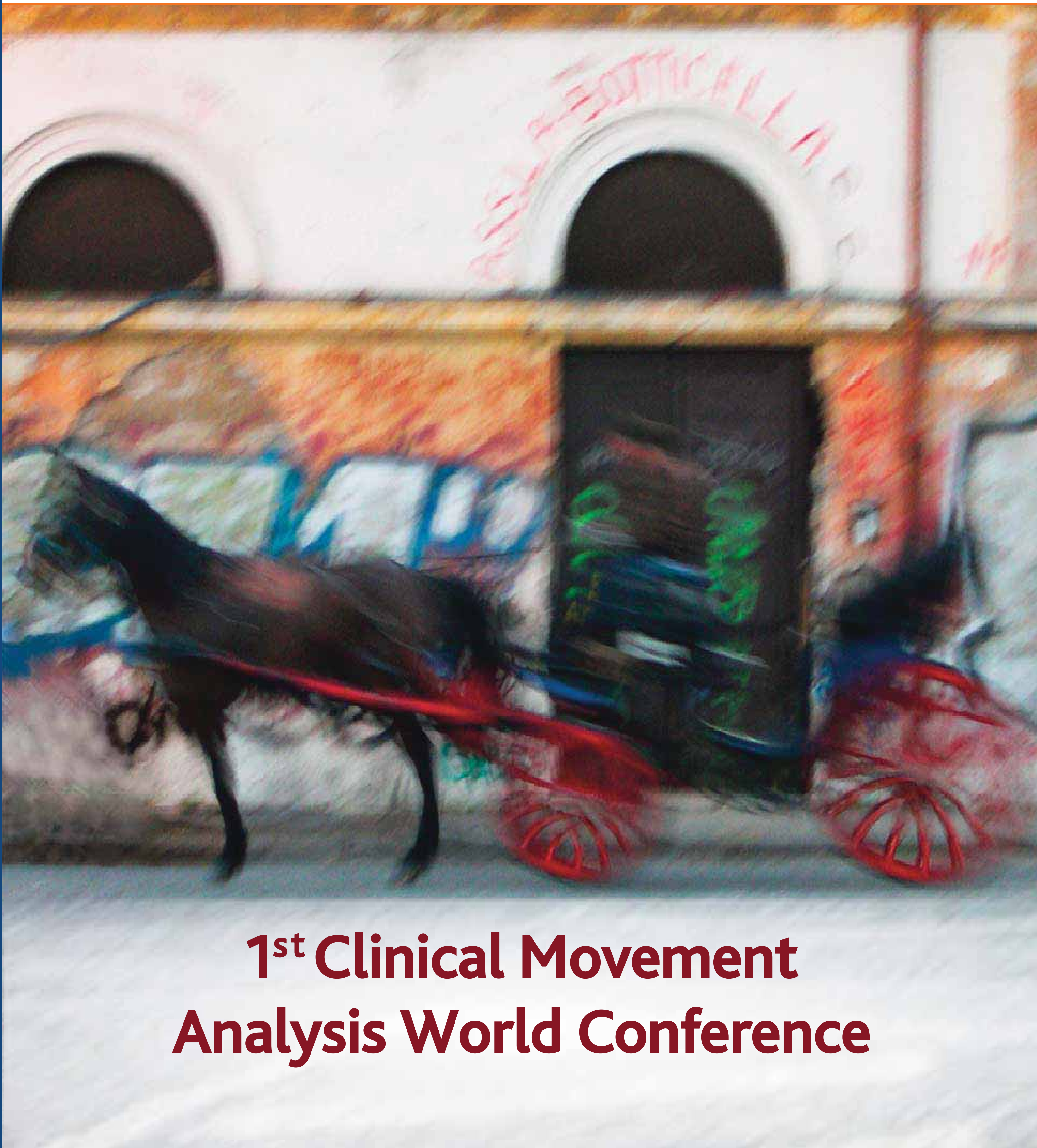
CONGRESS PROGRAMME

Bambino Gesù
OSPEDALE PEDIATRICO

SIAMOC
Società Italiana di Analisi del Movimento in Clinica

ESMAC
European Society for Movement Analysis in Adults and Childrens

Pegaso onlus



1st Clinical Movement Analysis World Conference

ROME, 29th September - 4th October 2014

WELCOME TO THE

1st Clinical Movement Analysis World Conference

15th Annual Meeting of the Italian Society of Clinical Movement Analysis

23rd Annual Meeting of the European Society for Movement Analysis in Adults and Children

ROME

29th September - 4th October 2014

CONTENTS

Dear members, colleagues and friends,

A very warm welcome to what we would like to call the 1st Clinical Movement Analysis World Conference. The conference reflects the merging of long-standing experiences of the SIAMOC and ESMAC societies. It embodies the 15th Annual Meeting of the Italian Society of Clinical Movement Analysis (SIAMOC) and the 23rd Annual Meeting of the European Society for Movement Analysis in Adults and Children (ESMAC). The conference is intended for those interested in the clinical and technical aspects of human movement analysis. Our multidisciplinary event provides a vibrant and enjoyable forum for researchers and clinicians to meet and discuss how to advance the state-of-the-art in movement analysis.

The Clinical Movement Analysis World Conference will be hosted by the Movement Analysis and Robotics Laboratory (MARLab), Division of Neurorehabilitation, Department of Neurosciences, "Bambino Gesù" Children's Hospital, and will be held in the Angelicum Conference Centre, Rome, Italy.

Rome, the eternal city, has the unique appeal of being a vast outdoor museum recalling 3000 years of the history of Western Civilization. Rome is also visited for its indoor museums and picturesque streets such as those in Trastevere, Campo dei Fiori, Testaccio or the Jewish districts, filled with charming lanes decorated with flower boxes and wonderful churches framed by historical palazzi. The Tevere and the Saint Peter cathedral dome are the magical backgrounds of most of the city's landscapes. But although it has its ancient monuments and art treasures, the city also dazzles with life in its beautiful piazze such as Navona or Trinità dei Monti, filled with charming cafés and fantastic restaurants. The ancient and characteristic artistic shops of Via Margutta, Via Giulia and Via dei Coronari go hand in hand with trendy new shops, restaurants, and contemporary cultural attractions such as the MACRO, GNAM and MAXXI museums which remind you that this is a city of the present and future, as much as it is of the past. Rome is really the eternal city in which you can also relax, experiencing Fellini's dolce vita sipping espresso or cappuccino in via Veneto, going on a major shopping spree, enjoying the latest nightlife hotspot, or going about without a destination in a typical Roman horse-drawn carriage.

We welcome you in Rome.

Dr. Maurizio Petrarca
Conference chair

Prof. Ugo Della Croce
President SIAMOC

Prof. Jaap Harlaar
President ESMAC

General Information

ORGANIZING SECRETARIAT

BioMedia
La condivisione del sapere

Via L. Temolo 4 - 20126 Milan (Italy)
www.biomedia.net
Ph. +39 02/45498282
Fax +39 02/45498199

http://www.esmac-siamoc2014.com/
e-mail: congress@esmac-siamoc2014.com

CONGRESS VENUE

Angelicum Congress Centre
Pontificia Università
San Tommaso D'Aquino
Largo Angelicum, 1 - 00184 Roma
Telefono 06.6702441
Mobile: 339.2770457
Fax 06.6702289
e-mail: congressi@pust.it
www.angelicumcongress.it

EXHIBITION AREA AND ACKNOWLEDGEMENTS

The exhibition Area is located in the Cloister Area and Sala delle Colonne.
It is open from 1st October, 4.00 pm to 4th October 1.00 pm.

The Organizing Committee gratefully acknowledges the support of the Companies and Associations participating in the Congress.

CONGRESS LANGUAGE

The Congress will be held in English.
Simultaneous Translation is provided for Symposium 8 and Keynote Lectures.

NAMES BADGES

Participants are requested to wear their name badge at all times during congress. Access to the Scientific Programme and Social Events is restricted to those who have registered and wear their badges.

CERTIFICATE OF ATTENDANCE

A certificate of attendance will be available to each registered congress participant at the end of the Congress.

CONTINUING MEDICAL EDUCATION **(ECM only for Italian participants – Biomedia Provider n. 148)**

The event addresses to the disciplines of Terapista Occupazionale, Medico Chirurgo, Fisioterapista, Terapista della Neuro e Psicomotricità dell'Età Evolutiva

In order to obtain credits, participants must attend the full educational programme (100% of the meeting) and pass the final learning test available on line on the site www.providerecm.it.

Id. 103487 **1st Clinical Movement Analysis World Conference (01/10/2014-04/10/2014)**
Credits 7

Id. 104943 Gait Course (29/09/2014-01/10/2014)
Credits 19.5

Symposia 1-8 (29/09/2014-01/10/2014)
Credits 3

Id. 104947 The many interplaying aspects influencing balance control
Id. 104974 Gait analysis in knee osteoarthritis - relevance, research and practice
Id. 105909 From cerebral palsy to subacromial pain syndrome: new methods and clinical applications of upper limb motion analysis
Id. 105910 Human movement simulation and modeling
Id. 105912 Movement analysis with inertial sensors
Id. 105920 Orthosis design
Id. 105922 Case series – adults and children

Id. 105927 Ecological rehabilitation
Credits 5

ABSTRACTS

Abstracts in all areas of clinical movement analysis are welcome and have been selected for the scientific program via a competitive, peer-review process.

AWARDS

During the conference four awards will be given.

Two of the awards will be jointly offered by both the SIAMOC and ESMAC societies. One will be assigned to the best methodological paper and one to the best clinical paper. The jury will be selected by both ESMAC and SIAMOC committees. Both awards will consist of paper publication in "Gait & Posture" via a fast review process as well as a money prize of 250 Euros. A third award will be offered by the local organizers of the conference and will be assigned to the best poster. The jury will be composed of the local organizers as well as a member selected by ESMAC and SIAMOC committees. This is the "Congress Prize" and will consist of a money prize of 250 Euros.

A final award will be offered by the BTS company - the "BTS Congress prize". It will be assigned to a young researcher (those under 30 years of age). The jury will be selected by ESMAC and SIAMOC committees. It consists of a travel grant to spend 5 days at a European movement analysis laboratory.

ABSTRACTS TIME TABLE

2nd October	AULA MAGNA	AULA MINOR
09.50 - 10.30	*Oral Communications* **C001-C004**	
11.00 - 12.30	*Oral Communications* **C005-C013**	*Oral Communications* **C014-C022**
14.10 - 15.00	*Oral Communications* **C023-C027**	
15.00 - 16.00	*Oral Communications* **C028-C033**	*Oral Communications* **C034-C039**
16.00 - 18.00	**Poster Session Coffee Break**	
3rd October	**AULA MAGNA**	**AULA MINOR**
09.40 - 10.30	*Oral Communications* **C040-C044**	
11.00 - 12.30	*Oral Communications* **C045-C053**	*Oral Communications* **C054-C062**
14.10 - 15.00	*Oral Communications* **C063-C067**	
15.00 - 16.30	*Oral Communications* **C068-C076**	*Oral Communications* **C077-C085**
17.00 - 18.00	*Oral Communications* **C086-C091**	*Oral Communications* **C092-C097**
4th October	**AULA MAGNA**	**AULA MINOR**
10.10 - 11.40	*Oral Communications* **C098-C0106**	*Oral Communications* **C107-C0115**
12.00 - 13.00	**Prizes, communications and wrap up**	

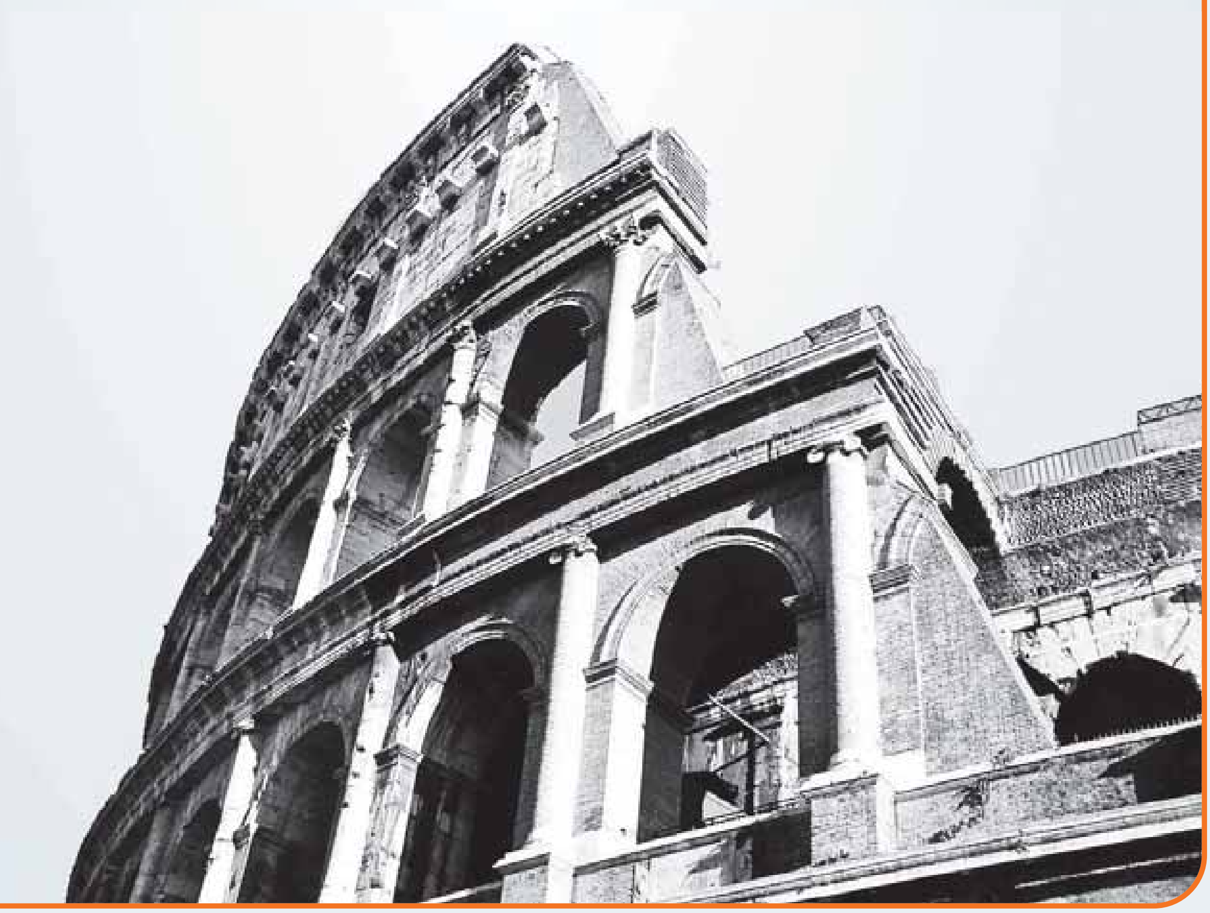
SOCIAL EVENTS

1 October 2014 - 8.00 pm
COCKTAIL at Terrazza Caffarelli
Adress: Terrazza Caffarelli dei Musei Capitolini
Piazzale Caffarelli 4, Rome

Website: www.museicapitolini.org/oltre_il_museo/caffetteria

3 October 2014 - 8.30 pm
GALA DINNER at Radisson Blu Hotel - 7 Floor
Adress: Radisson Blu es. Hotel, Rome
Via Filippo Turati 171, Rome
With reservation only. Dinner costs 50.00 Euros.

Website: www.radissonblu.com/eshotel-rome



Unknown - The number of domes in Rome is unknown. It is difficult to count them and no one has done so. It could be a challenge for experts in measurement and estimation. San Peter's Domeemerges from the city landscape, impressive for its elegance and lightness born from the mind of Michelangelo. But it is not the largest Dome in Rome, because with its 42 meters of diameter it is surpassed by the oldest one: the Pantheon! The greatest load-bearing dome in the world with a diameter of more than 43 meters (here in a painting by Canaletto, 1700).The total height of the Pantheon is the same as the diameter of the dome, that is, it can perfectly contain a sphere of a 43-meter diameter. An elegance completed in 128 AD and dedicated to all of Rome's divinities. It was built so that you would feel you were in the face of divinity: very small!


San Peter's Dome


Pantheon's Dome

The third Roman dome is that of Saint Giovanni Bosco in the Cinecittà district. Cinecittà is Rome's Movie City, the Italian Hollywood where many famous movieswere made in its indoor and outdoor theatres. Recently, an historical movie was made, not in Rome, even though it was set during the Roman Empire: Gladiator. Indeed, it is a remake, achieved with modern techniques because Marco Aurelius' triumphant victory over the Marcomanni was already represented in the bas-relief on the Marcus Aurelius Column, that was erected in about 150 AD and is now in the centre of Piazza Colonna in front of Palazzo Chigi, hosting the Italian government. Certainly, Rome harbors many Columns and Obelisks.

The Marcus Aurelius Column was constructed after the Trajan Column, that was erected around 100 AD and is now near to the Angelicum Conference Centre, exiting on the left. Its sculptures in bas-relief describe Trajan's triumph over the Dacia.

Thirteen - there are thirteen Egyptian obelisks in Rome, the largest number in the world. They have an unusual history because, after the conquest of Egypt, the Romans and all of western culture was influenced by the Egyptian myth of Ra, the divinity of the sun. The obelisks represent a petrified ray of Aten, the sun disk. The Romans brought 8 obelisks from Egypt and reproduced 5 of them in Rome as perfect copies of Egyptian obelisks, hieroglyphics included. It is known that originally there were more than thirteen, and now they are not standing in the place in which the Romans put them. In fact, they fell after the end of the Roman Empire and were forgotten during the Middle Ages, except for the one in Saint Peter's square that stood until 37 AD, and had been originally on the wall of Nero's Circus. All the otherswerere-discovered and re-erectedduring the sixteenth century in the Renaissance period, with the aim to adorn Rome and to indicate some of the most important places in a sort of reference system that facilitates navigation in and around the city (a Renaissance GPS!).


Marcus Aurelius Column

Obelisk in Piazza Navona over the Quattro Fiumi fountain

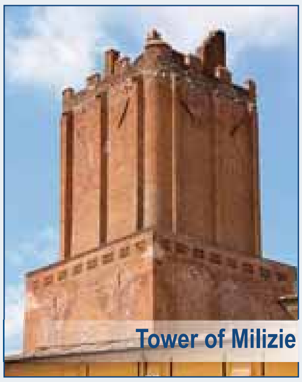
The highest obelisk (in the world) is the one close to Saint John in Laterano, the second is in front of Saint Peter's Basilica. One of the smallest but most beautiful, is the one on the dorsum of a little elephant in the Minerva square. The smallest is in Villa Celimontana and dates back to the age of Ramsete II. They witness 3000 years of human culture.

Two thousand - there are 2000 fountains in Rome. During the Roman empire many aqueducts were built, and Rome was full of thermal baths like Caracalla. These aqueducts were abandoned during the Middle Ages and rebuilt during the Renaissance. In this period, incredible fountains were built. Everyone knows the Trevi Fountain and the Triton Fountain, but fewer people know the Turtle Fountain in the Jewish district. Now you are advised, there are 2000, so good hunting!

Turtle Fountain

Two thousand - there are 2000 "nasoni", literally the "big noses" as they are familiarly called by the Roman citizens, the fountains with a curved tube perforated on the upper side in order to facilitate drinking. Yes, the water from the public aqueducts in Rome is superior and cheaper than most of the water sold in bottles. But in all the Roman restaurants you will find longer lists of wines to select than mineral water lists. In fact it is also known that in Marino, near Rome, wine flows from the Fountains, as a popular Roman song tells us! Indeed, in the first week of October in Marino, an annual wine festival is held, and on this occasion wine really flows from the fountains! Furthermore, near Rome some of the best wines in the world are produced. Drink with moderation if you are driving!

Three hundred - there were 300 towers in the city and the skyline was similar to the ears of wheat in a field. At present there are still 50 of them, even though most of them are difficult to find or recognize, because they were embedded in buildings during the Renaissance. During the Middle Ages most of them were destroyed during political conflicts among the aristocracy and the middle class. The towers were the privilege of the aristocracy. One of the most ancient towers is the Milizie, also known as the leaning tower. It is right in front of you when you exit the Conference Centre. Originally, it was comprised of three levels, the highest of which collapsed during earthquakes. One popular legend tells us that it is the tower where Nero observed Rome burning while he was playing the lira. Another legend is that the tower is the watching eye of an underground building belonging to the Emperor Augustus and when he reawakes he will climb up in his tower to see the city. Please look at him when you exit the conference!!!



Tower of Milizie

HOTELS

For reservation or information, please contact
EvArt – Arte ed Eventi
Via Aurelia, 455 – 00165 Roma
Tel. 063207958 – e-mail infoevart@libero.it

Congress Programme & Oral Communication

Aula Major **Overture ceremony**

16:00-17:00 **Welcome messages**

17:00-17:40

REFERENT CONTROL OF MOTOR ACTIONS AND RELATION TO SENSORIMOTOR IMPAIRMENT

Anatol G. Feldman
Department of Neuroscience, University of Montreal
Feil&Oberfeld/Jewish Rehabilitation Hospital Research Centre, Center for Interdisciplinary Research in Rehabilitation (CRIR), Laval, Qc, Canada

e-mail: feldman@med.umontreal.ca

ABSTRACT. Accumulating data suggest that neither kinematic, muscle forces nor EMG patterns are directly specified by the nervous system. Instead, neural control of actions focuses on pre-determining a task-specific, referent position of body segments at which muscles become active. Kinematic and kinetic patterns emerge depending on the deviation of body segments from the referent position. This understanding of central control of actions is beneficial in solving several classical problems in behavioral neuroscience, e.g. the posture-movement problem of how movement from a stable posture can be produced without evoking resistance of posture-stabilizing mechanisms and how a single step or continuous gait can be produced without falling. Spinal and brain lesions may impair the referent control, resulting, in particular, in spasticity and/or muscle weakness.

17:40-18:30

DISORDERED MOTOR CONTROL AND SPASTICITY

Mindy F. Levin
School of Physical and Occupational Therapy, McGill University, Montreal, Qc, Canada
Feil&Oberfeld/Jewish Rehabilitation Hospital Research Centre, Center for Interdisciplinary Research in Rehabilitation (CRIR), Laval, Qc, Canada

e-mail: mindy.levin@mcgill.ca

ABSTRACT. The equilibrium-point threshold control theory of motor control describes how central regulation of muscle activation thresholds, including that of the stretch reflex, results in different motor actions, in particular, muscle relaxation, motion, and isometric torque production in single- or multi-joint systems.After damage to the central nervous system such as brain injury or stroke, sensorimotor activity is disrupted and individuals are less able to accomplish functional tasks using pre-morbid muscle activation and/or kinematic patterns. Disrupted movement ability may be explained by limitations in the regulation of muscle activation thresholds at the single and double-joint level. The SRT depends on direct and indirect descending influences on motoneuronsas well as the velocity of change in the muscle length. How deficits in agonist-antagonist muscle activation in the single-joint elbow system in patients with spastic hemiparesis are related to limitations in the range of regulation of SRTs and motor compensations as well as implications for sensorimotor recovery will be discussed.

19:00 - 22:00

Welcome cocktail
Terrazza Caffarelli

9:00-9:50 **BAUMANN LECTURE**
Aula Major

Tim Theologis
MSc, PhD, FRCS
Consultant Orthopaedic Surgeon
Nuffield Orthopaedic Centre, Oxford, UK

e-mail: Tim.Theologis@ouh.nhs.uk

ABSTRACT. The management of flexible flat feet in children remains controversial. The majority of children with flat feet have no symptoms or physical limitations.
However, some children develop symptoms of varying severity and this affects their quality of life as measured by the Oxford Foot and Ankle Children's Questionnaire.
The development of symptoms and physical limitations does not always correspond to the severity of the deformity as assessed clinically. Kinematic analysis of children with flexible flat feet using the Oxford Foot Model showed that some aspects of forefoot motion are mostly associated with increased disability. MRI studies showed that anatomical changes in the subtalar joint may be related to increased navicular drop. Associating the level of symptoms and disability to specific morphological and functional characteristics in these children is likely to throw more light into our understanding of the condition and its management.

9:50-10:30 **ELDERLY DISEASES**
Aula Major ***Chairs: Paolo Zerbinati, Enrico Castelli***

9:50-10:00 A STATISTICAL APPROACH TO DISCRIMINATE BETWEEN NON-FALLERS, RARE-FALLERS AND FREQUENT FALLERS IN OLDER ADULTS
A. Merlo, P. Quadri, E. Maranesi, D. Zemp, I. Campanini, S. Fioretti

10:00-10:10 THE IMMEDIATE EFFECT OF PATELLAR TENDON STRAP ON WEIGHT BEARING ASYMMETRY DURING SQUATTING IN PATIENTS WITH UNILATERAL KNEE OSTEOARTHRITIS: A PILOT STUDY
I. Demirbüken, S. Özyürek, S. Angın

10:10-10:20 THE INFLUENCE OF WEAKNESS ON POSTURE CONTROL, A SIMULATION STUDY
M. Afschrift, F. De Groote, S. Verschueren, J. De Schutter, I. Jonkers

10:20-10.30 STRIDE-BY-STRIDE GAIT SPATIO-TEMPORAL PARAMETERS ESTIMATE FROM SHANK-WORN IMU RECORDINGS: VALIDATION ON PARKINSON, CHOREIC, HEMIPARETIC AND HEALTHY ELDERLY SUBJECTS
D. Trojaniello, A. Cereatti, E. Pelosin, A. Mirelman, J.M. Hausdorff, L. Avanzino, U. Della Croce

10:30-11:00 **Coffee break**

A STATISTICAL APPROACH TO DISCRIMINATE BETWEEN NON-FALLERS, RARE-FALLERS AND FREQUENT FALLERS IN OLDER ADULTS WITHOUT COGNITIVE IMPAIRMENT

A. Merlo (1), P. Quadri (2), E. Maranesi (3), D. Zemp (2), I. Campanini (1), S. Fioretti (3)
(1) LAM – Motion Analysis Laboratory – AUSL of Reggio Emilia, Italy
(2) Servizio Sottocenerino di Geriatria, Regional Hospitals of Lugano and Mendrisio, Switzerland
(3) Department of Information Engineering, Università Politecnica delle Marche, Ancona, Italy

Main topics: Movement analysis in clinical practice, Functional outcome measures in mobility, Analysis of clinical movement data

INTRODUCTION and AIM

The identification of subjects at risk of falling has become a strategic goal in health policy programs and relies on clinical screening tools. Instrumental balance assessments can improve the predictive performance of these clinical scales [1].

Frequent fallers (FF) are known as subject at very high risk of fall and do not need any further screening to be categorized. Conversely, the early identification of future new-fallers among older people would permit to focus the delivery of fall prevention programs on selected individuals only (intervention appropriateness).

Single posturographic parameters (PP) have been proven to differentiate between non-fallers (NF) and FF but not between NF and first or, more in general, rare fallers (RF) [2]. In this study, we applied the statistical technique of Principal Component Analysis (PCA) on a set of posturographic data obtained from a large sample of elderly to investigate the discriminant capacity of tuned mixtures of posturographic variables.

PATIENTS, MATERIALS and METHODS

The study population consisted of 130 cognitively able individuals (clinical dementia rating, CDR ≤ 0.5), 58 M and 84 F, mean age 77 ± 7 years and age range 62–91 years, seen consecutively at the Memory Clinic of the Regional Hospitals of Mendrisio and Lugano, Switzerland. Subjects were categorized as NF (N=67), RF (one or two falls, N=45) and FF (more than two falls, N=18) according to their last year fall history. Postural stability was assessed in five different conditions: eyes open (EO) and closed (EC) on both a firm and a soft surface (EOFS, ECFS, EOSS, ECSS), and in dual task, that is with eyes open on a firm surface while performing a cognitive task (backward counting). Protocol details are described in [3].

Principal Component Analysis (PCA, Kaiser criterion, Varimax rotation) [4] was used to select the most significant features among the set of 17 parameters that characterize the posture maintenance task. PCA-derived parameters, rather than the individual PP, were used to test, in each task, statistically significant differences between the NF, RF and FF groups (Wilcoxon test, alpha=0.05).

RESULTS

In the EOFS and EOCS tasks, the PCA analysis showed that 4 PCs accounted for 88% and 89% of the variance in the whole set of parameters. The Kaiser-Meyer-Olkin measure of sampling adequacy had a value of 0.78 and of 0.77, respectively, thus confirming a good factor analysis. PCA allowed to reduce the number of PP introducing new ones (i.e. the PCA derived parameters) characterized by being, for each experimental trial, a linear combination of the most significant PP (loading value higher than 0.4 in absolute value). The PCA-derived parameter based on a combination of a set of CoP medio-lateral variables in the EOFS condition was different between NF and FF ($P < 0.001$), in accordance with the literature [2]. The PCA-derived parameter based on a combination of a set of CoP antero-posterior variables in the EOSS condition was different among all groups, that is between NF and RF ($P < 0.05$), and between RF and FF ($P < 0.05$).

DISCUSSION and CONCLUSIONS

For the first time a method to discriminate between RF and NF was presented, based on posturographic data. PCA allowed to define summarizing variables with a better discriminant ability than the single PP.

The EOSS condition was found to better discriminate among classes of fallers, in accordance with [3], and should be included in protocols aiming at assessing the risk of falling in older people with no or mild cognitive impairment.

To overcome the limits of retrospective studies, a prospective study to validate the presented results is currently underway. The main results of the present work is new to the literature and could lead to a relevant improvement in the performance of the available fall risk assessment tools.

REFERENCES

[1] Panzer et al, Arch Phys Med Rehabil, 2011; 92:905-12
[2] Piirtola et al, Gerontology, 2006; 51:1-16, Review
[3] Merlo et al, Gait Posture, 2012; 36:662-6
[4] Maranesi et al., Gait & Posture, 2014, 39, 501-5.

THE IMMEDIATE EFFECT OF PATELLAR TENDON STRAP ON WEIGHT BEARING ASYMMETRY DURING SQUATTING IN PATIENTS WITH UNILATERAL KNEE OSTEOARTHRITIS: A PILOT STUDY

İlkşan Demirbüken (1), Seher Özyürek (2), Salih Angın (2)
(1)Marmara University, Faculty of Health Sciences, Dept. of Physiotherapy and Rehabilitation, İstanbul, Turkey
(2)Dokuz Eylul University, School of Physical Therapy and Rehabilitation, İzmir, Turkey

Main topics: Experimental studies in human movement science, Orthotics.

INTRODUCTION and AIM

Knee osteoarthritis (OA) has commonly been associated with a symptom of pain resulting in deteriorated physical performance and functional mobility [1]. The common observed compensation strategy during functional tasks was an inter-limb weight bearing asymmetry (WBA) [2]. WBA is thought to be primarily arisen from the pain of the affected side to reduce loading of the limb. Several pharmacologic and non-pharmacologic interventions are used for relief of knee pain and to be able to get involved in functional activities for people with knee OA. Patellar tendon strap (PTS) is one of the non-pharmacologic interventions that reduces loading of the tendon at its insertion by altering the angle and direction of stress at the site of injury, unloading the effected site and decreasing the pain by distributing forces on it. The aim of the present study was to investigate the immediate effect of a PTS on WBA during squatting in people with unilateral knee OA.

PATIENTS/MATERIALS and METHODS

Ten patients (6 female, 4 male, aged 43-66 years) with unilateral knee OA were included in our study if they had documented radiological alterations in the knee joint of grade 2 or more according to Kellgren-Lawrence criteria, and had weight bearing knee pain of >4 on a 10 cm Visual Analog Scale on their affected knee. WBA of patients was assessed using a Weight Bearing Squat Test (WBST) of the Balance Master System (NeuroCom version 8.1 International, Inc., USA). This test quantifies the percentage of body weight borne by each leg. The patients were instructed to look forward and stand erect and then squatting in two positions of knee flexion (30º and 60º). The WBST was repeated twice; firstly without wearing PTS and then with PTS. WBA was calculated using the formula: WBA: $|(A\%-NA\%) / (A\%+NA\%)| \times 100\%$ where A and NA represent affected and non-affected limb, respectively. The WBA value of 0% would represent perfectly symmetrical weight bearing in terms of percentage weight bearing between the affected and non-affected limb. Wilcoxon signed rank test was used to compare the values of WBA at different squat positions with and without PTS.

RESULTS

The results demonstrated no significant differences in WBA values of people with unilateral knee OA before and immediately after wearing PTS (Table 1, $p>0.05$).

DISCUSSION and CONCLUSIONS

PTS has been largely used as a conservative intervention of knee pain. Furthermore athletes report a substantial benefit in wearing variety of patellar orthotics during sportive activities. The underlying mechanism of PTS by which this improvement occurs is unclear. Due to its effect on changing patellar tendon angle and direction of the stress [3], it was expected that PTS may also have positive effect on WBA during squatting in people with knee OA. However, so far no studies have assessed the effect of these straps in people with knee OA although they suffer from quadriceps arthrogenic muscle inhibition and knee pain. The results of the current study showed improved values of WBA during squatting but indicating no significance. Further research with larger sample sizes investigating the effect of PTS on WBA during functional activities in people with knee OA is warranted.

REFERENCES

[1] Page CJ et al. Physiotherapy management of knee osteoarthritis. Int J Rheum Dis 2011;14(2): 145-51.
[2] Christiansen CL et al. Weight-bearing asymmetry during sit-stand transitions related to impairment and functional mobility after total knee arthroplasty. Arch Phys Med Rehabil 2011;92(10): 1624-9.
[3] Lavagnino M et al. Infrapatellar Straps Decrease Patellar Tendon Strain at the Site of the Jumper's Knee Lesion: A Computational Analysis Based on Radiographic Measurements. Sports Health 2011;3(3): 296-302.

Table 1: Changes in weight bearing asymmetry (WBA) values after wearing PTS during standing and squatting.

Time WBS	before median (interquartile range)	immediately after median (interquartile range)	*p*- value
Standing	5.0 (2-10)	7.0 (2-15)	0.372
30º of squatting	12.0 (4-17.5)	7.0 (2-11.5)	0.095
60º of squatting	9.0 (5.5-16.5)	4.0 (2-12.5)	0.206

THE INFLUENCE OF WEAKNESS ON POSTURE CONTROL, A SIMULATION STUDY

M. Afschrift (1), F. De Groote (2), S. Verschueren (3), J. De Schutter (2), I. Jonkers (1)
(1) Human Movement Biomechanics Research Group, Department of Kinesiology, KU Leuven, Belgium
(2) Division PMA, Department of Mechanical Engineering, KU Leuven, Belgium
(3) Research Group for Musculoskeletal Rehabilitation, Department of Kinesiology, KU Leuven, Belgium

Main topics: elderly, posture, simulation

INTRODUCTION

The high incidence of falls in the elderly is a highly important topic in our ageing society. One of the factors that influence posture control in the elderly is the person's capacity to generate stabilizing joint moments through coordinated muscle action [1]. However it is difficult to establish a causal relationship between weakness and balance control using an experimental approach due to many confounding variables. Therefore it's difficult to predict the impact of weakness at a specific joint on posture control. Therefore, a simulation approach is used in the present study to evaluate the relative importance of the influence of ankle versus hip joint weakness on postural stability. This insight is however highly relevant for the design of effective fall prevention training, focussing either at the strengthening ankle or hip musculature.

METHODS

OpenSim was used to create a feedback control model based on a generic musculoskeletal model [2]. This model had six degrees of freedom (i.e. hip flexion/extension, knee flexion/extension and ankle plantarflexion/dorsiflexion of the right and left leg). A constraint was used to keep the feet flat on the ground during the simulation. The balance of the model was perturbed by a forward momentum of 37.5 Ns acting at the centre of mass (COM) of the torso. Linear feedback of the whole body COM trajectory and torso orientation (position, velocity and acceleration) determined by feedback gains controlled the ideal moment actuators of the hips and ankles. Position, velocity and acceleration feedback gains followed from an optimization that minimizes the COM movement and actuator work. Weakness was induced by reducing the maximal moment generating capacities around the (1) ankle and (2) hip joint by 40%. Difference in ankle and hip kinematics and kinetics (especially work) were evaluated throughout the simulation duration.

Figure 1: The musculoskeletal model with COM feedback control to simulate posture control.

RESULTS

Weakness at the ankle joint has an important effect on the kinematics and kinetics required to restore postural stability (Table 1): there is an increase in anterior displacement of the COM and maximal hip and ankle range of motion (ROM). At the level of kinetics, there is an increase in the work provided by the ankle and hip actuators. Comparing the effect introduced by the ankle vs hip actuators, a similar amount of weakness at the ankle joint has amore effect on posture control than weakness at the hip joint as reflected in the analysed kinematics and kinetic parameters. In particular, there is an increase of 111% in anterior COM displacement and an increase of 53% in total work delivered by the actuators.

Table 1: The influence of weakness on kinematic and kinetic variables of posture control.

	COM movement	Hip ROM	Ankle ROM	Total Work	Ankle Work	Hip Work
Strong model	0.09 m	20°	7°	116J	37J	38J
Ankle weak	0.19 m	45°	22°	168J	77J	64J
Hip weak	0.09 m	18°	6°	110J	33J	28J

DISCUSSION and CONCLUSION

A forward simulation approach was used to quantify the influence of weakness around the ankle and hip joint on the posture control strategy. The results indicate that weakness around the ankle joint has a major influence on the posture control strategy. Persons with ankle weakness use a hip strategy that increases the hip contribution to control the COM movement. Despite its success in restoring balance, this strategy causes an increase in total work which influences metabolic energy consumption and fatigue. Weakness around the hip joint did not influence the posture control strategy to a similar extent. Therefore, this study suggests that effective fall prevention training programs should focus on increasing the strength of the muscles around the ankle joint.

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STRIDE-BY-STRIDE GAIT SPATIO-TEMPORAL PARAMETERS ESTIMATE FROM SHANK-WORN IMU RECORDINGS: VALIDATION ON PARKINSON, CHOREIC, HEMIPARETIC AND HEALTHY ELDERLY SUBJECTS

D. Trojaniello (1), A. Cereatti (1), E. Pelosin (2), A. Mirelman (3), J. M. Hausdorff (3), L. Avanzino (2), U. Della Croce (1)
(1) Information Engineering Unit, POLCOMING Department, University of Sassari, Italy
(2) Department of Neurosciences, University of Genoa, Italy
(3) Movement Disorders Unit of the Department of Neurology, Tel Aviv Sourasky Medical Center, Israel

Main topics: Analysis of clinical movement data, Analysis of gait and motor disorders

INTRODUCTION

In recent years, methods for estimating spatio-temporal parameters of gait from wearable inertial sensors (IMUs) measurements have been proposed and tested, mostly on healthy subjects, with few exceptions [1,2], which focused on single pathologies. No method was validated for the stride by stride analyses of spatial measures in various gait abnormalities. In this work, we evaluate a novel IMU based technique for the determination of both gait temporal and spatial parameters in four groups, characterized by different gait patterns.

MATERIALS and METHODS

The study included 11 hemiparetic (H) (FAC=3.6±1.5), 12 choreic (C) (UHDRS=34.9±16.9), 10 Parkinsonian (P) (UPDRS=62.7±19.1) and 10 healthy elderly (E). Data from two IMUs (Opal, APDM) attached to the subject ankles (20 mm above the malleolus) were acquired simultaneously with data from an instrumented gait mat (GAITRite, CIR System) used as gold standard (GS). Subjects walked for one minute at a self-selected speed, back and forth along a 12-meter walkway. Gait events (GEs) (initial contact - IC and final contact - FC) and resulting gait temporal parameters (stride T_{str} and stance T_{stn} duration) were estimated using an algorithm previously developed based on the preliminary identification of trusted gait phases and then of GEs search intervals in the IMU signals [3]. The stride length (L_{str}) was then estimated from the antero-posterior accelerations (i.e. along the direction of maximum average velocity in swing) by applying a modified version [3] of the OFDRI technique [4], followed by a further simple integration. The error in estimating IC, FC, T_{str}, T_{stn} and L_{str} was calculated as the difference of the IMU-based estimates and the GS estimates. Left and right side errors were averaged except for the H group (affected (A) and non-affected (NA) side). The relevant mean, standard deviation and mean absolute values (mae_S) were averaged within groups (*m*, *sd* and *mae*). A Kruskal–Wallis test was used to compare the mae_S among the groups.

RESULTS

In total, 1642 gait cycles (E=574, P=532, C=290, H=246) were analyzed. Two C and one H subjects were excluded from the analysis since the method could not estimate L_{str}. The descriptive statistics of the errors in estimating IC, FC, T_{str}, T_{stn} and L_{str} for all tested groups are reported in Table 1. None of the errors was significantly different among groups (p>0.05).

DISCUSSION and CONCLUSIONS

The method proposed was shown to be extremely accurate in estimating GEs, T_{str} and T_{stn} for all groups (Table 1). Moreover, L_{str} estimate maximum error for E and P groups was lower than those reported in previous studies [1]. The L_{str} estimation algorithm failed in one H subject probably due to the extremely low subject speed (<0.44m/s) and in two C subjects due to the excessive lateral swaying and stride-by-stride lateral deviations from the forward direction which prevented a correct signal realignment. The results are particularly promising considering the high variability of abnormal gait patterns evaluated (i.e. festinating, hyperkinetic, hemiparetic).

Table 1: Mean errors (m), standard deviation (*sd*) and mean absolute errors (mae) of gait parameters estimates.

		IC [ms]		FC [ms]		T_{str} [ms]		T_{str} [ms]		L_{str} [mm]	
	speed [m/s]	m (sd)	mae	m (sd)	mae	m (sd)	mae	m (sd)	mae	m (sd)	mae
E	1.18 ± 0.15	0 (8)	9	-7 (14)	20	0 (12)	9	-8(18)	21	2(20)	17
P	0.85 ± 0.15	10 (11)	13	-10 (18)	20	1 (15)	12	-9(19)	24	2(26)	19
C	1.03 ± 0.22	8 (13)	14	- 2 (15)	19	0 (18)	14	-9(19)	25	-8(30)	27
H (NA)	0.71 ± 0.19	-5 (11)	14	11 (13)	19	0 (15)	12	16(16)	23	1(30)	28
H (A)		4 (12)	17	19 (9)	20	0 (16)	13	17(14)	25	9(25)	26

ACKNOLEDGEMENT

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11:00-12:30 | **GAIT / CEREBRAL PALSY**
Aula Major | ***Chairs: Caroline Stewart, Reinald Brunner***

11:00-11:10 DOES INDUCED ACCELERATION ANALYSIS CONTRIBUTE TO THE INTERPRETATION OF DIFFERENT GAIT PATTERNS IN CHILDREN
F. João, A. Veloso, V. Moniz-Pereira, S. Cabral, R. Martins, V. Bagão, C. Escalda, J. Campagnolo, C. Duarte, S. Almeida, T. Kepple

11:10-11:20 KINEMATIC DIFFERENCES IN PRIMARY GENU RECURVATUM GAIT IN CEREBRAL PALSY – EARLY VS LATE ONSET
M. Klotz, M. Niklasch, M. Maier, D. Heitzmann, S. Wolf, T. Dreher

11:20-11:30 FATIGUE IMPACT ON GAIT IN CHILDREN WITH CEREBRAL PALSY: KINEMATICS AND ELECTROMYOGRAPHIC APPROACH
A. Parent, A. Pouliot-Laforte, P. Marois, C. Forsythe, M. Raison, L. Ballaz

11:30-11:40 IS CROUCH GAIT INEFFICIENT IN CHILDREN WITH CEREBRAL PALSY
K. Steele, M. Schwartz

11:40-11:50 SPATIO-TEMPORAL ANALYSIS OF TURNING IN CHILDREN WITH CEREBRAL PALSY
P.C. Dixon, J. Stebbins, T. Theologis, A.B. Zavatsky

11:50-12:00 CHANGES IN ARM MOVEMENTS DURING WALKING IN CHILDREN WITH DIPLEGIC CP
P. Van de Walle, J. De Rijck, J. Kenis , D. Monari, K. Desloovere, A. Hallemans, P. Meyns

12:00-12:10 THE RELATION BETWEEN ANALYTICAL AND FUNCTIONAL MEASUREMENTS OF SPASTICITY IN CHILDREN WITH CEREBRAL PALSY
L. Bar-On, G. Molenaers, E. Aertbeliën, D. Monari, H. Feys, K. Desloovere

12:10-12:20 DIFFERENCES IN TORQUE VALUES BETWEEN A FIXED AND NON-FIXED STANDARDIZED ISOMETRIC STRENGTH MEASUREMENT: A PILOT STUDY
M. Goudriaan, K. Delanghe, J. Casie, K. Desloovere

12:20-12:30 IMPACT OF MAJESTRO-FROST SURGERY IN THE TREATMENT OF INTERNAL HIP ROTATION IN CEREBRAL PALSY
D. Neves, M. Fujino, M. Filho, C. Kawamura, F. Blumetti, J.A. Lopes, S. Bittencourt, F. Farcetta, C.A. Santos

DOES INDUCED ACCELERATION ANALYSIS CONTRIBUTE TO THE INTERPRETATION OF DIFFERENT GAIT PATTERNS IN CHILDREN WITH CEREBRAL PALSY? (WORK IN PROGRESS)

F. João (1), A.P. Veloso (1), V. Moniz-Pereira (1), S. Cabral (1), R. Martins (1), V. Bagão (1), C. Escalda (2), J. Campagnolo (3), C. Duarte (2), S. Almeida (2), T. Kepple (4)
(1) CIPER, LBMF, Faculdade de Motricidade Humana, Universidade de Lisboa, Lisboa, Portugal
(2) Hospital Garcia de Orta, Almada, Portugal
(3) CHLC, Hospital Dona Estefânia, Lisboa, Portugal
(4) C-Motion, Inc., Germantown, MD, USA

Main topics: Analysis of clinical movement data, Experimental studies in human movement science.

INTRODUCTION and AIM

Two common gait patterns in children with spastic diplegic cerebral palsy (CP) are crouch gait and jump gait. Over time, these children develop progressive musculoskeletal deformities, fixed contractures and joint degeneration [1]. The correct interpretation of muscle function is crucial before a surgical intervention in order to improve functional mobility. The use of induced acceleration analysis (IAA) can help us to determine which net joint moments of force, developed by the muscles, provide support and forward progression in gait [2]. This study aimed to analyze the contributions of the different lower limb joint moments of force (MF) to support and progression in these two gait patterns.

PATIENTS/MATERIALS and METHODS

Fourteen children diagnosed with spastic diplegic CP, aged 11,2±3,3 yrs and GMFCS I/II/III participated in this study. One subject with a typical crouch gait pattern and another one with a jump gait pattern were chosen for this specific analysis and compared with normal. Motion capture was collected with an optoelectronic system of 15 Qualisys cameras operating at 100Hz and ground reaction force was collected with 2 Kistler and 1 AMTI force plates. 37 reflective markers and 4 marker clusters were used to reconstruct 12 body segments and 7 were used for this analysis. Joint moments of force (MF), segments' pose and centre of pressure position relative to the contact foot were computed in Visual 3D. The IAA was performed using two contact models: for the crouch and jump gait the foot rotated over the COP around an axis parallel to its medio-lateral axis, for the normal gait the same model was used except during foot flat period, in which the foot was not allowed to rotate [3].

RESULTS

The contribution to support in crouch gait comes mainly from the knee and ankle MF during the loading response (similar to normal), with an increase of the ankle contribution in the late stance and a permanent knee MF contribution. In jump gait the ankle MF (increased relative to normal) is always predominant during stance.

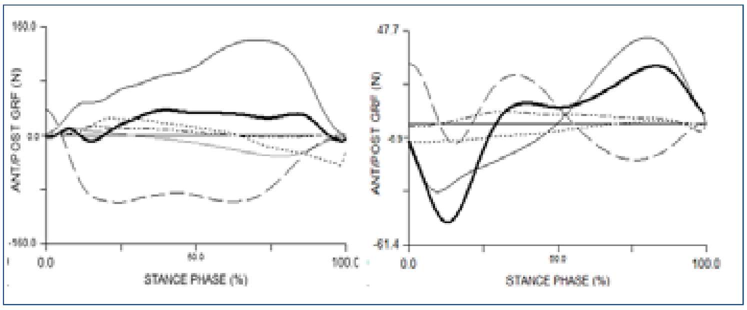

Figure 1: Contribution of the ankle flex/ext (solid), ankle abd/add (grey), knee flex/ext (dash), hip flex/ext (dot) and hip abd/add (dash dot) MF to ant/post GRF component (bold) in crouch (left) and jump (right) gait.

In forward progression, the braking phase in crouch is residual due to the counteraction of ankle+hip vs. knee MF, while propulsion has the contribution of the ankle MF (Fig.1). Contrarily to normal, the braking phase in jump gait is due to the ankle and hip MF, while the knee and hip abductor MF propel the body forward. The push-off period is mostly due to the ankle MF contribution while the knee MF slows down the body especially in late stance.

DISCUSSION and CONCLUSIONS

The increased ankle MF contribution to support the body against gravity in jump gait, especially in the first half of stance is possibly a consequence of the equinus position of the feet. In crouch gait, the 1st half of support is close to normal but the 2nd half has an abnormal contribution of the knee MF. In both gaits, hip MF has a reduced contribution to support when compared to normal, due to the increased hip flexion. The forward progression of the body in crouch gait results from the contribution of the ankle MF against an increased and opposite knee MF, and in jump gait the ankle MF is increased and compensates the knee MF braking. This type of analysis revealed to be important to better interpret the characteristics of these gait patterns and may aid the clinical intervention to improve the impaired mobility of these subjects.
ACKOWLEDGMENTS: This work was supported by CIPER-FCT (project: PEst-OE/SAU/UI447/2014)

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KINEMATIC DIFFERENCES IN PRIMARY GENU RECURVATUM GAIT IN CEREBRAL PALSY – EARLY VS LATE ONSET

Klotz MCM[1], Wolf SI[1], Niklasch M[1], Maier MW[1], Heitzmann DW, Dreher T[1]
[1]Department of Orthopaedic and Trauma Surgery, Heidelberg University Hospital, Heidelberg, Germany
Matthias.klotz@med.uni-heidelberg.de

INTRODUCTION and AIM

Compared to crouch or stiff gait genu recurvatum (GR) is less frequently found in cerebral palsy. It is characterized by knee hyperextension, which occurs most likely in mid- and late stance phase. Simon et al introduced a classification of an early and a late type GR depending on the maximum knee hyperextension during stance [1]. In this context Svehlik et al reported an increased prevalence of dynamic equines in early GR while fixed equinus was found in late GR types [2]. Treatment of GR depends on the underlying factors, but investigations addressing kinematic characteristic in early and late type GR are rare in the literature. Since equinus is seen as one major underlying factor in GR and the treatment of dynamic and fixed equinus vary among different authors, there is need for a better understanding of this pathology and its treatment

PATIENTS/MATERIALS and METHODS

In this retrospective study 463 patients with BSCP (GMFCS Level I-II) received three-dimensional gait analysis and were scanned for the presence of primary GR. GR was defined as a knee hyperextension of more than one standard deviation of an age matched control group during stance phase in either one or both of the limbs. Primary GR was defined as a GR without having previous surgery regarding the lower extremity, no selective dorsal rhizotomy and/or interventions like botulinum-toxin-A injection, shock wave therapy or serial casting during the last 6 months in the patient history. The classification into early and late type GR was done according to Simon et al and Svehlik et al [1, 2]. Finally, 30 patients (42 limbs, mean age 7.5 ± 5.5 years) matched the determined inclusion criteria and were therefore included for further analysis in this study. 20 limbs showed an early GR while 22 limbs showed a late type GR. T-test was used to compare the sagittal plane kinematics of the lower extremity between the early and late type GR limbs.

RESULTS

In our patient population, the prevalence of primary GR was 6.5% among patients with BSCP and GMFCS I/II. The prevalence of early (47.6%) and late (52.4%) type GR was almost equal. Knee hyperextension was 14.7° in limbs with an early type GR while it was smaller (11.9°) in late type GR limbs during stance. This difference was found to be significant ($p = 0.006$). 70% of the limbs with an early GR showed an equinus. In contrast only in 41% of the limbs with a late GR equinus was present. There was a trend for increased lack in ankle dorsiflexion in early GR ($p = 0.072$). Patients with late type GR showed increased hip flexion ($p = 0.044$) while the range of motion in pelvic tilt was significantly decreased ($p = 0.002$) compared to the patients with early GR. Despite a slight increased anterior trunk lean in limbs with late GR, there was no significant difference between the groups in mean anterior trunk lean ($p > 0.05$).

Table 1: shown are the kinematic parameters of the analyzed limbs during total stance and midstance phase in degrees. Subgroups into early and late type GR were built. # marks significant differences ($p < 0.05$).

		All	Early GR	Late GR	Norm group
	Patients	30	15	17	32
	Limbs	42	20	22	64
	Age in years (SD)	7.5 (5.5)	7.9 (6.6)	7.2 (4.4)	10.5 (4.5)
STANCE	Min knee flexion stance (SD)	−13.2 (8.5)	−14.7 (9.2)	−11.9 (7.8)	3.0 (3.7)
	% Gait cycle (SD)	32.2 (10.0)	23.0 (4.6)	40.6 (4.6)	
MIDSTANCE	Min knee flexion	−11.5 (9.6)	−14.6 (9.3)#	−8.8 (9.2)#	7.4 (4.6)
	Max dorsiflexion	−4.8 (16.1)	−8.1 (14.9)	−1.8 (16.9)	9.2 (2.8)
	Maximum hip flexion	16.3 (6.9)	15.0 (7.5)#	17.6 (6.2)#	32.1 (6.5)
	Max pelvic tilt	23.8 (7.0)	25.6 (7.0)	22.2 (6.7)	12.9 (4.9)
	Pelvic range	2.7 (1.6)	3.4 (1.6)#	2.0 (1.2)#	1.5 (0.8)
	Max trunk tilt	0.5 (10.3)	−0.9 (13.9)	1.8 (5.7)	
	Trunk range	2.5 (1.5)	2.5 (1.5)	2.4 (1.5)	
	Total equinus (<0)	23 (55%)	14 (70%)	9 (41%)	

DISCUSSION and CONCLUSIONS

The prevalence of primary GR was 6.5%, which supports previous reports mentioning a decreased prevalence of GR compared to crouch or stiff gait. The prevalence of early and late type GR was almost equal. In contrast to Svehlik et al., which reported no significant difference in severity between the early and the late type GR [2], in this study limbs with early GR showed a more severe knee hyperextension compared to the limbs with late GR type. The prevalence of equinus was increased in limbs with early GR compared to those with late type indicating that equinus is more important as underlying factor in early GR (plantar-flexion-knee-extension-couple). During late stance proximal factors like an anterior trunk lean and hip flexion, which were found to be significantly higher compared to early GR group, may be important in affecting knee extension. These findings should be considered when planning treatment of GR.

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FATIGUE IMPACT ON GAIT IN CHILDREN WITH CEREBRAL PALSY: KINEMATICS AND ELECTROMYOGRAPHIC APPROACH

A.Parent (1,2), A.Pouliot-Laforte (2,3), P.Marois (2), C.Forsythe (4), M. Raison (1,2), L. Ballaz (2,3)
(1) École Polytechnique, Montreal, Canada
(2) UHC Sainte-Justine (CRME), Montreal, Canada
(3) Université du Québec à Montréal, Montreal, Canada
(4) Quebec UHC, Quebec, Canada

Main topics: Analysis of gait and motor disorders; Rehabilitation

INTRODUCTION and AIM

Fatigue is often reported in children with cerebral palsy (CP) and is associated to a decreased muscle force-generating capacity [1]. Muscle fatigue can occur during repeated maximal muscle contraction or prolonged submaximal exercise. However, the impact of muscle fatigue on functional activities, such as walking, is little known. Usually, muscle fatigue is induced and evaluated with repeated maximal contractions. This exercise modality largely differs from functional task such as gait, which implies body weight load with coordinated movements at several joints. Moreover, contradictions are observed in the literature concerning muscle fatigue susceptibility in children with CP. Indeed, both increased and reduced fatigue resistance has been reported during sustained submaximal contractions [2-3]. Consequently, the aim of this study was (1) to evaluate the impact of muscle fatigue on gait kinematics and (2) to quantify muscle fatigue using an electromyographic (EMG) approach in children with CP.

PATIENTS/MATERIALS and METHODS

This study included 9 children with spastic diplegic CP. Children were aged between 4 and 15 years. They were asked to walk around a path of 23.2 meters during 6 minutes, at their comfortable pace. Before and after this 6-minute walking exercise, children were asked to walk along a 10-meter walkway to measure muscle activity and gait kinematics. Kinematics was evaluated using a 12-camera motion capture system (*T40S*, *Vicon*, UK) with a sampling frequency of 100 Hz. Lower extremity kinematics were recorded based on *Vicon Plug-in-Gait* model. Muscle activity of the five following muscles was recorded at 1000 Hz with a surface EMG system (*FreeEMG300*, *BTS*, Italy): rectus femoris, tibialis anterior, semitendinosus, gastrocnemius lateral, and gluteus medius. A wavelet transform was applied to the EMG data to evaluate muscle fatigue during gait [4]. Median and mean frequency shifts were used as muscle fatigue indicators.

RESULTS

Significant differences ($p<0.05$) were observed in kinematics parameters after the 6-minute walking exercise compared to the initial condition. Specifically, the ankle range of motion and the ankle plantar-flexion increased after the 6-minute walking exercise. Moreover, the knee range of motion decreased after the 6-minute walking exercise. No significant difference was reported when comparing median and mean frequencies before and after the 6-minute walking exercise. Finally, no correlation was found between the frequency shift and lower limb kinematics.

DISCUSSION and CONCLUSIONS

Children modify their gait pattern by toe walking and limited movement at knee after the 6-minute exercise. These gait alterations were observed after an exercise that aimed to generate muscle fatigue during self-paced walking, corresponding to a daily functional activity. However, these alterations were not correlated with muscle fatigue. Although visual inspection of the power spectrum density suggested modification, the used parameters did not show significant frequency shift toward lower frequencies after the 6-minute walking. This could be explained by the variability of functional level of children included in this study. Indeed, the 6-minute of walking at comfortable pace was tiring for some of them, but not for all children. In conclusion, this study shows the impact of a 6-minute of walking on lower limb joint kinematics in children with CP. Muscle fatigue was not reported using the EMG approach after a walking exercise. The power spectrum tends to change, but the used parameters were not sufficient to quantify muscle fatigue. Further analyses will be performed to evaluate muscle co-activation rate after a 6-minute walking. Further, gait analysis of other children with CP are planned.

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IS CROUCH GAIT INEFFICIENT IN CHILDREN WITH CEREBRAL PALSY?

K.M. Steele (1), M.H. Schwartz (2,3)
(1) University of Washington – Dept. of Mechanical Engineering, Seattle, USA
(2) Gillette Children's Specialty Healthcare, St. Paul, USA
(3) University of Minnesota – Dept. of Orthopaedic Surgery, Minneapolis, USA

Main topics: Analysis of gait and motor disorders, motor control and motor learning

INTRODUCTION
Crouch gait, a common gait pattern among individuals with cerebral palsy (CP), is often cited as an inefficient way to walk [1]. However, there are many factors that contribute to energy costs of walking and it is unclear if a crouched posture is inherently more inefficient [2]. We sought to determine the relative contributions of crouch severity, walking speed, and neuromuscular control to the energy costs of walking in CP.

METHODS
We identified subjects with a diagnosis of CP who had a prior gait analysis including EMG, kinematics, and oxygen cost (N = 549). For each subject, we collected net nondimensionalized oxygen cost during a 6-minute walking trial [3], minimum knee flexion in stance (crouch severity), walking speed, and EMG. The EMG data was used to calculate walk-DMC, a summary metric of neuromuscular control complexity. Walk-DMC was calculated as the variance in EMG accounted for by one synergy from nonnegative matrix factorization [4] and scaled to a normalized z-score relative to typically-developing children (N=84). Thus, a walk-DMC>100 was equivalent to normal dynamic motor control and each 10 point decrement reflected a 1 standard deviation reduction. A stepwise linear regression model was used to predict oxygen cost based upon crouch severity, speed, and walk-DMC.

RESULTS
Crouch severity was not associated with energy cost of walking among individuals with CP (r² < 0.001, Fig. 1). However, walk-DMC and walking speed were both correlated with oxygen cost and together accounted for an r² = 0.39 (p < 0.001). Subjects that walked slower and had more impaired neuromuscular control (lower walk-DMC) had higher oxygen cost.

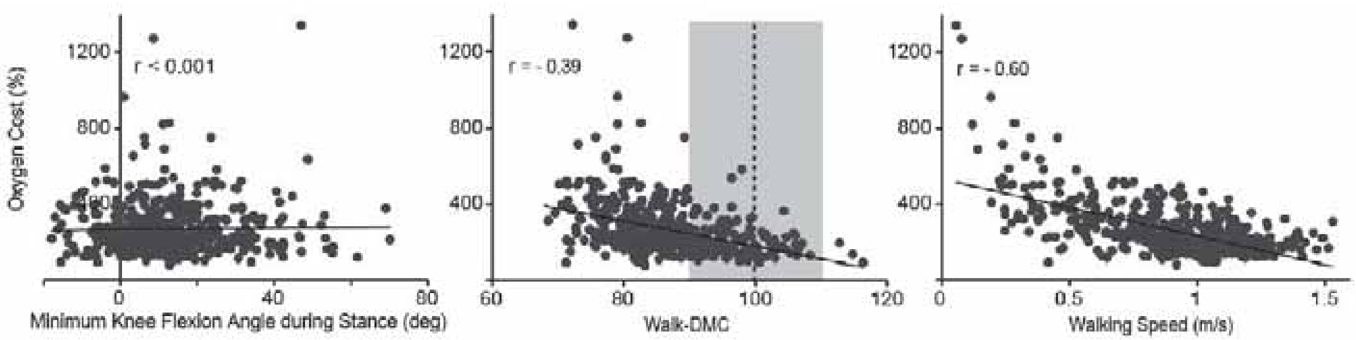

Figure 1. Net nondimensionalized oxygen cost normalized to percent speed match control versus (left) minimum knee flexion angle during stance, (center) walk-DMC, and (right) walking speed.

DISCUSSION
Kinematics were not a significant predictor of energy cost of walking among individuals with CP and crouch gait was not inherently less efficient than other pathologic gait patterns. However, altered motor control was associated with oxygen cost. Addressing altered motor control may provide a pathway for novel treatments and strategies to reduce fatigue and improve community participation for individuals with CP.

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TITLE – SPATIO-TEMPORAL ANALYSIS OF TURNING IN CHILDREN WITH CEREBRAL PALSY

PC. Dixon (1), J. Stebbins (2), T. Theologis (2), AB. Zavatsky (1),
(1) University of Oxford, Oxford, United Kingdom
(2) Nuffield Orthopaedic Centre, Oxford, United Kingdom

INTRODUCTION and AIM
Gait deviations during straight walking in children with cerebral palsy (CP) are well documented, but there is limited information about adaptations required for successful turning [1]. The aim of this study was to investigate potential changes in spatio-temporal parameters (STPs) during 90° turns in children with CP.

PATIENTS/MATERIALS and METHODS
Nineteen children with spastic dipelgic CP (8 GMFCS 1 and 11 GMFCS 2) (12.2 ± 2.9 years) and thirty-nine typically developing (TD) controls performed straight and 90° turns while fit with the Plug-in Gait markers (Vicon, Oxford Metrics, Oxford, UK). Turn style (step or spin) was determined as previously reported [2].

In the CP group, turning towards the more or less affected side had no effect on STPs, thus data from both turning directions were pooled. Stride velocity, stance time, stride length, and stride width were computed for the approach, turn, and depart phases of turning [3]. Stride length and stride width were normalised by leg-length (Matlab v12b, The Mathworks Inc. Natick, USA). A 2 × 3 ANOVA (group by phase) was performed for each turn style. Simple main effects for group were tested in the case of a significant interaction. Greenhouse-Geisser correction was made when unequal variance amongst variables was found. (SPSS 20, IBM. Armonk, NY, USA).

RESULTS
Stride velocity and stride length were consistently reduced across phases and turn styles ($p < 0.002$) in the CP group. Moreover, there were significant group by turn phase interactions in stride width for both spin ($p = 0.013$) and step ($p = 0.01$) turns. Follow-up tests showed that for the CP group, stride-width was decreased for the turn phase of both turn styles and also increased for the step approach phase compared to TD controls (Fig.1).

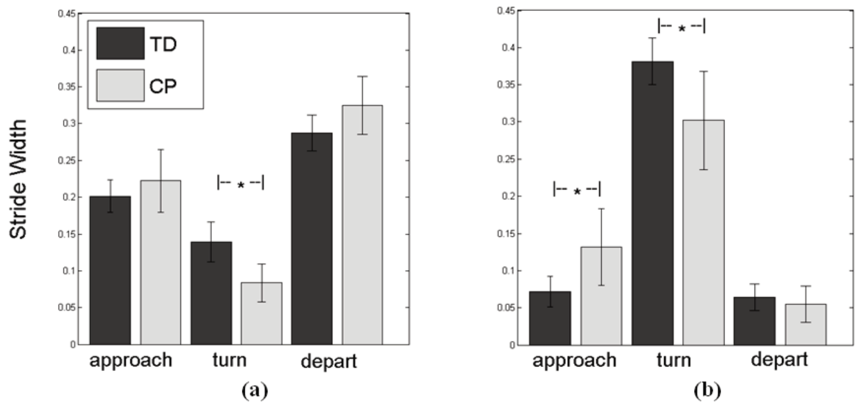

Figure 1: Stride width (dimensionless) by group and phase for a) spin and b) step turns. Mean and confidence intervals shown.

DISCUSSION and CONCLUSIONS
The analysis reveals that although children with CP show a smaller overall gait velocity and stride length compared to the TD controls during turning, these parameters change in a similar way across phases in each group; however, the manner in which stride width is modulated is group specific. Children with CP tend to approach the turn with a wider base of support only to reduce their stride width during the turn. This strategy might improve stability in the early phase of the turn, but may lead to increased risk of tripping as the turn progresses. Further exploration of phase specific adaptation is warranted in this population.

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CHANGES IN ARM MOVEMENTS DURING WALKING IN CHILDREN WITH DIPLEGIC CP

P. Van de Walle (1,2,3), J. Kenis (2), J. De Rijck (2), K. Desloovere (2,3), A. Hallemans (1), D. Monari (3), P. Meyns (2) (1) Faculty of Medicine and Health Care, University of Antwerp, Belgium; (2) Faculty of Kinesiology and Rehabilitation Sciences, KU Leuven, Belgium; (3) Clinical Motion Analysis Laboratory, University Hospital Pellenberg, Belgium

INTRODUCTION and AIM

In cerebral palsy (CP), clinical gait analysis (GA) mainly focuses on lower limb kinematics. However, also abnormal trunk and arm movement can be observed (1,2,3). Reciprocal arm-swing is an important feature of typical gait serving both to increased postural control and gait efficiency. The role of arm and trunk movements in gait efficiency has been recognized before (4), but the changes in arm movements itself are only documented in small groups (1,2,3). The goal of this study was to investigate changes in arm movement patterns in children with diplegia, compared to age-related typical children, in order to confirm these first results.

PATIENTS/MATERIALS and METHODS

From a group of 30 children with diplega (GMFCS I-II; age: 6-12 years) undergoing a full body 3D GA during barefoot walking at self-selected speed (Vicon, PlugInGait Marker Set) the 3D upper limb joint angles were calculated for 13 patients and 13 sex and age-matched typical developing peers (TD) . For each participant 3 left and 3 right trials were analyzed. Range of motion (RoM), angle at initial contact (IC) and mean position over the gait cycle were compared between groups in sagittal (shoulder, elbow, wrist), coronal (shoulder, wrist) and transversal plane (shoulder) by means of a Mann-Whitney U test with level of significance set at $p<0.05$.

RESULTS

For all joints, in all planes, physiological movement patterns of arm swing can be observed in CP, although with more variation (figure 1). For all joints, in all planes a significantly larger RoM was observed in CP. In the sagittal plane, the shoulder started in more extension (CP:-18.3°±19.0; TD: -11.6°±10.1) and also the mean extension position was increased in CP. In the coronal and transversal plane no differences were found at IC, but in CP the mean shoulder position was in significantly more abduction (CP:7.5°±14.8; TD:5.3°±5.8) and less exorotation (CP:-6.2±20.8; TD:-12.2±14.9). At the elbow, the flexion-extension RoM (CP:24.8°±15.4 vs. TD:17.4°±10.6; p=0.001) as well as the mean flexion position was higher in CP (CP:52.9°±20.1; TD: 38.2°±8.4). At the wrist the mean position was in more dorsiflexion (CP:18.3°±13.9; TD:12.1°±6.8) and endorotation (CP: 1.8°±12.6; TD:-0.9°±7.3) in CP.

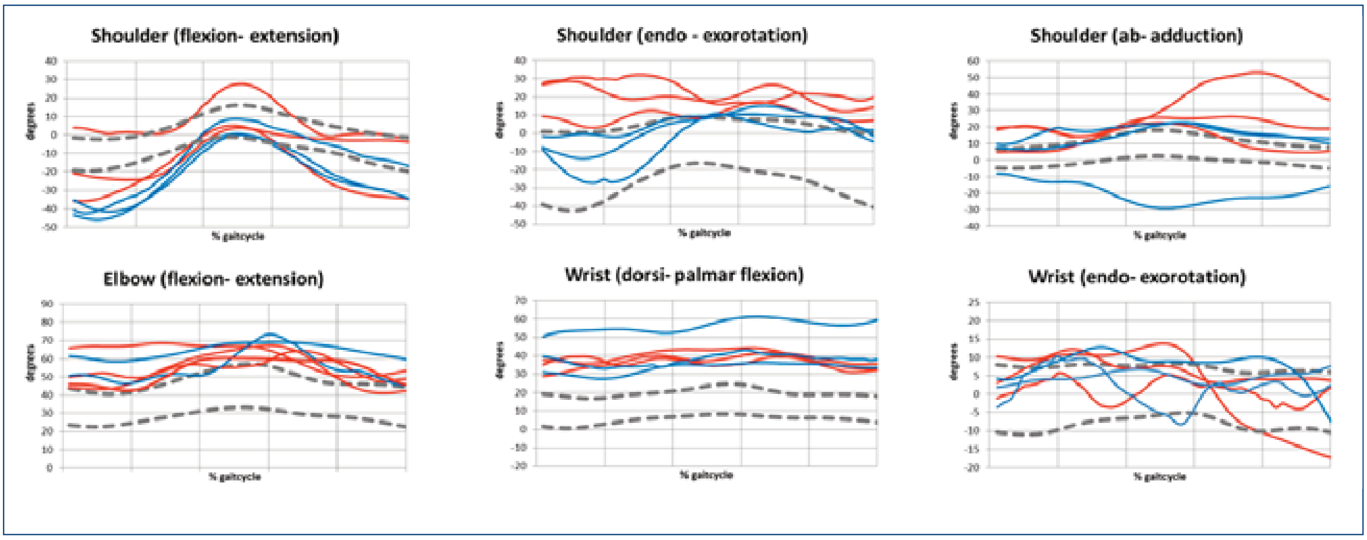

Figure 1: Consistency plots of a 6 year old girl with diplegic CP (dashed lines: + /– one standard deviation of TD)

DISCUSSION and CONCLUSIONS

Although children with CP presented with physiological movement patterns, some specific changes were detected. At the shoulder, more extension, abduction and internal rotation was observed, which is in contrast with the results of Galli et al. (3) who only found an increased abduction position in CP. In fact, the increase in extension (49%) and exorotation (51%) was about as large as that in abduction (40%). At the elbow, increased mean elbow flexion with physiological pattern confirmed previous results. Similar, but smaller, increases in shoulder extension, elbow flexion and wrist extension and larger variability, are also seen in immature arm swing (5) and could therefore result from immature neuromotor control in CP. Whereas increased abduction is probably related to stability issues. Future research should aim at better understanding of the observed changes.

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THE RELATION BETWEEN ANALYTICAL AND FUNCTIONAL MEASUREMENTS OF SPASTICITY IN CHILDREN WITH CEREBRAL PALSY

L. Bar-On (1,4), G. Molenaers (1,2), E. Aertbeliën (3), D. Monari (3,4), H. Feys (1), K. Desloovere (1,4)
(1) KU Leuven, Dept. of Rehabilitation Sciences; (2) KU Leuven, Dept. of Development and Regeneration (3) KU Leuven, Dept. of Mechanical Engineering; (4) Clinical Motion Analysis Laboratory, University Hospital Pellenberg, Belgium.
Main topics: Analysis of gait and motor disorders; Analysis of clinical movement data.

INTRODUCTION and AIM
There is much debate about how spasticity contributes to the movement abnormalities seen in children with spastic cerebral palsy (CP). This study explored the relation between stretch reflex characteristics in passive muscles, active muscles, and peak *muscle lengthening velocity* (MLV) during the swing phase of gait.

PATIENTS/MATERIALS and METHODS
Lower-limb joint kinematics and surface electromyography (sEMG) from 24 children with CP (average age 10.4±3.3yrs, 14 bilateral-, 9 unilateral-involvement, GMFCS I-III) were collected using 3D gait analysis while walking at three velocities: self-selected, faster and fastest. The gastrocnemius (GAS), medial hamstrings (MEHs), and rectus femoris (REF) were additionally assessed at rest using an instrumented spasticity assessment that simultaneously recorded joint kinematics and sEMG during high-velocity passive muscle stretches [1]. MLV during both assessments was calculated using OpenSim software [2]. The *stretch reflex threshold* was defined as the MLV at EMG onset during passive muscle stretch. Muscle activation was quantified with root mean square EMG (rms-EMG) during passive muscle stretch and during the muscle lengthening periods in the swing phase of gait. Parameters from passive muscle stretch were compared to those from the gait analysis.

RESULTS
In half the children, GAS peak MLV during the swing phase of gait did not exceed its stretch reflex threshold with increasing walking velocity. In contrast, in the MEHs and REF the threshold was almost always exceeded (Figure 1). In the GAS, stretch reflex thresholds were positively correlated to peak MLV during the swing phase of gait at the faster (r=0.46) and fastest (r=0.54) walking conditions. In the MEHs, a similar relation was found, but only at the faster walking condition (r=0.43). No such correlations were found in the REF. RMS-EMG during passive stretch showed moderate positive correlations to RMS-EMG during the swing phase of gait at all walking conditions in the GAS (r=0.46-0.56), moderate to good in the REF (r=0.46-0.72), and good in the MEHs (r=0.69-0.77). RMS-EMG during passive stretch was not correlated to peak MLV during the swing phase of gait in any muscle.

DISCUSSION and CONCLUSIONS
We conclude that a reduced stretch reflex threshold in the GAS and MEHs constrains peak MLV during gait in children with CP. With increasing walking velocity, this constraint is more marked in the GAS, but not in the MEHs. Hyper-activation of stretch reflexes during passive conditions is related to muscle activation during the swing phase of gait, but has a limited contribution to reduced MLV during swing. Larger studies are required to confirm these results, and to investigate the contribution of other impairments such as passive stiffness and weakness to reduced MLV during gait.

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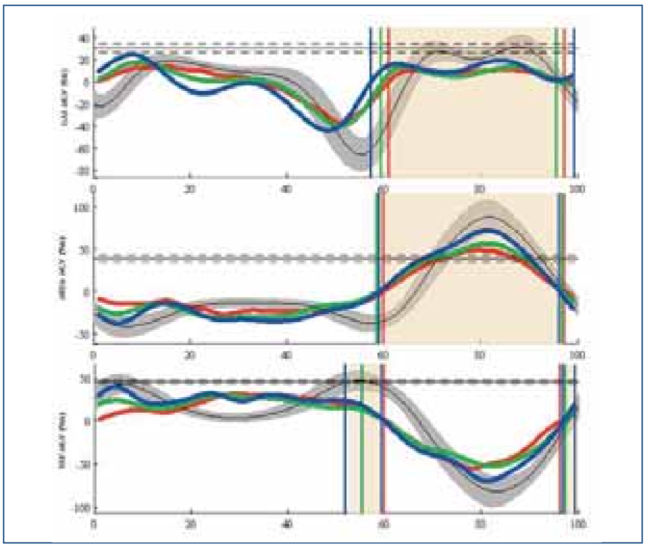

Figure 1. Example of average muscle lengthening velocity (MLV) in (A) the gastrocnemius (GAS), (B) the medial hamstrings (MEHs), and (C) the rectus femoris (REF) from different trials per walking condition [self-selected walking (red line), faster (green line), and fastest (blue line)] plotted against percentage gait cycle in a child with CP. Muscle lengthening velocities are expressed as a percentage of the muscle length at anatomical position. Shaded areas, outlined by vertical coloured lines, represent periods during the swing phase when the muscle was lengthening in each walking condition. The straight horizontal grey line is the average stretch reflex threshold and its standard deviation (dashed grey lines) defined during high velocity passive muscle stretch.

DIFFERENCES IN TORQUE VALUES BETWEEN A FIXED AND NON-FIXED STANDARDIZED ISOMETRIC STRENGTH MEASUREMENT: A PILOT STUDY.

[1]Marije Goudriaan, [2]Karlien Delanghe, [2]Julie Casie, [1,2]Kaat Desloovere.
(1) KU Leuven, Group Biomedical sciences, Department of Rehabilitation Sciences, Leuven, Belgium
(2) Clinical Motion Analysis Laboratory, CERM, University Hospital Leuven, Belgium.

Main topics: Analysis of clinical movement data and rehabilitation.

INTRODUCTION and AIM
Hand-held dynamometry (HHD) is frequently used to quantify muscle strength in both typically developing (TD) and cerebral palsy (CP) children [1], [2]. Often the participants nor the HHD are fixated, which might result in compensation mechanisms during the assessments. More-over measurement outcomes might depend on the strength of the assessor, especially in stronger children [3]. The aim of this study was to determine the difference in muscle torques for plantar flexion (PF), dorsiflexion (DF), knee extension (KE) and knee flexion (KF) when both, the subject and HHD, were fixed (HHD_f) and when the subject and HHD were not fixed (HHD_nf). All measurements were performed in a standardized lower limb position, representing the averaged joint angles as observed during gait. Additionally, we determined if these test positions resulted in different muscle torques when compared to the normative data by Eek et al. [2].

PATIENTS/MATERIALS and METHODS
A total of 10 TD children (M ± SD: age 10.3 ± 4.2) participated in the study and both test conditions were conducted in a custom made chair, both left and right side were tested. Differences between the two conditions (HHD_f and HHD_nf) were analyzed by means of a repeated measures Anova and significant interaction effects were analyzed with a paired samples t-test. Additionally we compared our results with the results of Eek et al.[2]

RESULTS
No significant differences were found between the HHD_f or HHD_nf, but there was a significant interaction effect between the two conditions and the different muscles.

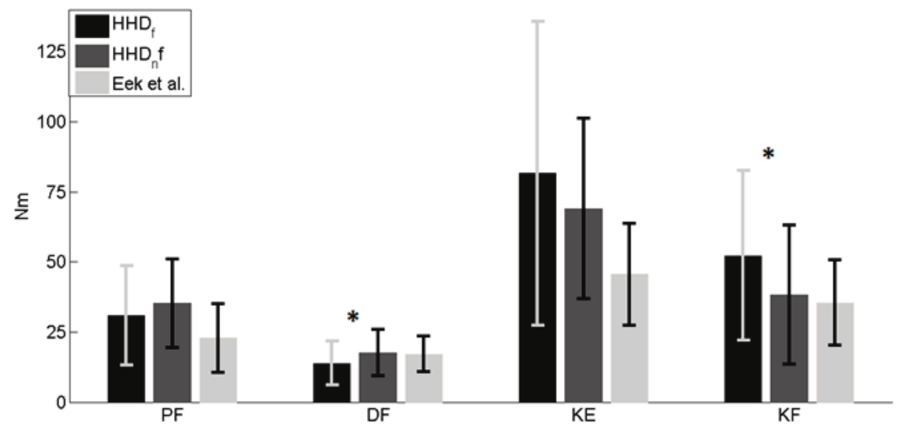

Figure 1. Mean torque values + stds of HHD_f, HHD_nf and the data of Eek et al.[2]. Significant differences ($p<0.01$) are indicated with a *.

DISCUSSION and CONCLUSIONS
The lower values in the upper leg for the HHD_nf compared to the HHD_f, might be explained by influence of the strength of the assessor. The higher values in muscle torque seen in the lower leg for the HHD_nf condition might be a result of compensation mechanisms, since the strength of the assessors has a lower impact in this weaker muscle group. The differences between our mean muscle torques and the muscle torques measured by Eek et al [2], may be related to the use of different test positions. However, to be able to give a more definitive conclusion on the effect of our fixed standardized position, we will have to increase the number of our test subjects.

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IMPACT OF MAJESTRO-FROST SURGERY IN THE TREATMENT OF INTERNAL HIP ROTATION IN CEREBRAL PALSY

DL Neves(1), MH Fujino(2), MC Filho(3),C Kawamura(4), FC Blumetti(5), JA Lopes(6), SO Bittencourt(7), FF Junior(8) e CA Santos(9).
(1,2,3,4,5,6,7,8,9) AACD, São Paulo, Brazil

INTRODUCTION and AIM

Children with Cerebral Palsy (CP) frequently walk with excessive internal rotation of the hip. Proximal femur external rotation osteotomy is a common procedure used for the correction this problem; however the recurrence is related in the literature. The aim of this study is to evaluate the results of Majestro-Frost surgery as an option for treatment of internal rotation of the hip in cerebral palsy.

PATIENTS/MATERIALS and METHODS

Retrospective study with clinical and kinematic evaluation of 20 diparetic and hemiparetic spastic CP patients, Gross Motor Function Classification System (GMFCS) I- III who had undergone a correction of internal rotation of the hip through the transposition of the anatomical origin of the internal rotators (Majestro-Frost surgery) from October 2008 to December 2012, and with complete documentation at gait laboratory.

RESULTS

Of 20 patients, 13 were male and 7 were female, 17 were spastic diplegic, with a mean age at time of surgery of 8.95 years, 70.5 % underwent unilateral surgery, 75/ % were GMFCS motor level II and the average time between examinations gait ranged from 11 months to 3 years and 3 months with an average of 1 year and nine months. Regarding the data of physical examination, only the external hip rotation showed significant result, with an average increase of 25.3 ° to 33.5 °. The kinematic data in the coronal plane, show significant difference in pelvic obliquity difference of means and hip adduction, and the transverse plane, both data analyzed showed significant improvement. There was a reduction in the average hip internal rotation of 18.5° to 3.17° and the average the progression angle of 17.2 ° to 3.5°. There was also significant improvement of average GDI from 51.7 to 61.8.

DISCUSSION and CONCLUSION

We conclude that Majestro –Frost surgery in the sample, significantly reduces internal hip rotation in the kinematics as well as the foot progression angle, but with impact on the coronal plane, with increase external hip rotation at physical exam and improvement in mean GDI.

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11:00-12:30
Aula Minor

POSTURE / BALANCE
Chairs: Paolo Cappa, Fabrizio Patanè

11:00-11:10 THE INFLUENCE OF THE VISUAL INPUT ON POSTURAL CONTROL IN PATIENTS WITH STROKE: SIX MONTHS FOLLOW-UP STUDY
A. Kleiner, C. Rigoldi, M. Galli, R.M.L. Barros

11:10-11:20 THE TIME-TO-BOUNDARY FUNCTION TO ASSESS UPRIGHT STANCE IN STATIC AND DYNAMIC CONDITION
C. D'Anna, F. Patané, M. Schmid, P. Cappa, E. Castelli, S. Gazzellini, S. Conforto, M. Petrarca

11:20-11:30 HIPPOTHERAPY WITHOUT A HORSE: THE EFFECTS OF PASSIVE MOVEMENT ON CORE CONTROL
G.J. Barton, C. Moine, M.B. Hawken

11:30-11:40 SEATED POSTURAL NECK AND TRUNK MOVEMENTS DUE TO LATERAL PERTURBATION
T. Stenlund, R. Lundström, O. Lindroos, C. Häger, L. Burström, G. Neely, B. Rehn

11:40-11:50 MOTOR STABILITY EVALUATION IN ELDERLY SUBJECTS THROUGH INSTRUMENTAL STABILITY MEASURES AND CLINICAL RATING SCALES
F. Riva, P. Tamburini, A. Coni, R. Stagni

11:50-12:00 FOOT JOINTS MOBILITY AND PLANTAR PRESSURE IN THE NORMAL FOOT
P. Caravaggi, A. Leardini, C. Giacomozzi

12:00-12:10 VISUAL CUEING COMBINED WITH TREADMILL TRAINING IN PARKINSON'S DISEASE: EFFECTS ON GAIT AND BALANCE
S. Cornelia, W. Sarah, E. Alina, I. Josef

12:10-12:20 FREQUENCY ANALYSIS OF VERTICAL FORCES IMPROVES BALANCE MEASUREMENTS
F. Martelli, C. Giacomozzi, M. Lillia, A. Fadda

12:20-12:30 APPLICATION OF SURFACE EMG IN YOUNG CHILDREN AFFECTED BY TEMPOROMANDIBULAR DISORDERS: A PILOT STUDY
F. Spolaor, Z. Sawacha, F. Cocilovo, C. Cobelli , A. Gracco

12:30-13:30 **Lunch**

THE INFLUENCE OF THE VISUAL INPUT ON POSTURAL CONTROL IN PATIENTS WITH STROKE: SIX MONTHS FOLLOW-UP STUDY

AFR Kleiner (1,2,3), C Rigoldi (3), M Galli (3,4), RML Barros (1).
(1) Laboratory of Instrumentation for Biomechanics, Faculty of Physical Education, University of Campinas, Campinas, Brazil.; (2) CAPES Foundation, Ministry of Education of Brazil, Brasília, Brazil; (3) “Luigi Divieti” Posture and Movement Analysis Laboratory, Department of Electronics, Information and Bioengineering, Politecnico di Milano, Milano, Italy; (4) “Motion analysis Lab”, IRCCS San Raffaele Pisana, Rome, Italy. **Main topics:** Analysis of clinical movement data.

INTRODUCTION and AIM

This study aimed to evaluate the strategies performed by patients with stroke during quite standing making use of the center of pressure sway analyses in the antero-posterior (AP) and medio-lateral (ML) directions, in order to investigate the possible changes in postural control in a post-stroke period of six months.

PATIENTS/MATERIALS and METHODS

Ten participants in post-stroke (age: 62.83 ± 6.86 years; body mass: 69.50 ± 13.96 kg; height: 1.68 ± 0.06 m; post-injury time: 6.1 ± 2.8 months after stroke) and ten an age matched group of healthy subjects (CG) were analysed. However, two participants were not able to perform the eyes closed condition and so they were excluded from our sample. The subjects were evaluated in three sessions with an interval of three months (S1, S2 and S3) under two condition, eyes open (EO) and eyes closed (EC). The participants were instructed to maintain an upright standing position for 60s on a force platform. COP displacement and speed were computed in the AP and ML directions. Two statistical analyses were performed: the first aimed to characterize the postural control of stroke patients. So, all the Stroke group (S1 data) were compared with the control group in the EO and EC conditions. For this analysis a two-way ANOVA for repeated measures was performed. The second analysis was performed aiming to understand the Stroke patients’ postural control in a follow-up setup. The data of the 3 sessions did not present normal distribution so they were treated by the Mann-Whitney test the differences between the EO and EC conditions separately for each session. The Wilcoxon test performed comparisons between each session (S1, S2 and S3) separately for each condition (EO and EC).The tests significant level was $\alpha<0.05$.

RESULTS

Differences between the EO and EC conditions for the stroke group were found in all variables, what were not observed in the control group. The stroke patients during the EC conditions reached higher values than in the EO. Moreover, there were also significant differences between the Stroke and Control groups, were the stroke group performed higher values than the CG in all variables. When the EO and EC were compared for each session differences were found for the COPap in the S1 and S3 (Figure 1a) for MVap in the all the sections (Figure 1b); and, for MVml in S3 (Figure 1c). Differences among sections were seen in the MVml in the EO condition between S1 and S3 (Figure 1c).

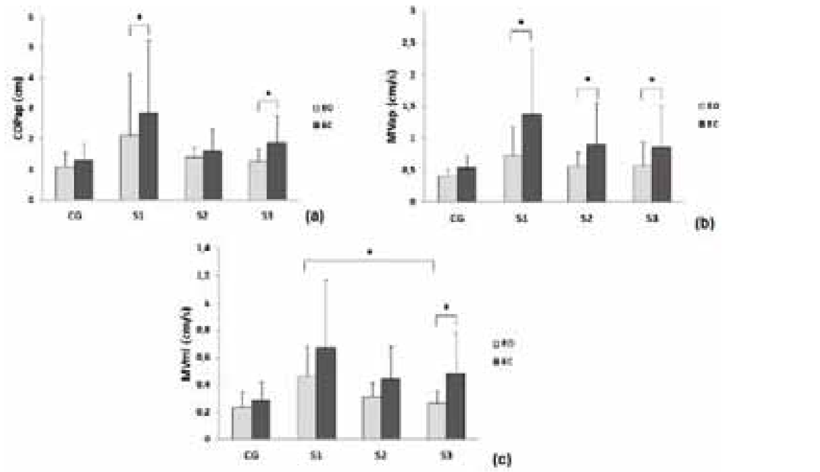

Figure 1. Comparisons of control group (CG) and participants with stroke (S) in the three sessions in terms of mean, standard deviation and statistical values for the EO and EC conditions of follow variables: (a) range of COP displacement in AP; average speed for AP (b) and ML (c) directions. Legend: * = $p<0.05$

DISCUSSION and CONCLUSIONS

Stroke patients rely more on visual information for postural control than healthy age-matched individuals. As well, the balance recovery without intervention in individuals with stroke is characterized by a reduction in postural sway and instability during the EO condition, but there is no reduction in visual dependency. Moreover, the most important impact on postural control recover should be reached in the first 6 months[1]. During this period an intervention focusing the standing with eyes closed might be interesting, since sensorial systems can be training and, also the individual with stroke can better explore new control mechanisms to the restoration of support functions and equilibrium reactions of the paretic leg.

REFERENCES

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THE TIME-TO-BOUNDARY FUNCTION TO ASSESS UPRIGHT STANCE IN STATIC AND DYNAMIC CONDITION

C.D'Anna (1), F.Patanè (2,3), M.Schmid(1), P.Cappa (2,3), E. Castelli (3), S. Gazzellini (3), S. Conforto(1), M. Petrarca (3)
(1) Biolab3, Department of Engineering, University Roma TRE, Rome, Italy
(2) Department of Mechanical and Aerospace Engineering, "Sapienza" University of Rome, Rome, Italy
(3) Pediatric Neuro-Rehabilitation Division, Children's Hospital "Bambino Gesù" IRCCS, Rome, Italy

Main topics: Movement analysis in clinical practice

INTRODUCTION and AIM
Parameters extracted from CoP data have been used in several studies to describe, interpret and assess the postural control in both static and dynamic conditions. Among these the Time-to-Boundary function (TtB) was introduced in the framework of postural stability by moving a concept defined in the theory of the time-to-collision to visual perception and calculated in upright stance trials. This variable takes position, velocity, and acceleration of the CoP trajectory into account, to estimate the temporal margin to the stability boundaries [1].
No study up to now has studied the TtB function in dynamic posture, so that the aim of this study is to evaluate the difference of the temporal limits of stability in static and dynamic balance, considering eyes-open and eyes-closed visual conditions.

PATIENTS/MATERIALS and METHODS
Experiments were conducted in seven volunteers healthy children (age range 9-14 yrs, height 1.5±0.11 m, weight 46.7 ± 9.8 kg). Subjects stood on the RotoBit [2] force plate with heels 2 cm apart, externally rotated at around 30°, and were asked to maintain an upright posture with eyes-open (EO) and eyes-closed (EC), in static (stat) and dynamic (dyn) conditions. In dynamic conditions, the RotoBit plate was free to tilt with an angular range of about ± 10° for roll and pitch. Each condition was repeated three times and each repetitions lasted 30 s. The CoP coordinates were stored for further offline processing. This included mean value removal and digital low-pass filtering (cut-off frequency of 10 Hz). They were used to extract the TtB function and the median value over time was calculated for each repetition. Descriptive statistic and 2-way Anova test with repeated measures (with vision condition (EO/EC) and force plate movement condition (stat/dyn) as factors) were calculated.

RESULTS
The statistical analysis shows significant difference ($p<0.05$) in EC_dyn/EC_stat and EO_dyn/EC_dyn comparisons. No significant difference is shown for EO_stat/EO_dyn and EO_stat/EC_stat comparisons.
The analysis of numerical result shows that the TtB value in dynamic condition decreases respect to the static condition when participants had their eyes closed. In the comparison EO_dyn/EC_dyn, the TtB value increase when participants stood in upright stance with eyes open. All results are shown in Fig.1.

DISCUSSION and CONCLUSIONS
The preliminary results show that the temporal margin of stability decrease when the participants performed a postural trial in dynamic condition respect to the static condition. The TtB parameter can be useful to assess different postural control strategies used in the two motor tasks. This behaviour is promising to asses and monitor feature rehabilitation protocols based on dynamic task.

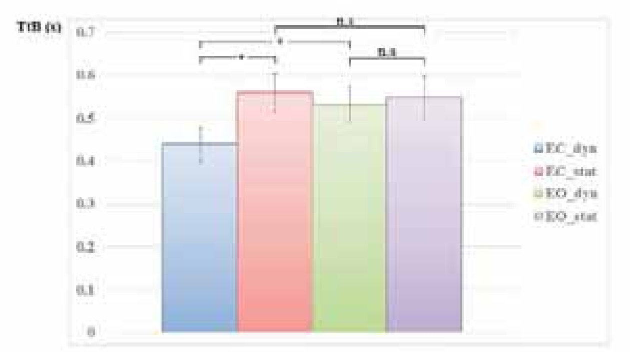

Figure 1: Mean ± standard deviation of TtB function. The significant difference (*$p<0.05$) is shown for all comparisons

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HIPPOTHERAPY WITHOUT A HORSE: THE EFFECTS OF PASSIVE MOVEMENT ON CORE CONTROL

G J Barton (1), C Moine (2), M B Hawken (1)
(1) Research Institute for Sport and Exercise Sciences, Liverpool John Moores University, Liverpool, UK.
(2) School of Osteopathy, Osteobio, Cachan, France.

Main topics: Motor control and motor learning, Robotic devices in human movement science and rehabilitation.

INTRODUCTION and AIM

Hippotherapy or therapeutic horseback riding provides biological movement stimuli imitating movements of the human pelvis during gait, and was found to improve postural control and balance in children with cerebral palsy in a meta-analysis [1]. Limited access to horse riding, however, makes the intervention difficult to obtain, but children have access to their parents or guardians who can provide passive movement stimuli by carrying the child. We aimed to test if passively experiencing the movement of a human pelvis on a simulator can improve motor control of the trunk as measured by performance in a game task.

PATIENTS/MATERIALS and METHODS

Five unimpaired volunteers (Group 1) spent 20 minutes over 5 consecutive days sitting on a saddle mounted on the moving platform of the CAREN system (Motek Medical, Amsterdam) which was driven by the position and orientation signals of pelvis motion reconstructed from 3D motion capture (Qualisys Oqus, Gothenburg) during normal gait. In the following week they continued at the same intensity and frequency playing computer games with a joystick. In a cross-over design, a second group of five participants (Group 2) played games with the joystick in the first week, followed by riding the simulator. Movement control of their trunk was measured by establishing the maximum settled speed reached while playing the Goblin Post Office (GPO) game for 5 minutes driven by rotation and tilt of the trunk [2,3]. Outcome measures were taken before training, after the first week and at the end of training. A between/within subject ANOVA was used to examine differences between the two groups and the three game test sessions, with between subjects factor GROUP [1,2] and within subjects factor SESSION [Pre, Mid, Post].

RESULTS

The interaction between GROUP and SESSION was not significant ($F_{[2,16]}$=1.177, p=0.334). The main effect of SESSION ($F_{[2,16]}$=10.315, p=0.001) was significant, but GROUP ($F_{[1,8]}$=0.166, p=0.695) was not. Participants improved their trunk control over the three sessions, and the interaction plot suggests that training on the simulator increased trunk control (measured by the GPO game score) more than using a joystick with hands (Figure 1). Training on the moving simulator was more effective regardless of the order of simulator training and joystick use, although the effect did not reach significance.

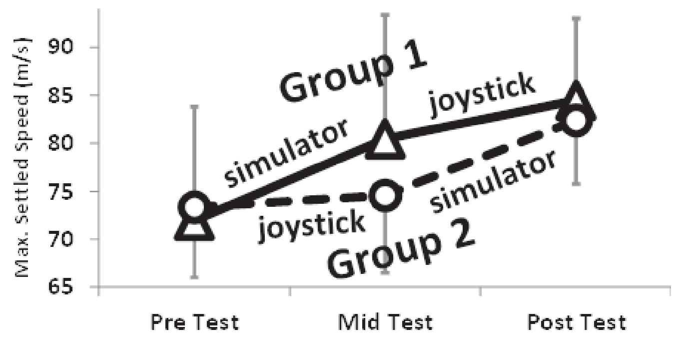

Figure 1: Measure of trunk control (mean±SD) derived from game play in response to the motion simulator and joystick use for the two groups.

DISCUSSION and CONCLUSIONS

Considering that all participants were free of any impairment and they trained on the simulator for only a short time over 5 days, the indication of improved trunk control justifies further investigation. If a measurable improvement is found in patients with movement problems using the pelvis simulator, then that would support the recommendation that parents/guardians should carry their disabled child more often. This simple and free intervention would bring the advantages of hippotherapy to more children.

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SEATED POSTURAL NECK AND TRUNK MOVEMENTS DUE TO LATERAL PERTURBATION

T. Stenlund [a], R. Lundström[b,c], O. Lindroos[d], C. Häger[a], L. Burström[c], G. Neely[e], B. Rehn[a]
[a] Dept. of Community Medicine and Rehabilitation, Physiotherapy, .
[b] Dept. of Radiation Sciences, Biomedical Engineering, , .
[c] Dept. of Public Health and Clinical Medicine, Occupational Medicine, Umeå University, Umeå, Sweden.
[d] Dept. of Forest Biomaterials & Technology, of Agricultural Sciences, Umeå, .
[e] Dept. of Psychology

Main topics: Experimental studies in human movement science, motor control and motor learning

INTRODUCTION

Rough vehicle-rides involve exposure to mechanical shocks or perturbations generated from the seat, (often in lateral directions) (1) and research studies report musculoskeletal problems from the neck region among drivers (2). Whether this latter is associated with the exposure to shocks remains unclear. The aim of the present laboratory study was to investigate seated postural reactions in the neck and trunk among healthy adults exposed to lateral perturbations from the chair with different accelerations. The first hypothesis was that a higher peak acceleration perturbation would result in a larger angular displacement in all body segments even distal from the seat and the second hypothesis was that there would be smaller angular displacements in the final perturbation compared the first perturbation due to adaptation.

PATIENTS/MATERIALS and METHODS

Twenty-three healthy male participants (age 24 ± 5 years, height 1.81 ± , weight 79 ±) seated on a chair mounted on a motion system, were randomly exposed to 10 unidirectional lateral perturbations (distance at two peak accelerations 5.1 or 13.2 m/s^2). During tests, the participants sat with their eyes open in a self-selected sitting posture with arms and feet placed in pre-defined positions. Each perturbation were randomized in time. Before the experimental trials began a practice session was administered, where each of the perturbations were presented once. Inertial sensors registered angular displacements from the neck, trunk and pelvis in the frontal plane. The first and second peak angular displacement, i.e. the first two peak angular displacements that occur as a result of movement between two adjacent sensors after perturbation, was registered and statistics were performed with a paired sample t-test (SPSS 21).

RESULTS

The high peak acceleration compared to the low peak acceleration provoked significantly larger ($p<0.001$) angular displacements in the neck, trunk and pelvis in all cases except for the second neck peak angle that was significantly smaller ($p=0.01$). There were no significant differences ($p>0.05$) in angular displacements between the first and the final perturbations for the high peak acceleration.

DISCUSSION and CONCLUSIONS

Our first hypothesis was confirmed as the high peak acceleration increased the angular displacements also for the neck region except for the second neck peak angle. The opposite result for the second neck peak angle might be explained by the perturbations smooth deceleration making it possible for the neck to go back near its neutral position without overcompensating. The second hypothesis was rejected as there was no significant difference in displacements between the first and the final tenth perturbation. This indicates that there was no adaptation between the first and the final measured reaction, but we cannot exclude the possibility that the practice phase may have influenced these results. Although the postural reactions were small, a higher acceleration seems to influence postural reactions which may affect musculoskeletal tissues even distal from the vibration source. Further studies with a perturbation followed by a counter perturbation, as it would be in real terrain conditions, is warranted.

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MOTOR STABILITY EVALUATION IN ELDERLY SUBJECTS THROUGH INSTRUMENTAL STABILITY MEASURES AND CLINICAL RATING SCALES

F. Riva (1), P. Tamburini (1), A. Coni (1), R. Stagni (1, 2)
(1) DEI - Department of Electrical, Electronic, and Information Engineering 'Guglielmo Marconi', University of Bologna, Italy
(2) Health Sciences and Technologies – Interdepartmental Center for Industrial Research (HST – ICIR), University of Bologna, Italy

Main topics: Experimental studies in human movement science, Movement deviation indexes

INTRODUCTION and AIM

Falls in the elderly represent a major community and public health problem, with large clinical and economic consequences [1]. The understanding of locomotor stability is a critical issue in clinical assessment procedures. Clinicians typically use clinical rating scales of motor function tests for fall risk assessment purposes. However, this approach highly relies on the clinician's subjective judgement [2]. Variability and stability measurements of stride time and trunk accelerations during gait resulted promising in the assessment of gait stability and fall risk in healthy elderly subjects [3] and could lead to a more reliable and objective quantification of motor function, potentially representing a valid and objective complement to clinical rating scales. For an effective exploitation in clinical practice, the association between stability measures and clinical scales has to be assessed. The aim of the present study is the assessment of the relationship between instrumental variability and stability measures based on trunk accelerations during gait and some widely used clinical rating scales.

PATIENTS/MATERIALS and METHODS

Seventy community dwelling old adults (35 males and 35 females, 76 ± 7 years, 76 ± 13 kg, 168 ± 9 cm) participated in the study. Barthel Index (BI), Cumulative Illness Rating Scale (CIRS) and Mini-BESTest (MBT) were administered to subjects by the same operators. Due to time/location constraints, MBT was only administered to 39 subjects (19 males and 20 females, 76 ± 6 years, 77 ± 12 kg, 168 ± 8 cm). Subjects also performed an instrumented over-ground gait task (on a 100 m long road) wearing an IMU located on the trunk, at the height of the fifth lumbar vertebra. Eleven gait variability/stability measures were calculated on stride time and trunk acceleration data during gait, namely Standard Deviation (SD), Coefficient of Variation (CV), Nonstationary index (NI), Inconsistency of Variance (IV), Poincaré Plots (PSD1/PSD2), Maximum Floquet Multipliers (maxFM), short/long-term Lyapunov exponents (sLE/lLE), Harmonic Ratio (HR), Index of Harmonicity (IH), Multiscale Entropy (MSE) and Recurrence Quantification Analysis (RQA). Each measure was calculated for anterior-posterior (AP), medio-lateral (ML) and vertical (V) acceleration directions. In order to assess the correlation between clinical parameters and variability/stability measures, log transformed measures were used as inputs for linear regression models.

RESULTS

SD, CV, PSD1 and PSD2 showed negative correlation with BI and MBT. The only stability measure that correlated (positively) with MBT and BI was IH in the ML direction. CIRS correlated with MSE (ML and V directions), maxFM and lLE.

DISCUSSION and CONCLUSIONS

BI and MBT negatively correlated with stride time variability measures, meaning that a relationship exists between the deterioration of the overall motor functionality and the increase in stride time variability. BI and MBT were also found to be linked to the harmonicity of acceleration signal in the ML direction, confirming the importance of ML trunk oscillations during gait for functionality assessment. CIRS correlated with stability measures, in particular with MSE in ML and V directions, suggesting a link between cumulative illness and gait stability in elderly subjects. Moreover, MSE was previously found to be linked to fall history in elderly subjects, and should hence to be taken into consideration for gait stability assessment.

In conclusion, gait variability and stability measures showed promising correlation with clinical rating scales in the elderly population, and could be considered for complementing the standard clinical scores in the assessment of fall risk. A more reliable quantification of locomotor features could be obtained from instrumental measurements, allowing to avoid inter-operator differences.

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FOOT JOINTS MOBILITY AND PLANTAR PRESSURE IN THE FOOT

P. Caravaggi (1), C. Giacomozzi (2), A. Leardini (1)
(1) Movement Analysis Laboratory, Istituto Ortopedico Rizzoli, Bologna, Italy
(2) Department of Technology and Health, Istituto Superiore di Sanità,

Main topics: Experimental studies in human movement science, Functional outcome measures in mobility

INTRODUCTION and AIM

The foot is generally regarded as a flexible structure which can adjust its flexibility in response to various external conditions and variable dynamic states, i.e. gait phases, within the motor tasks. In gait, both joint kinematics and plantar pressures have shown to be affected by functional and structural factors [1]. In fact pressure distribution can be seen as the effectiveness of the musculoskeletal system in absorbing the ground reaction forces via the foot and its joints. Excessive foot pressure may develop into calluses, which become sites of peak pressure and pain. The relationship between foot joints mobility and plantar pressure has not been thoroughly investigated. Aim of this study was to combine a multi-segment kinematics model [2] and advanced baropodometric analysis based on anatomical masking [3], to investigate correlations between intersegmental kinematics and regional baropodometric parameters in the normal foot.

PATIENTS/MATERIALS and METHODS

Ten able-bodied subjects (26.8 ± 6.9 years; 67.5 ± ; BMI 22.0 ± 2.7) volunteered in the study. An eight-camera motion system () was used to track foot segments during the stance phase of level walking, according to an established protocol [2]. Simultaneously, a pressure plate (Novel Gmbh,) recorded foot plantar pressure over three repetitions. An anatomical-based selection was employed to divide the pressure footprints in seven subareas [3]. Maximum of mean and peak pressure, of vertical force, contact-area and -time, and pressure- and force-time integrals, were determined for each subarea. The relationship between range of motion (ROM) of each foot joint and baropodometric parameters in each subarea was investigated using Pearson's and Spearman's coefficients.

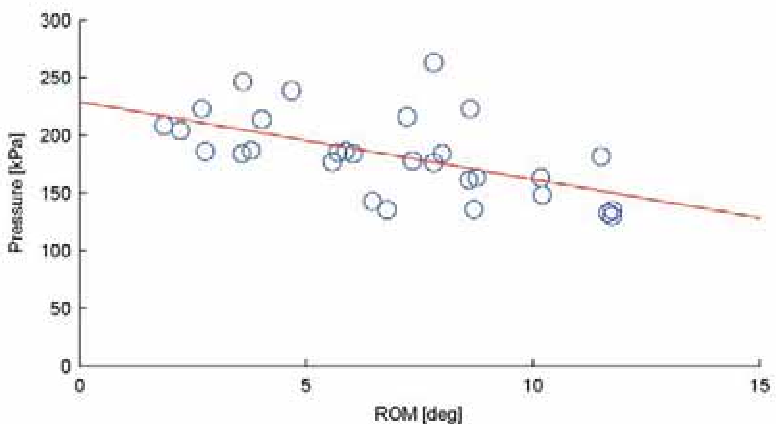

Figure 1: A Pearson's r = - 0.57 (r^2=0.32, p=0.001) was found between peak pressure (kPa) at the forefoot and frontal-plane ROM (deg) at the ankle joint. The linear regression line (red) is superimposed to the data points.

RESULTS

Most of the statistically significant correlations (p<0.05) between foot joints ROM and baropodometric parameters were moderate (Pearson's |r| =0.36 – 0.67). In general, motion at the foot joints was negatively correlated with pressure and pressure-time integral at rearfoot and forefoot (Figure 1) and positively correlated at midfoot. Strong correlation was found between ROM of the medial longitudinal arch angle and pressure-time-integral at the forefoot (Spearman Rho = - 0.93, p<0.05).

DISCUSSION and CONCLUSIONS

According to the sample of normal feet analyzed in this study, those feet presenting smaller joint mobility are associated with larger pressure at the rear- and forefoot. A trend for decreased pressure at the midfoot was also detected in feet with a stiffer medial longitudinal arch. A more flexible foot may allow better distribution of pressure at the plantar foot surface during gait thus limiting the contribution to plantar tissue damage especially in at-risk groups such as the diabetic feet.

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VISUAL CUEING COMBINED WITH TREADMILL TRAINING IN PARKINSON'S DISEASE: EFFECTS ON GAIT AND BALANCE

C. Schlick (1,2), S. Wagner (1), A. Ernst (1), J. Ilmberger (1).
(1) University Hospital of Munich (LMU), Department of Orthopedic Surgery, Physical Medicine and Rehabilitation, Munich, Germany
(2) Ludwig-Maximilians-University, German Center for Vertigo and Balance disorders, Munich, Germany

Main topics: Analysis of gait and motor disorders, Outcomes after clinical intervention, Rehabilitation.

INTRODUCTION and AIM

Different cueing strategies as well as treadmill training can improve gait and posture impairments in patients with Parkinson's disease [e.g. 1,2]. Based on this background, we developed a strategy combining both visual cues and treadmill walking. This pilot randomized controlled trial aimed to investigate the effects of the combined training approach compared with pure treadmill training on gait and balance in a group of patients with a moderate to severe stage of Parkinson's Disease.

PATIENTS/MATERIALS and METHODS

A total of 20 patients (Hoehn&Yahr II-IV) were randomly allocated into two different training groups. The cueing group received visual cues in shape of the individual footprints combined with treadmill training (software: RehaWalk®, Fa. zebris Medical GmbH; Figure 1). In the pure-treadmill group, training consisted of only treadmill walking. All patients completed 12 training sessions within five weeks. Instrumented gait and stance analysis was performed before and after the training period. Outcome measures were gait speed, stride length and cadence to evaluate gait, and normalized sway path length (curviness of the center-of pressure trajectories, higher values indicate alterations in postural stability) and sample entropy (regularity of center-of-pressure fluctuations, higher values suggest an increase in automaticity of postural control) to evaluate balance [3].

Figure 1. Patient's perspective on the visual cues projected onto the treadmill belt.

RESULTS

Results are shown as intra- and intergroup differences.

Gait speed and stride length increased in both groups (cueing group: 0.9 kmh ± 0.4 kmh, $p < 0.001$, and 29.3 cm ± 19.9 cm, $p < 0.01$; pure-treadmill group: 1.1 kmh ± 0.7 kmh, $p < 0.01$, and 29.3 cm ± 21.1 cm, $p < 0.01$). Cadence did not change, indicating that the increase in gait speed was achieved by enhancing the stride length rather than the cadence. No intergroup differences were found.

Sample entropy increased in the cueing group (0.38 ± 0.42; $p < 0.05$) but not in the pure-treadmill group (0.07 ± 0.35; $p > 0.05$) and the sample entropy values were significantly higher in the cueing group after the training period ($p < 0.05$). Normalized sway path length did not show any intra- and intergroup differences.

DISCUSSION and CONCLUSIONS

Both training strategies are effective in normalizing the impaired gait pattern of patients with Parkinson's disease but only the additional use of visual cues during treadmill training can improve balance performance. In particular, the findings of this study suggest that the rhythm-generating cueing technique stimulates an increase in automaticity of postural control.

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FREQUENCY ANALYSIS OF VERTICAL FORCES IMPROVES BALANCE MEASUREMENTS

F. Martelli (1), C. Giacomozzi (1), M. Lillia (2), A. Fadda (1)
(1) Istituto Superiore di Sanità, Rome, Italy
(2) Electronic High School ISIS Arturo Malignani, Udine, Italy

Main topics: Technical developments in movement science.

INTRODUCTION and AIM

Balance during orthostatic standing is usually investigated through force platforms, to be intended as gold standard technology, and consolidated sets of parameters and protocols [1]. Force instantaneous changes associated to centre of mass vertical oscillations had been scarcely investigated [2], maybe due to inadequate signal quality. However, they might represent an added value to gain knowledge in neuro-muscular strategies adopted to maintain balance under pathological conditions. The present study focusses on the independent assessment of a newly arranged commercial technology, which integrates a traditional podoscope with accurate load cells, and which claims accuracy high enough to allow a reliable insight into the vertical force frequency spectrum. The study also analyzes two small samples to evaluate feasibility and relevance of the proposed analysis, i.e. a normal active healthy population (Controls) and trained Athletes.

PATIENTS/MATERIALS and METHODS

The assessed device, the PODATA force plate (GPS400, Chinesport, Udine, Italy), is CE certified as class I medical device with measuring function, and relies on 6 load cells which deliver a highly accurate dataset in terms of instantaneous COP coordinates and vertical force value (12bit A/D converter; overall resolution 0.0125 kg, linear accuracy 5%, angular accuracy 2.5%, sampling rate 200 Hz). The observation period is limited to 20s according to the Manufacturer pre-market clinical investigations outcomes. Tests with a calibrated static mass of 40kg (392.4N) were conducted on the Podata platform to estimate the 95% noise threshold; similar tests were conducted for comparison on a calibrated force platform and on a calibrated pressure platform. To complete the assessment, a preliminary application was conducted on two homogeneous groups of healthy young women, i.e. 10 with regular physical activity and 10 athletes in the field of classic and modern dance and ice skating. They were examined during open-eye orthostatic standing. COP and vertical force frequency spectra were obtained by applying a rectangular FFT over 4096 samples (observation time 20.48s, frequency resolution 0.05Hz).

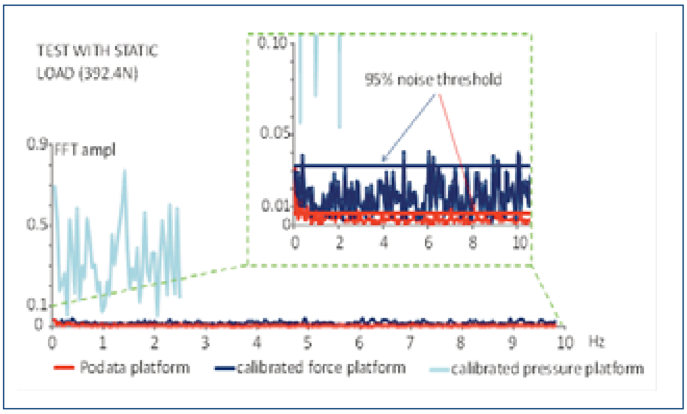

Figure 1: FFT amplitude of the vertical force signal from three different devices under controlled static loading.

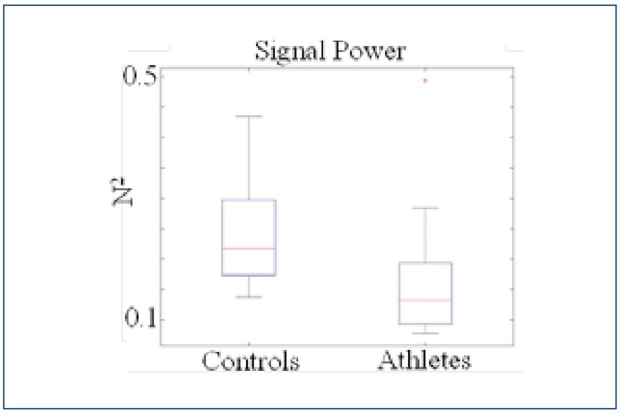

Figure 2: Box plot of the total signal power (DC removed) for Controls and Athletes

RESULTS

The technical assessment proved the device to be very accurate in terms of vertical force measurements and able to correctly detect signal variation <1% b.w. As for the preliminary application outcomes, none of the athletes showed frequency peaks below 3.6 Hz while controls showed peaks < 1Hz. The total signal power (DC removed) was much lower in the athletes group (Fig. 2).

DISCUSSION and CONCLUSIONS

High accuracy was found in the measurement of vertical force variation, which is not easily reproducible with other force/pressure measuring devices, even when properly calibrated. While at very low frequencies the signal might be correlated with COP signals, especially with ant-post COP signal, it proved to have a further meaningful frequency content in the range 1-10Hz, clearly distinguishable from noise. The application to the two groups of healthy women and well trained athletes showed that the vertical force FFT investigation is feasible and worth to be investigated. Main current drawbacks of the device resulted: i) the height of the platform, which prevented us from performing more demanding balance tasks and from examining pathologic conditions; ii) the observation period limited to 20s.

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APPLICATION OF SURFACE EMG IN YOUNG CHILDREN AFFECTED BY TEMPOROMANDIBULAR DISORDERS: A PILOT STUDY

F. Spolaor (1), Z. Sawacha (1), F. Cocilovo (2), C. Cobelli (1), A. Gracco (2).
(1) Department of Information Engineering, University of Padova, Padova,Italy
(2) Department of Neuroscience University of Padova, Padova, Italy

Main topics: Analysis of clinical movement data, Experimental studies in human movement science

INTRODUCTION and AIM

Temporomandibular (T) disorders (TMD) are a heterogeneous group of pathologies affecting the T joint, the masticator muscles, or both. A specific aetiopathogenesis is rarely demonstrable, because most cases have to be reconducted to a multifactorial aetiopathogenetic pathway [1]. The aim of this work is to verify weather subjects with TMD display different T joints muscles activation patterns than controls during consecutive chewing task.

PATIENTS/MATERIALS and METHODS

17 subjects participated in the study (mean age 9±2; mean BMI 19±6): 3 healthy (control subjects (CS), 14 with temporomandibular disorder (TMDS) who had not south any treatment. Subjects were asked to eat a cookie, and surface electromyography (sEMG) activity was recorded while chewing. Afterword 2 maximum voluntary contractions (MVC) were performed through maximum teeth clenching either with or without cotton roll. Kinematics data (glabella, right and left T joints markers trajectories) were acquired together with sEMG signals of Right Temporalis (RT), Right Masseter (RM), Left Temporalis (LT) and Left Masseter (LM). A BTS motion capture system (6 cameras, 60-120 Hz) synchronized with a Free EMG system (8 channels SEMG system, BTS, Srl) were used. sEMG linear envelopes were evaluated and the following parameters defined: peak of envelope position (PoE), Peak of Envelope (PE) and RMSD [2]. With respect to chewing tasks 5 consecutive chewing cycles were identified through motion capture data and 10 consecutive seconds out of the central part of the acquired signal were selected from MVC trials. Welch's t test (which is an adaptation of Student's *t*-test intended for use with two samples having possibly unequal variances) was performed between sEMG variables of TMD and CS groups (SPSS, version 13.0) in order to account for different sample size.

RESULTS

During each motor task every muscles in TMD group showed a significant higher value of PE (Figure 1) and a delay in PoE when compared to CS ($0.007<p<0.041$). Both groups showed a symmetric activation of right and left muscles during chewing activities.

DISCUSSION and CONCLUSIONS

Preliminary results showed that sEMG allowed to highlight differences in timing of muscles activation between TMDS who had not south treatment and CS. Delay in PoE and higher PE values can be justified by considering that TMD subjects exhibit neuromuscular alterations that can lead to functional alterations. The latters may determine delayed muscle activation accompanied by larger amplitude of the muscle activity in order to cope with the underling deficit.

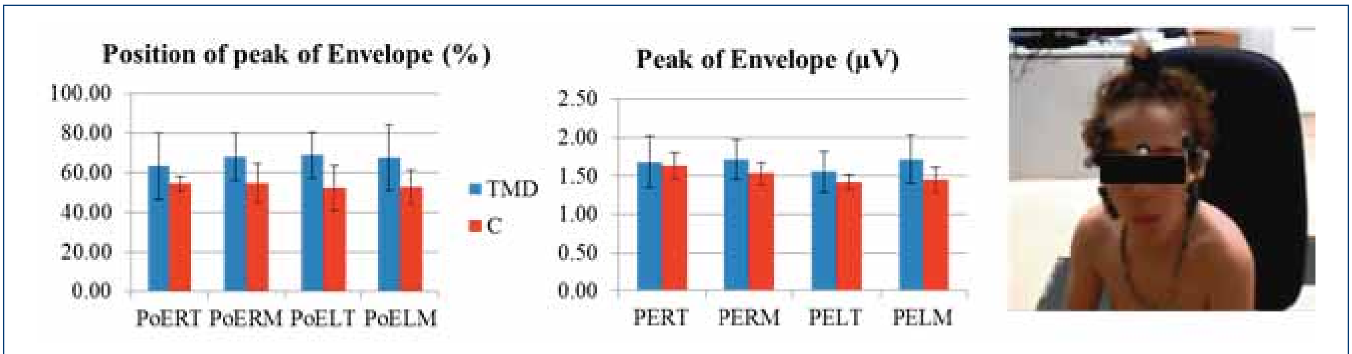

Figure 1: Left: Each muscles mean and standard deviation of PoE and PE of TMD and CS (Red=C; Blue=TMD) . Significant $p<0.05$; Right: a patient while executing the task

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13:30-14:10
Aula Major

A DYNAMICAL SYSTEM APPROACH TO DISORDERED MOVEMENT: IMPLICATIONS FOR REHABILITATION

Sérgio T. Fonseca
Department of Physical Therapy of the Universidade Federal de Minas Gerais (UFMG) Brazil
School of Physical Education, Physical Therapy and Occupational Therapy of the UFMG
Visiting Scholar at the Center for the Ecological Studies in Perception and Action of the University of Connecticut

e-mail: sergioteixeirafonseca@gmail.com

ABSTRACT. Movement is an emergent pattern that results from complex systems (neural, mechanical and physiological) that interact, change and evolve over time. Therefore, movement cannot be prescribed and controlled by one entity (e.g. central nervous system). Instead, movement is the result of a process called self-organization in which energy flows (mechanical and perceptual) govern the behavior. In line with this principle, our research evaluateshow the available dynamic resources of an individual affect the observed emergent pattern. Dynamic modeling and movement analysis are used to understand disordered movements and to propose approaches to improve the functional behavior of individuals with such disorders.

14:10-15:00
Aula Major

CHILDREN DISEASES. IN HONOUR TO PROF. SILVANO BOCCARDI
Chairs: Maurizio Ferrarin, Stefano Negrini

14:10-14:20
DOES DECREASED SPASTICITY IMPROVE GAIT IN CHILDREN WITH CP AFTER SELECTIVE DORSAL RHIZOTOMY?
C. Huenaerts, P. Pauwels, G. Molenaers, A. Van Campenhout, B. Nuttin, J. De Cat, D. Monari, J. Paquet, K. Desloovere

14:20-14:30
EFFECTS OF VERTICAL STIFFNESS ABSORPTION ON GAIT KINEMATICS OF HEALTHY CHILDREN AND CHILDREN WITH HEMIPLEGIA
A. Pacilli, S. Rossi, A. Colazza , F. Patanè, E. Castelli, P. Cappa, M. Petrarca

14:30-14:40
EFFECT OF INTRA ARTICULAR FOOT JOINT INJECTIONS ON GENERATING MUSCLE POWER DURING WALKING IN CHILDREN WITH JUVENILE IDIOPATHIC ARTHRITIS
A. Esbjörnsson, M. André, M.D. Iversen, S. Hagelberg, M. Schwartz, E.W. Broström

14:40-14:50
MEASUREMENT OF NEUROMECHANICAL ANKLE PARAMETERS IN CEREBRAL PALSY
L. Sloot, M. van der Krogt, E. de Vlugt, J. Harlaar

14:50-15:00
THE LEVEL OF CO-ACTIVATION DURING MAXIMAL AND SUBMAXIMAL DYNAMOMETRY TESTING IN ADOLESCENTS WITH SPASTIC CEREBRAL PALSY
M.M. Eken, A.J. Dallmeijer, C.A. Doorenbosch, H. Dekkers, J.G. Becher, H. Houdijk

DOES DECREASED SPASTICITY IMPROVE GAIT IN CHILDREN WITH CP AFTER SELECTIVE DORSAL RHIZOTOMY?

C. Huenaerts (1), P. Pauwels (2), G. Molenaers (2), A. Van Campenhout (2), B. Nuttin (3), J. De Cat (4), D. Monari (5), J. Paquet (3), K. Desloovere (1,4)
(1) Clinical Motion Analysis Laboratory, Univ Hosp Leuven; (2) Dept Develop and Regen; (3) Dept Neurosc; (4) Dept Rehab Sc; (5) Dept Mech Eng, KU Leuven, Belgium

Main topics: Analysis of gait and motor disorders, Outcomes after clinical intervention

INTRODUCTION and AIM

Selective dorsal rhizotomy (SDR) is a neurosurgical procedure aimed to reduce spasticity and thereby increase functionality in children with spastic cerebral palsy (CP). Although it is described that spasticity is clearly diminished after SDR, there is less evidence that gait and functionality is improved [1]. This may be related to the finding that strength has a higher correlation with function [2]. The aim of this study was to evaluate spasticity, strength and gait, one year after SDR.

PATIENTS/MATERIALS and METHODS

Forty-two children with spastic diplegic CP underwent an SDR between 2001 and 2013 and received 3D lower limb gait analyses, including kinematics, kinetics, EMG and a clinical examination prior to and one year post (range 11-17 months) SDR. The Gait Profile Score (GPS), the Movement Analysis Profiles (MAPs) and seven clinically important kinematic parameters were calculated. Paired T-test was used to investigate whether there were significant differences between pre and post SDR condition. Difference scores (DS) were calculated between post and pre condition to be able to correlate the changes after SDR to the pre SDR condition. Comparison of Modified Ashworth Scale (MAS) and strength measurements pre versus post SDR condition was done by means of the Wilcoxon signed rank test. Correlation between MAS, strength, the amount of rootlets cut (%RC) and pre SDR gait was studied using the Pearson Correlation Coefficient. A subgroup of 22 patients also received a second follow-up 3D gait analysis two years after SDR (range 23-36 months). The same gait parameters were compared between pre, one year post and two year post SDR.

RESULTS

The GPS showed no significant difference between pre and post SDR condition. Taking into account the MCID of the GPS (1.6° [3]) there was an improvement in 27% of the children. 50% showed no change and 23% had a higher GPS. At the knee, the MAPS showed significant less deviation ($p<0.001$) due to improved knee extension at initial contact (IC) and midstance and increased flexion in swing. The ankle motion tended to be less deviated from normal, however not significant. The ankle position at IC was significantly better after SDR. MAPS of the pelvis and hip in the sagittal plane showed significant increased pathology after SDR. Correlation between DS and pre SDR condition showed low to moderate correlations for all MAPs indicating that there was more improvement in more affected children. These correlations were higher in the coronal and transverse plane compared to the sagittal plane. MAS and strength respectively decreased ($p=0.000$) and increased ($p=0.001$) for all observed muscles post SDR. Correlation between strength and GPS showed low but significant correlations for hip extensors ($r=-0.412$), hip abductors ($r=-0.460$) and dorsiflexors ($r=-0.499$). Between MAS and GPS, there were only low correlations for the hip flexors ($r=0.317$), hip adductors ($r=0.414$) and the total MAS score ($r=0.409$). Low correlation was also found between %RC and the pre GPS ($r=0.314$).
In the subgroup of 22 patients, there were no significant differences between one and two year post SDR.

DISCUSSION and CONCLUSIONS

One year after SDR, gait significantly improved at the knee and ankle. However, due to increased pelvic anterior tilt and hip flexion there was no overall reduction of the gait deviation, as expressed by GPS. The second follow-up one year later showed no reversal of this pattern. We observed only low correlations between spasticity and gait, which is in accordance to previous studies [1, 2] and may explain why the reduced spasticity does not result in an overall improved gait pattern. While psoas spasticity decreased and hip extensors strength increased, the pathological pelvic anterior tilt remained. These findings, especially at the proximal levels, may be related to possible loss of sensory control after SDR due to the afferent rootlets that were cut. This imbalance in treatment response between proximal and distal levels may be tackled by a more careful SDR procedure when rootlets of the proximal muscles are involved and by targeted rehabilitation pre- and post SDR on hip and pelvis.

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[3] Baker et al, Gait & Posture 2012

EFFECTS OF VERTICAL STIFFNESS ABSORPTION ON GAIT KINEMATICS OF HEALTHY CHILDREN AND CHILDREN WITH HEMIPLEGIA

A. Pacilli (1), S. Rossi (2), A. Colazza (3), F. Patanè (4), E. Castelli (3), P. Cappa (1,3) & M. Petrarca (3)
(1) Dept. of Mechanical and Aerospace Engineering, Sapienza University of Rome, Roma, IT
(2) Dept. of Economics and Management – Industrial Engineering, University of Tuscia, Viterbo, IT
(3) Movement Analysis and Robotics Laboratory, IRCCS Children's Hospital "Bambino Gesù", Palidoro (RM), IT
(4) School of Mechanical Engineering – Niccolò Cusano University, Roma, IT

Main topics: Analysis of gait and motor disorders, Robotic devices in human movement science.

INTRODUCTION and AIM

Children with hemiplegia utilize a greater vertical stiffness and a greater ratio of kinetic forward energy to potential energy during walking [1]. It is also possible to delve deeper into the knowledge of this mechanism by analyzing the strategies provided by the entire body when a floor perturbation is imposed during walking [2]. Therefore, our goal is to quantify the effects induced by an increase in the floor compliance aimed to absorb the vertical stiffness; moreover, we want to figure out if healthy children and children with hemiplegia provide different motor strategies to compensate for this perturbation.

PATIENTS/MATERIALS and METHODS

Ten healthy, right-handed children (11±2 y) and ten age matched children with hemiplegia were asked to walk along a predefined linear path over the RotoBit3D platform [3]. The platform could randomly (1) be blocked, acting as the conventional floor, or (2) it could change the tilt angle from 0° to 6° with a time constant of 0.3 s (Figure 1). The limb hitting the platform, called "P" leg, was the right one for the control group and the more affected one for the children with hemiplegia; the other limb was called instead "NP" leg. Using a motion capture system, we acquired for both limbs: (a) the maximum ankle flexion and (b) extension, (c) the maximum and (d) minimum knee flexion and (e) the hip ROM, during the three steps: the step before the perturbation (S0), the perturbed step (S1) and the step following the perturbation (S2). All data were analyzed with GROUP x LIMB x STEP, i.e. 2 x 2 x 3, mixed ANOVA design tests, with GROUP (healthy vs. pathologic) as between-subjects factor, and with LIMB (P, NP) and STEP (S0, S1, S2) as within-subjects factors.

RESULTS

In Table 1 the results for the P limb of the two groups are summarized; data are clustered according to the three step conditions S0, S1 and S2. From the ANOVA test, a main factor STEP ($p<0.05$) for all the computed variables and a main effect GROUP for the hip ROM resulted statistically different. Moreover, we found a significant interaction effect GROUP x STEP for both ankle flexion and extension and for the hip ROM.

Figure 1: The platform tilting during the perturbed step (S1).

Table 1: Perturbed limb: mean angles and standard deviations for the step conditions S0, S1 and S2.

Angle (°)	Healthy children			Children with hemiplegia		
	S0	S1	S2	S0	S1	S2
Ankle flexion	14,5 (3.9)	10.4 (3.8)	14.8 (2.7)	12.2 (6.4)	10.1 (6.1)	11.5 (5.9)
Ankle extension	12.6 (7.9)	15.3 (7.5)	12.0 (6.6)	13.4 (9.5)	13.2 (10.9)	17.1 (12.2)
Knee flexion	70.8 (6.4)	73.7 (7.1)	68.3 (6.1)	62.3 (7.5)	70.2 (7.1)	61.3 (7.7)
Knee minimum flexion	9.8 (5.1)	10.2 (5.3)	9.6 (5.7)	8.7 (5.0)	9.2 (7.7)	6.7 (6.3)
Hip ROM	6.6 (1.1)	7.0 (1.3)	6.1 (1.5)	9.4 (3.4)	12.2 (3.7)	9.0 (1.9)

DISCUSSION and CONCLUSIONS

The imposed perturbation affects the lower limb kinematics in both healthy children and children with hemiplegia but in a different manner, as revealed by the interaction effects of the ANOVA test. In healthy children the perturbation is primarily absorbed by the ankle and slightly by the knee. Moreover, the effects of the perturbation are entirely absorbed during the S1, without consequences during S2. In subjects with hemiplegia, instead, the perturbation propagates from the ankle, that is just slightly influenced, up to the hip, which shows significant differences between S0 and S1. Moreover, at S2 kinematics is still affected by the S1 perturbation.

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EFFECT OF INTRA ARTICULAR FOOT JOINT INJECTIONS ON GENERATING MUSCLE POWER DURING WALKING IN CHILDREN WITH JUVENILE IDIOPATHIC ARTHRITIS

Esbjörnsson AC(1), André M(2), Iversen MD(1,3), Hagelberg S(1), Schwartz M(4), Broström EW(1)
[1] Department of Women's and Children's Health, the Karolinska Institute, Stockholm, Sweden
[2] Department of Neurobiology, Care Science and Society, the Karolinska Institute, Stockholm, Sweden
[3] Dept of Physical Therapy, Movement & Rehabilitation Sciences, Northeastern University and Division of Rheumatology, Brigham & Women´s Hospital, MA, United States
[4] Gillette Children's Specialty Healthcare, MN, United States

Main topics: Outcomes after clinical intervention, Analysis of gait and motor disorders

INTRODUCTION and AIM

Children with Juvenile Idiopathic Arthritis (JIA) characteristically ambulate with reduced walking speed and show attenuated kinematics and kinetics [1]. Those with ankle involvement demonstrate reduced ability to generate ankle power during push-off in walking [1]. Joint inflammation and associated muscular weakness around the affected joints, even in children *without* active JIA, leads to decreased plantar flexor strength [2]. This study includes children with JIA with foot involvement undergoing treatment with intra-articular corticosteroid joint injections (ICI). We aim to evaluate the long-term effects of ICI (3 months post-injection) on generating ankle power.

PATIENTS/MATERIALS and METHODS

43 children with JIA were consecutively recruited, 35 girls and 8 boys, mean (SD) age 11.1 (4.2) yrs., mean (SD) disease duration 4.5 (3.6) yrs. 65% were diagnosed with polyarthritis. All children had inflammation in the foot and 63% had additional injections in knee and/or hip. Children were evaluated pre- ICI, 3 weeks and 3 months after injections with three dimensional gait analyses; power generation and walking speed were primary outcomes. Forty age and gender matched typically developing children comprised the control group. Inflammatory joint symptoms (number of swollen joints, painful joints and joints with limited range of motion) in the lower extremity were summarized (joint score 0= no impairments to 26 = max impairments). Peak power generation and positive work, defined as the sum of generating muscle power, during push-off in ankle and hip and was calculated. Walking speed was made non-dimensional according to Hof (1996). Parametric and non-parametric statistics were used depending on the distribution and nature of the data.

RESULTS

Inflammatory joint symptoms decreased significantly at 3 weeks post ICI and remained improved 3 months after treatment (median (min-max) pre 10 (1-18) at 3 weeks 2 (0-12) and at 3 months 3 (0-18); $p<0.05$).

Before injection, children with JIA walked significantly slower as compared to healthy controls (mean (SD) JIA; 0.43 (0.1), control; 0.49 (0.1); $p< 0.001$); generating power at the ankle was significantly lower (mean (SD) 3.0 (1.2) compared to controls (3.8 (0.67) $p<0.01$); peak generating hip power did not differ from controls; positive work at hip and ankle did not differ statistically from controls before treatment even though there was a tendency towards decreased level of positive work at the ankle and increased work at the hip. The ratio of ankle/ hip peak generation power (mean (SD) JIA; 2.5 (1.0), control; 3.1 (1.1) and positive work (mean (SD) JIA; 1.6 (0.7), control; 2.1 (0.8) J/kg; $p<0.01$) was significantly lower before treatment as compared to controls. None of the measures of power improved with treatment except for the ratio ankle/hip power which improved at 3 month.

DISCUSSION and CONCLUSIONS

Despite reduction in inflammatory joint symptoms, children with JIA still ambulated with reduced walking speed and ankle power after ICI. All children with JIA had active inflammation in the foot at baseline and most had their disease for several years. Muscle strength was not assessed but it is to be expected that they had reduced muscular strength around the ankle. Consistent with data in other population samples, lower ratios between ankle/ hip and work indicate that hip flexors were compensating for the weaker plantar flexors during push-off [3]. These data suggest compensatory walking strategies persist after treatment with ICI, despite improvements in inflammatory parameters, indicating the need for improved training programs.

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MEASUREMENT OF NEUROMECHANICAL ANKLE PARAMETERS IN CEREBRAL PALSY

LH. Sloot (1), MM. van der Krogt (1), E. de Vlugt (2), J. Harlaar (1)
(1) Dept. of Rehabilitation Medicine, MOVE Research Institute Amsterdam, VU University Medical Center, Amsterdam, The Netherlands
(2) Dept. of Biomedical Engineering, Delft University of Technology, Delft, The Netherlands

Main topics: Analysis of clinical movement data; Musculoskeletal modelling

INTRODUCTION and AIM

Spastic Cerebral Palsy (CP) is characterized by increased joint stiffness, caused by a mix of increased stretch reflex activity and muscle tone, as well as altered visco-elastic tissue properties. Since treatment depends on the specific cause, objective quantification of the ankle neuro-mechanical parameters would contribute to patient specific treatment. Previous assessment was limited to the triceps surae muscle group and the distinction between reflex activity and tissue visco-elasticity [1,2]. To gain more muscle specific information, the instrumented assessment (IA) combined with system identification was extended to include baseline muscle tone and to differentiate between the three major lower leg muscles. We evaluated the ability of the extended IA to discriminate between children with spastic CP and controls.

PATIENTS/MATERIALS and METHODS

21 children with spastic CP (11.1±3.3 yr, GMFCS 1-3) and 34 control children (10.2±2.7 yr) were included. Their most affected foot was fixated to a motor driven footplate that rotated around the ankle joint. Two passive slow (5 º/sec) and fast (100 ºgrad/s) ramp-and-hold rotations were applied in the sagittal plane over the full range of ankle motion (ROM), at two different knee angles (20º and 70º) to discriminate between the triceps muscles. Ankle angle and EMG of the gastrocnemius (GAS), soleus (SOL) and tibialis anterior (TIB) muscles were used to optimize a nonlinear neuromuscular model to match the measured ankle torque. Tissue stiffness and viscosity were based on the slow trials and taken at the highest plantar (40º) and dorsiflexion (5º) angle reached by all subjects. Root-mean-squares of baseline muscle tone and reflex torque were taken from the fast trials. Non-parametric tests with Bonferroni correction were performed to assess the difference between CP and controls.

RESULTS

In CP, there was a trend of 1,62 times increased stiffness in the SOL (p=0,02; Fig 1A) and viscosity was 4.0 and 2.8 times larger for the SOL and TIB (p<0.001; p=0.03). The reflex torque was enlarged in CP by 5.2 and 3.8 times in the GAS and SOL respectively (both p<0.001), but not in TA (Fig 1B). Baseline muscle tone was 2.4 and 1.9 times increased in the GAS and SOL (p=0,007; p<0,001; Fig 1C). Variances were generally larger for CP and ratios between stiffness and reflex torque differed considerably between patients.

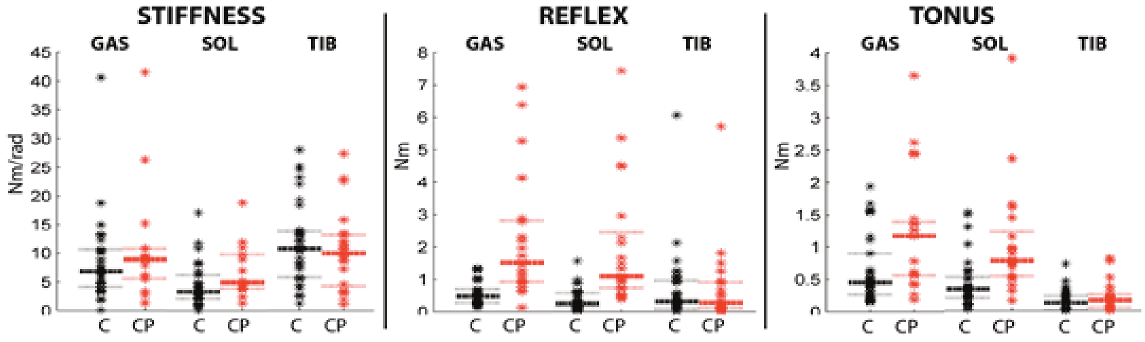

Figure 1: median values and 25/75 percentiles for stiffness (A), reflex (B) and tonus (C) for CP patients and controls (C).

DISCUSSION and CONCLUSIONS

The IA was able to discriminate between CP patients and controls. In CP, reflex torque and muscle tone were found to be increased in the triceps muscles, which are often treated for spasticity. Stiffness only showed an increase for SOL, although a difference also emerged for GAS when choosing a higher dorsiflexion angle, at the expense of decreasing the group of subject. The large variances and ratio differences in CP indicates that instrumented assessments could allow for subject specific therapy selection.

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THE LEVEL OF CO-ACTIVATION DURING MAXIMAL AND SUBMAXIMAL DYNAMOMETRY TESTING IN ADOLESCENTS WITH SPASTIC CEREBRAL PALSY

M.M. Eken (1,2), A.J. Dallmeijer (1), C.A.M. Doorenbosch (1,3), H. Dekkers (2), J.G. Becher (1), H. Houdijk (2,4)
(1) Department of Rehabilitation Medicine, MOVE Research Institute Amsterdam, VU University Medical Center, Amsterdam, the Netherlands
(2) Heliomare Rehabilitation, Research and Development, Wijk aan Zee, the Netherlands
(3) Academy of Human Kinetic Technology, University of Applied Sciences, the Hague, the Netherlands
(4) MOVE Research Institute Amsterdam, Faculty of Human Movement Science, VU University, Amsterdam, the Netherlands

Main topics: Analysis of clinical movement data, Rehabilitation

INTRODUCTION and AIM
Muscle weakness is a common motor impairment in individuals with spastic cerebral palsy (CP). Dynamometry is widely used among individuals with CP to quantify this impairment. However, increased muscle co-activation might reduce the validity of dynamometer strength measurements in these individuals. Therefore, the aim of this study is to investigate the degree of muscle co-activation during maximal and submaximal dynamometer tests in adolescents with CP in comparison to TD adolescents.

PATIENTS/MATERIALS and METHODS
Surface electromyography (EMG) recordings were made of quadriceps (m.rectus femoris (RF), m.vastus medialis (VM), m.vastus lateralis (VL) and hamstrings (m.biceps femoris (BF), m.semitendinosus (ST)) of 16 adolescents with CP (age: 13-19y; GMFCS level I/II) and 14 TD peers (age: 12-19y) during maximal voluntary *isometric* knee extension and flexion contractions (MVCs) and series of submaximal *isotonic* knee extension contractions at three different loads (mean %MVC lowest load: 65%; medium load: 75%; highest load: 85%). After rectifying and low pass filtering (5Hz), EMG amplitude (amp) was normalized to the amplitude found during the MVC. Co-activation index (CAI) was calculated as: $1-(|amp_{agonist}| - |amp_{antagonist}|)/(|amp_{agonist}| + |amp_{antagonist}|)$ [1] and averaged over the extension contraction. CAI was averaged over three contractions for both maximal and submaximal contractions. Differences in CAI between CP and TD were analysed using a Mann-Whitney U-test. To test the influence of load on CAI, a Friedman's ANOVA was used separately for both groups ($p<.05$).

RESULTS
Higher CAI levels were observed during maximal contractions in adolescents with CP compared to TD adolescents in all agonist-antagonist pairs (mean RF/BF CP: .486, TD: .344; RF/ST CP: .401, TD: .210; VM/BF CP: .479, TD: .272; VM/ST CP: .415, TD: .221; VL/BF CP: .445, TD: .282; VL/ST: CP: .396, TD: .225). No differences in CAI were observed between the groups during submaximal contractions at different loads (Fig. 1, example of RF/BF).

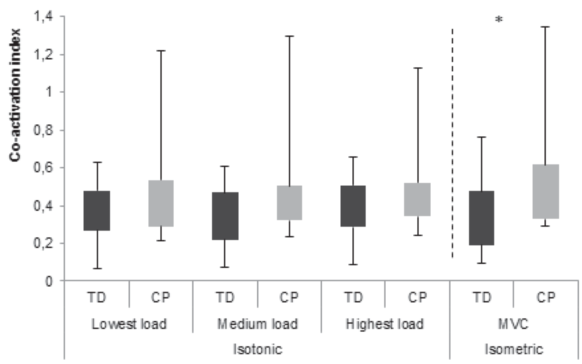

Figure 1: Boxplots of CAI of agonist-antagonist pair RF/BF separately for the isotonic and isometric tests; * p<.05.

DISCUSSION and CONCLUSIONS
During isometric MVCs, adolescents with CP showed higher CAI levels than TD adolescents, while there were no differences in CAI during submaximal isotonic contractions. The results suggest that dynamometer measurements with maximal contractions are more influenced by co-activation than submaximal contractions in adolescents with CP. Submaximal muscle testing may therefore be preferred when assessing muscle strength in individuals with CP.

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15:00-16:00 *Aula Major*	**FOOT AND ANKLE** ***Chairs: Julie Stebbins, Alberto Leardini***
15:00-15:10	A ROBOTIC DEVICE FOR ANKLE MOTOR EVALUATION AND REHABILITATION IN PATIENTS WITH UPPER MOTOR NEURON SYNDROME *M. Caimmi, A. Chiavenna , C. Giovanzana, M. Malosio, F. Molteni, L. Molinari Tosatti*
15:10-15:20	QUANTIFYING SPASTICITY OF THE TRICEPS SURAE USING AN INSTRUMENTED SPASTICITY ASSESSMENT IN CHILDREN WITH CEREBRAL PALSY *S.H. Schless, K. Desloovere, E. Aertbeliën, G. Molenaers, M. de Jong, L. Bar-On*
15:20-15:30	THE RELATIONSHIP BETWEEN QUALITY OF LIFE AND FOOT KINEMATICS IN FLATFOOTED CHILDREN *A. Kothari, P. Dixon, J. Stebbins, A. Zavatsky, T. Theologis*
15:30-15:40	CHANGES IN MUSCLE ACTIVITY DURING EQUINUS GAIT IN CHILDREN. *L. Houx, M. Lempereur, O. Rémy-Néris, R. Gross, S. Brochard*
15:40-15:50	EVALUATION OF 3D FOOT DYNAMICS DURING HEEL - RAISE IN CHILDREN WITH FLATFOOT. *B. Krautwurst, S. Wolf, S. Mueller, E. von Stillfried, T. Dreher*
15:50-16:00	NEW FOOT SEGMENTATION MODEL: REPEATABILITY AND REPRODUCIBILITY STUDY. *C. Mahieu, P. Salvia , P. Martin-Sisteron, B. Beyer, J. Coupier, O. Snoeck, H. Bajou, J. Sterckx, V. Feipel, S. Van Sint Jan, M. Rooze*

A ROBOTIC DEVICE FOR ANKLE MOTOR EVALUATION AND REHABILITATION IN PATIENTS WITH UPPER MOTOR NEURON SYNDROME

M. Caimmi (1), A. Chiavenna (1), C. Giovanzana (2), M. Malosio (1), F. Molteni (2), L. Molinari Tosatti (1)
(1) Inst. of Industrial Technologies and Automation, Council of National Research of Italy, Milan, Italy
(2) Villa Beretta Rehabilitation Center –Valduce Hospital, Costa Masnaga (LC), Italy.

Main topics: Assistive devices; Rehabilitation; Motor control and motor learning.

INTRODUCTION and AIM

The equinovarus foot is the commonest posture seen in the lower extremity in the Upper Motor Neuron Syndrome (UMNS). Equinovarus limits dorsiflexion and, in addition to loss of motor control, alters the cyclical kinematic pattern of the lower limb and trunk during gait, inducing compensations for the less involved limb, pain, fatigue and impaired function. Rehabilitation therapies addressing prevention/treatment of stiffness and equinovarus focus on passive mobilization. Further, proper exercises are performed to strengthen dorsiflexor muscles and improve selective motor control aiming at reducing the risk of the *learning nonuse* phenomenon due to weakness of the dorsiflexor muscles. The importance of monitoring muscle activity with dynamic polyelectromyographic analysis for treatment customization is known [1]. Aim of this preliminary work is to present first applicability tests of a custom designed robot for ankle rehabilitation and to verify if the acquisition of surface EMG (SEMG) along with kinematic and dynamic measures may be a proper method for setting up a specific robotic exercise fitted on the patient impairment and residual functionality.

MATERIALS and METHODS

Participants. Five healthy (neurologically and orthopedically intact) subjects (5 males, 32±8 years old). Two stroke patients (a 56 years old man with left hemiparesis, 14 months from stroke and a 57 years old woman with right hemiparesis, 60 months after stroke).
Equipment. PKankle, a six degrees of freedom robotic device based on a fully parallel spherical kinematic architecture designed for ankle rehabilitation. The device is equipped with modules for the acquisition of subject-robot interaction forces/torques and synchronized 4 channels wireless SEMG.
Protocol. For each subjects the activities of Tibialis Anterior m. (TA), Soleus m. (SOL), Gastrocnemius lateralis (GAL) and medialis m. (GAM) were recorded during gait at self-selected speed, during manual passive dorsiflexion to verify the presence of plantarflexor over-activity (only patients) and during mobilization with PKankle. PKankle movements consisted in: 1) Plantar-Dorsiflexion, 2) Full Circling Movement of the foot and 3) a complex movement of plantarflexion and dorsiflexion with alternately superimposed inversion and eversion. The three kind of movements were performed in two different conditions: firstly, the subject was asked to try to relax as much as possible during passive mobilization, secondly, he was asked to participate to the movement trying to slightly anticipate it. After tests, patients performed to 30 minutes of plantar-dorsiflexion mobilization.

RESULTS

All participants were mobilized without any problem. The female patient referred pain at the lateral side of the ball foot for a few days after the intervention. The intervention was repeated reducing ROM and consequently the dorsiflexion moment. No pain was referred anymore. The neuromuscolar activation pattern of the healthy subjects during mobilization highly resembles the one during gait (Fig.1). In the case of the 2 stroke patients, both the emg activity and dosiflexion torques were sensible to the range of mobilization.

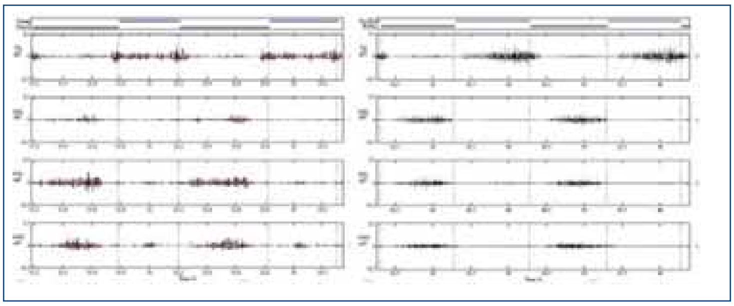

Fig.1. TA, GAL, SOL and GAM activity in gait (left) and PKankle (right).

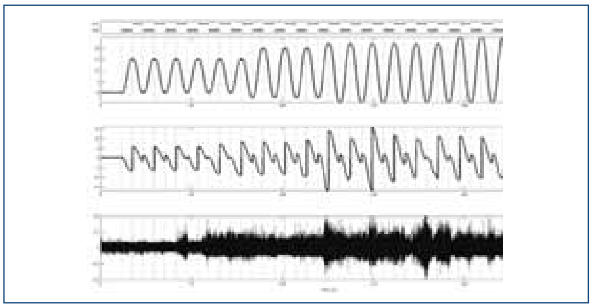

Fig.2 Dosiflex angle and torque and emg activity of TA m

DISCUSSION and CONCLUSIONS

First applicability tests are encouraging. Results refers to the importance of monitoring EMG and torques both to maximize muscle activity and to avoid complications. The Results on healthy subjects demonstrate that PKankle movements are highly ergonomic. Further tests on neurological patients will be done in the next months.

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QUANTIFYING SPASTICITY OF THE TRICEPS SURAE USING AN INSTRUMENTED SPASTICITY ASSESSMENT IN CHILDREN WITH CEREBRAL PALSY

SH Schless (1), K Desloovere (1), E Aertbeliën (2), G Molenaers (1), IM de Jong (3), L Bar-On (1)
(1) KU Leuven Department of Rehabilitation Sciences, Belgium
(2) KU Leuven Department of Mechanical Engineering, Belgium
(3) Delft University of Biomechanical Engineering, Netherlands

INTRODUCTION and AIM

Spasticity in triceps surae is thought to interfere with gait of children with cerebral palsy (CP). It is important to correctly assess spasticity to efficiently direct treatment. The Modified Ashworth Scale (MAS) is limited in its sensitivity in quantifying the amount of spasticity in the separate muscles of the triceps surae. In people with stroke, spasticity in soleus (Sol) is thought to be higher than the gastrocnemius muscles (1). In children with CP, the medial gastrocnemius (MeGa) is more often treated with Botulinum Toxin-A than lateral gastrocnemius (LaGa). Little research though, has been carried out to quantify the amount of spasticity in the selective muscles of the triceps surae of patients with CP. Therefore, the aim of this study was to compare the amount of pathological muscle activation in Mega, LaGa and Sol during passive muscle stretch, using an instrumented spasticity assessment (ISA) (2), in children with diplegic (Dip) and hemiplegic (Hemi) spastic CP.

PATIENTS/MATERIALS and METHODS

Eleven children with CP (Average Age: 12.1±3.3yrs; Dip/Hemi: 8/4; GMFCS: I-II) were assessed. The average MAS scores of the gastrocnemius and soleus for Dip children were 1.6±0.3 and 1.2±0.5, respectively, and 1.4±0.2 and 1.1±0.2 for Hemi children, respectively. With the subject lying in supine, and the tested leg 15° flexed at the knee on a support stand, joint angle characteristics and surface electromyography (EMG) from the Sol, LaGa and MeGa were recorded. A minimum of five, passive, high velocity stretches of triceps surae were applied by an experienced clinical therapist, with a 7 second rest between each stretch repetition. The most affected leg was always assessed, except in one child with diplegia who was assessed bilaterally. The average root mean square EMG (rms-EMG) was calculated as the area underneath the rms-EMG time curve, divided by the duration of EMG onset. Per muscle, average rms-EMG was normalized to the maximum voluntary contraction. Average rms-EMG was compared between muscles, and between children with Dip and Hemi, using dependent and independent non-parametric statistics, respectively. The relationship between average rms-EMG and age, was explored using Spearman's rank correlation coefficients. Significance was set to $p<0.05$.

RESULTS

EMG onset was detected in all three muscles during high velocity stretches. The median (Interquartile Range - IQR) values of average rms-EMG per muscle were: LaGa – 5.01% (8.7%), MeGa – 4.4% (13.6%), Sol – 7.9% (6.2%), but these differences were not significant (Fig. 1). There was a significantly higher average rms-EMG in the children with Dip, compared to the children with Hemi ($p= 0.001$) (Fig. 2). A moderate negative correlation between average rms-EMG and age was found ($r= -0.43$, $p<0.05$), which tended to be more marked in the children with Dip than in the children with Hemi (Fig. 3), most notably in the Sol, than in the MeGa or LaGa.

DISCUSSIONS and CONCLUSIONS

This small pilot study reports few differences between the amount of pathological muscle activation during passive stretch in the different muscles of the triceps surae in children with CP. There is more spasticity of triceps surae in children with Dip than of those with Hemi, and spasticity decreases with age. After these initial findings, future studies with larger samples should be carried out to verify these preliminary findings, and specific muscle behavior should also be explored during gait. This could help in directing muscle-specific treatment of the triceps surae in children with CP.

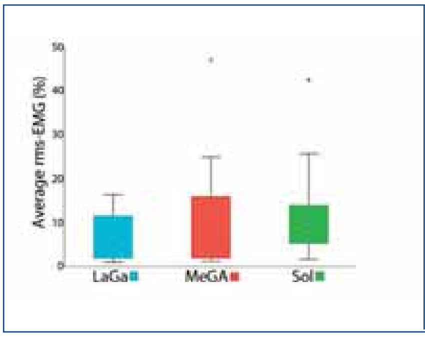

Figure 1: Average rms-EMG during high velocity passive stretch to each muscle of the triceps surae

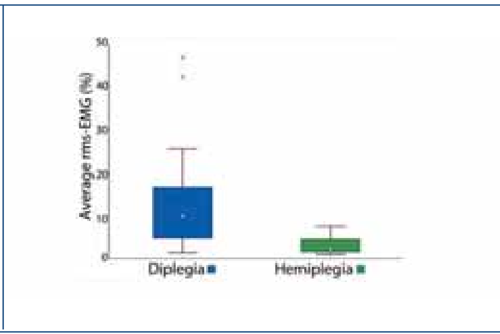

Figure 2: Average rms-EMG during high velocity passive stretch to the triceps surae

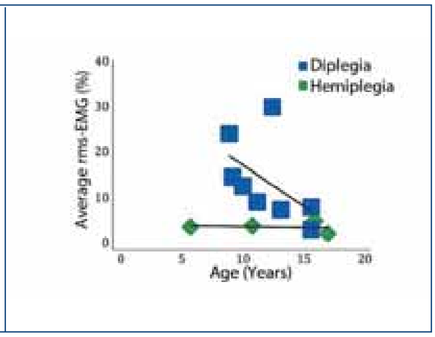

Figure 3: Correlation between average rms-EMG in the triceps surae and age, in both hemiplegic and diplegic children

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THE RELATIONSHIP BETWEEN QUALITY OF LIFE AND FOOT KINEMATICS IN FLATFOOTED CHILDREN

A Kothari(1), P C Dixon(2), J Stebbins(3), A B Zavatsky(2), T Theologis(1)
(1)Nuffield Department of Orthopaedics Rheumatology and Musculoskeletal Sciences, Nuffield Orthopaedic Centre, Windmill Road, Oxford, OX3 7LD, UK
(2)Department of Engineering Science, University of Oxford, Oxford, OX1 3PJ, UK
(3)Oxford Gait Laboratory, Nuffield Orthopaedic Centre, Oxford OX3 7LD, UK

Main topics: Analysis of clinical movement data, orthopaedics

INTRODUCTION and AIM

Flexible flatfeet (FF) is a common presentation to paediatric orthopaedic clinics. Controversy continues about whether treatment is required as there is little evidence to relate the structure or function of FF with symptoms and impairment in quality of life (QoL). The aim of this study was to use three-dimensional motion analysis (3DMA) to compare the function of children with FF to a neutral-footed (NF) group and to investigate how these differences relate to QoL in FF.

PATIENTS/MATERIALS and METHODS

Eighty-two children (age 8-15, 41 (NF) and 41 (FF)) completed the Oxford Ankle Foot Questionnaire for Children (OXAFQ_C) and underwent 3DMA using a Vicon MX system (Vicon UK), with the Oxford Foot Model (OFM) [1] and Plug in Gait marker sets [2]. OFM angles at heel strike (HS) and toe off (TO), as well as maxima, minima and range of motion (ROM) were obtained. Differences at discrete time points between groups were assessed using the Student's t-test and for the whole gait cycle via 95% Bootstrap confidence bands (BCBs). Spearman's rank was used to correlate with the OXAFQ_C physical domain scores with absolute foot angles where kinematic differences were displayed in the FF group.

RESULTS

There was no significant age difference between the FF and NF groups but there were more females in the FF group (M:F 18:23 (FF) vs 28:13 (FF) ($p=0.04$)). The BCBs demonstrated the FF group to have significantly more hindfoot valgus than the NF group with the difference most pronounced in late stance ($p<0.001$). Forefoot/hindfoot coronal angle (forefoot supination) was also significantly increased in the FF group for the majority of the gait cycle. This was most marked during the loading response ($p<0.001$). Correlation between discrete angular measures for hindfoot valgus and forefoot supination and OXAFQ_C scores demonstrated a strong negative relationship with forefoot supination (Table 1).

DISCUSSION and CONCLUSIONS

The main finding of this study was that the greater the amount of forefoot supination in relation to the hindfoot, the worse the QoL in children with flatfeet. Whilst the FF group were all, by definition, flexible the supination deformity was observed in both stance and swing phases. This finding suggests a more permanent alteration of the orientation of the forefoot in relation to hindfoot in some FF children. Excessive supination may also be evidence of peroneus longus defunctioning, leading to impaired 'push off' in late stance. Supination deformity is related to worse stages of adult acquired flatfoot deformity and we question whether this similar finding highlights a common pathway leading to worsening arthrosis and disability in certain individuals.
This study is the first to relate QoL with kinematics in FF and provides a biomechanical rationale for intervention. Intervention, be it non-surgical or surgical, should focus on correcting any forefoot supination deformity.

Table 1
Table demonstrating Spearman's Rho correlation coefficients between OxAFQ_C physical domain scores and joint angles at HS, TO as well as MAX, MIN and ROM. Coefficient as well as 95% confidence intervals (C.I.) shown and significance. * denotes statistically significant correlation.

	Hindfoot inversion/eversion		Forefoot supination/pronation	
	Correlation (95% C.I.)	Significance (p)	Correlation (95% C.I.)	Significance (p)
HS	0.20 (-0.01 to 0.40)	0.066	-0.40 (-0.56 to -0.29)	0.000*
TO	0.13 (-0.09 to 0.34)	0.250	-0.35 (-0.53 to -0.16)	0.001*
MAX	-0.21(-0.07 to 0.35)	0.057	-0.36 (-0.53 to -0.15)	0.001*
MIN	0.34 (-.14 to 0.52	0.002*	-0.35 (-0.53 to -0.14)	0.001*
ROM	0.15 (-0.41 to 0.01)	0.185	0.09 (-0.13 to 0.30)	0.403

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CHANGES IN MUSCLE ACTIVITY DURING EQUINUS GAIT IN CHILDREN

Laetitia Houx (1), Mathieu Lempereur (2), Olivier Rémy-Néris (3), Raphaël Gross (4), Sylvain Brochard (5)
(1) Department of Physical Medical and Rehabilitation, Morvan University Hospital, Brest, France
(2) Department of Physical Medical and Rehabilitation, Morvan University Hospital, INSERM U1101, Brest, France
(3) Department of Physical Medical and Rehabilitation, Morvan University Hospital, INSERM U1101, Brest, France
(4) Department of Physical Medical and Rehabilitation, Saint Jacques University Hospital, Nantes, France
(5) Department of Physical Medical and Rehabilitation, Morvan University Hospital, INSERM U1101, Brest, France

INTRODUCTION and AIM

During equinus gait in children (particulary in cerebral palsy gait), distinguishing lower limb muscle activation changes due to an abnormal motor control or to musculo-skeletal constraint remains a clinical challenge. The aim of this study was to determine a threshold degree of equinus at which changes in muscle activity and to characterize adaptive patterns of muscle activity in typically developing children walking with unilateral induced equinus.

PATIENTS/MATERIALS and METHODS

Ten typically developing children (8-12 years) were included. A customized orthosis which limited dorsiflexion was fitted to their right ankle1. Five conditions of limitation were evaluated: 10° dorsiflexion, 0°, 10°, 20° of plantarflexion and maximum plantarflexion (MP). The muscle activity of rectus femoris (RF), vastus lateralis (VL), hamstring (HA), tibialis anterior (TA) and soleus (SOL) muscles of both limbs was recorded.

RESULTS

Significant changes in muscle activation and co-activation occurred from 10° of plantarflexion in the limb ipsilateral to the orthosis and from MP in the contralateral limb. SOL activation occurred prematurely in terminal swing and increased with the degree of equinus. TA activation was increased during initial and mid swing and was decreased during terminal swing. HA activation was increased during the loading response with no significant modifications in RF and VL activation. Similar changes in TA and SOL activation occurred on the contralateral side. The main changes in co-activation occurred in the SOL/TA muscle pair in both limbs.

DISCUSSION and CONCLUSIONS

This study provides some indications regarding the role of musculoskeletal changes in the pattern of muscle activity in equinus gait in children. Above 10° equinus, it is highly likely that changes in muscle activation are directly related to the musculoskeletal constraints rather than to abnormal motor control. This data should help clinicians in decision making regarding treatments such as botulinum toxin injections in children with equinus gait.

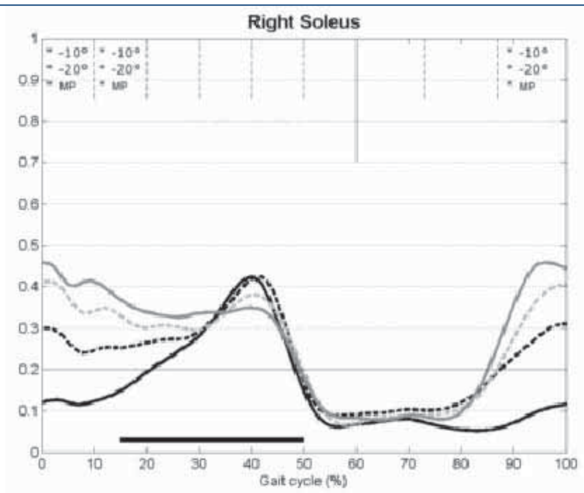

Figure 1: This figure represents the mean EMG soleus linear envelopes of the leg with the orthosis for 4 conditions : black line: orthosis free (OF), black dotted line: -10° of dorsiflexion, gray dotted line: -20° of dorsiflexion, gray line: maximal plantarflexion (MP). Significant differences between OF condition and each experimental condition are noted at the top of the graph.

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EVALUATION OF 3D FOOT DYNAMICS DURING HEEL-RAISE IN CHILDREN WITH FLATFOOT

BK. Krautwurst (1), Sl. Wolf (1), S. Müller (1), E. von Stillfried (1), T. Dreher (1)
(1) Department of Orthopedics and Trauma Surgery, Heidelberg University Hospital, Heidelberg, Germany

Main topics: Analysis of clinical movement data, Functional outcome measures in mobility.

INTRODUCTION and AIM

Flatfoot is common in young children with a prevalence of 54 % in 3 – year - olds and 26 % in 6 – year – olds [1]. Heel – raise and Jack – Test are well accepted examinations to detect flexibility of a paediatric flatfoot [2] in orthopaedic and physiotherapy daily practise. During these tests, especially the flexibility of medial arch and the position of hindfoot are observed. However, these tests are based just on subjective observation and therefore a large variability concerning the interpretation exists. Therefore the aim of this study was to introduce an objective evaluation of foot flexibility based on a three – dimensional foot model in paediatric flatfoot.

PATIENTS/MATERIALS and METHODS

18 feet in 9 children (mean age 5.5 years) underwent a 3D kinematic analysis of heel – raise, Jack – Test, analysis of foot pressure and a clinical examination including pain evaluation and detection of heel contracture. 7 markers were positioned on the foot and 2 on the shank similar to a well - described foot model [3]. The medial arch, medial border inclination and position of hindfoot were analysed. Medial border inclination was defined as the movement of the medial border from medial to lateral. Hindfoot valgus / varus described the tilt of the hindfoot in relation to the tibia in the frontal plane. The feet were classified in 8 non-painful flexible flatfeet, 6 painful flexible flatfeet and 4 reference-feet (no flatfoot). For the heel – raise, averaged data were analysed with Mann – Whitney – test to compare the flatfeet groups.

RESULTS

Figure 1 shows a child with painful flexible flatfeet during the heel-raising test with applied markers. The hindfoot is in valgus position during standing. During heel-raise the hindfoot position changes to a slight varus position. This flexibility could be shown for all the three groups (figure 2). Furthermore, the medial border inclination changed from medial to lateral. However, there was a clear offset between the groups, which caused that the painful flexible flatfeet demonstrated an increased medial inclined medial border (p = 0.01) and a higher hindfoot valgus (p = 0.11) compared to non – painful flexible flatfeet.

DISCUSSION and CONCLUSIONS

The objective assessment of the heel-raise was able to identify the flexibility of paediatric valgus feet. The dynamics of the medial border as well as of the hindfoot in the frontal plane could be reproduced. All groups demonstrated harmonic movements (figure 2). However, painful flexible flatfeet differed slightly from non-painful flatfeet and reference-feet, essentially by an offset. This study provides important objective information about the flexibility of flatfeet and may be an important tool to decide on the treatment – conservative or surgical.

Figure 1: heel – raise; left: beginning in standing position, right: ending in maximal heel – raise; black lines: shank and hindfoot axes, red dots: markers medial and lateral calcaneus.

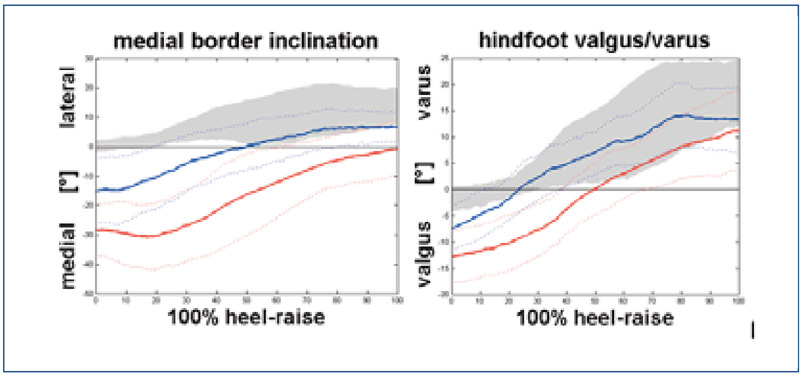

Figure 2: heel – raise (from heel-ground-contact (0 %) to maximal heel – raise (100 %)); grey area: references, red line: painful flexible flatfeet, blue line: non – painful flexible flatfeet.

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NEW FOOT SEGMENTATION MODEL: REPEATABILITY AND REPRODUCIBILITY STUDY

C. Mahieu (1), P. Salvia (1), P. Martin-Sisteron P. (1), B. Beyer (1), J. Coupier (1), O. Snoeck (1), H. Bajou (1), J-L Sterckx (2), V. Feipel (2), S. Van Sint Jan (1), M. Rooze (1, 2)
(1) Laboratory of Anatomy, Biomechanics and Organogenesis, Faculty of Medicine, Université Libre de Bruxelles, Belgium
(2) Laboratory of Functional anatomy, Faculty of Motor Sciences, Université Libre de Bruxelles, Belgium

Main topics: analysis of clinical movement data, reliability

INTRODUCTION and AIM

Due to the complexity of foot anatomy, our understanding of foot and ankle motion during gait is relatively limited. A wide variety of 3D multi-segment foot models have been previously published but recent reviews highlighted the lack of standardization and repeatability studies [1, 2]. We propose a new foot segmentation model (FSM) expected to be more anatomical, more functional and based on recommendations of Deschamps [1] and Bishop [2]. One particularity of the model is to provide information on clinical measures used in practice. The aim of this study is to estimate the reliability of marker placement of FSM and the propagation of palpation error on joint angles and on clinical measures.

PATIENTS/MATERIALS and METHODS

Our FSM included 2 clusters and 12 markers located on anatomical landmarks which divide the foot in 5 functional segments: hindfoot, midfoot, lateral forefoot, middle forefoot and medial forefoot. The repeatability protocol design (Fig1) was implemented in this study and performed by 4 operators on 6 adult volunteers.

Marker trajectories were recorded using stereophotogrammetry (VICON system). The local coordinates of markers and angles were computed using Matlab.

RESULTS

See tables 1, 2 and 3

Figure 1. Design of protocol

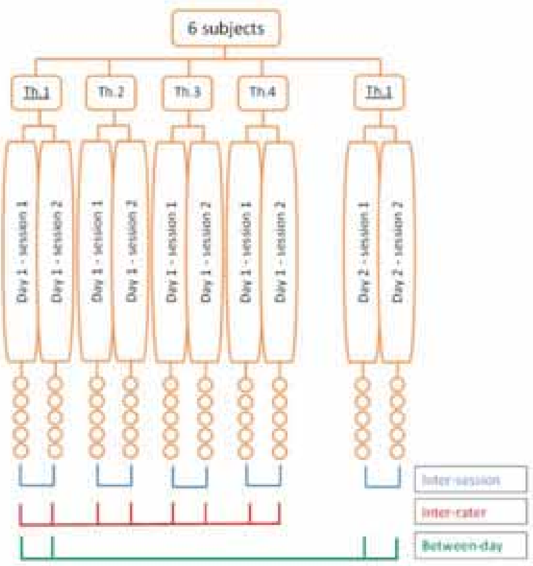

Table 1		
Palpation precision (mm)	Inter-session	Inter-rater
Within-day (RMSe)	2.2 +/- 0.3	7.0 +/- 1.4
Between-day (RMSe)	2.7 +/- 0.5	

Table 2		
Error propagation on offset (°)	Inter-session	Inter-rater
RMSe	1.2 +/- 0.2	3.0 +/- 0.3
Limits of agreement	[0.9 - 1.6]	[2.5 - 3.6]
SEM	2.8 +/- 1.1	3.5 +/- 1.4

Table 3		
Error propagation on range (°)	Inter-session	Inter-rater
RMSe	1.6 +/- 0.3	2.0 +/- 0.7
Limits of agreement	[1.1 - 2.1]	[0.7 - 3.3]
SEM	1.6 +/- 0.6	1.7 +/- 0.6

DISCUSSION and CONCLUSIONS

The good reproducibility and repeatability of this FSM including five functional segments opens new opportunities that may contribute to improve our understanding of human foot kinematics during gait and our assessment of foot deformities. Work in progress tackles with the estimation of error propagation on full kinematic curves and on clinical measures.

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15:00-16.00 — **TRUNK - SPINE ANALYSIS**
Aula Minor — ***Chairs: Davide Cattaneo, Maria Grazia Benedetti***

15:00-15:10 — A QUANTITATIVE METHOD TO ESTIMATE LOWER BACK REPOSITIONING BY MEANS OF A SINGLE INERTIAL SENSOR
I. Parel, A. Sassoli, L. Palmerini, S. Mellone, C. Tacconi, M. Branchini, M. Giacobazzi, L. Chiari, U. Van Daele

15:10-15:20 — RADIOGRAPHIC EVALUATION OF AN ENHANCED TRUNK MARKER SET IN PATIENTS WITH ADOLESCENT IDIOPATHIC SCOLIOSIS
S. Schmid, S. Lorenzetti, C. Hasler, J. Romkes, W. Taylor, R. Brunner

15:20-15:30 — COORDINATION OF THE HIP AND LUMBAR SPINE DURING SIT-TO-STAND IN HEALTHY SUBJECTS
K. Widhalm, T. Stamm, E.J. Hurkmans

15:30-15:40 — POST-ACUTE REHABILITATION AND FOLLOW-UP IN ISCHEMIC SPINAL CORD INJURY IN CHILDHOOD: A CASE REPORT
M.L. Salsano, A. Pisano, M. Petrarca, A. Maggi, G. Mosiello, E. Castelli

15:40-15:50 — EFFECT OF MONO- OR BISEGMENTAL SPINAL FUSION SURGERY (L3 – S1) ON TRUNK RANGE OF MOTION AND GAIT PERFORMANCE
F. Stief, M. Rickert, J. Wienand, M. Rauschmann, A. Meurer

15:50-16:00 — TEST-RETEST RELIABILITY OF THREE-DIMENSIONAL GAIT ANALYSIS IN CHRONIC LOW BACK PAIN INDIVIDUALS: A PRELIMINARY STUDY
R. Fernandes, V. Moniz-Pereira, A. Veloso, P. Armada-da-Silva

A QUANTITATIVE METHOD TO ESTIMATE LOWER BACK REPOSITIONING BY MEANS OF A SINGLE INERTIAL SENSOR

I.Parel(1,3), A.Sassoli(2),L.Palmerini(3), S.Mellone(3), C.Tacconi(3), M.Branchini(2), M.Giacobazzi(2), L.Chiari(3), U.VanDaele(4)
(1) Cervesi Hospital, Motion Analysis Laboratory, Rimini, Italy
(2) University of Bologna, Degree Course in Physiotherapy, Univ.Hospital S. Orsola - Malpighi, Bologna, Italy
(3) University of Bologna, DEI and CIRI-SDV, Bologna, Italy
(4) University of Antwerp, Department of Rehabilitation Sciences & Physiotherapy, Antwerp, Belgium

Main topics: analysis of clinical movement data; technical developments in movement science

INTRODUCTION and AIM

Research has provided evidence on impairments in sensorimotor control of the lower back in low back pain (LBP) patients [1]. Evaluating sensorimotor control is a challenge because of the number of neurophysiologic processes that are involved and the many, sometimes subjective, measurement options that are available. Repositioning tasks are often described to evaluate proprioception in LBP patients [2]. According to Gill and Callaghan [3], the repositioning test (pelvic tilt in four-point-kneeling position) represents a reliable and stable test to assess the proprioception ability in patients with LBP. The estimate of the repositioning accuracy is currently obtained visually by means of a ruler. The aim of this study is to obtain quantitative estimates of lower back repositioning by using a single wearable sensor.

PATIENTS/MATERIALS and METHODS

Eleven healthysubjects were involved in the study.Data were collected by means of a wearable inertial sensing unit(EXEL srl, Bologna, IT) and a motion capture system including 4 optical cameras (VICON-Bonita), which was considered the gold standard (GS).All subjects performed the repositioning test consisting in the following steps: 1) start in neutral position; 2)reach the maximum flexion of the lumbar spine (de-lordosis); 3) reach the maximum extension of the lumbar spine (lordosis);4) back to neutral position (Figure 1).The test outcome is the repositioning error, i.e, the difference in L4 positionbetween 1)and 4). A physical therapist positioned two sensors on L4 and S1.Accuracies were then compared to assess the better positioning for the sensor.The gyroscope was used to segment the 4 phases and the accelerometer was used as an inclinometer.Abiomechanical model describing the relative movement between pelvis and L4 was developed, with the distance between L4 and the coccyx (measured by the physical therapist) as an additional input to the model.

RESULTS

The repositioning error measured with the GS was 1.07 ± 1.00 cm. Root mean squared errors (RMSE) between sensor-based estimates and the GS were 1.04 cm for L4 position and 1.51 cm for S1 position.

DISCUSSION and CONCLUSIONS

In this study a wearable and quantitative tool for the estimate of repositioning error was presented and preliminarily validated. Encouraging results in the accuracy of the sensor estimates were obtained in healthy subjects. The better sensor position was found to be L4. Further validation is needed to assess the accuracy of this tool in LBP patients.

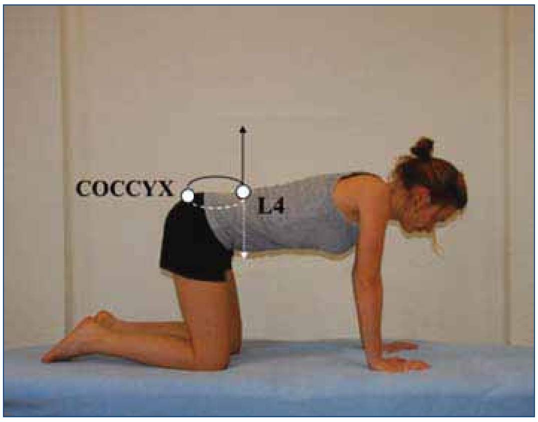

Figure 1: Repositioning test

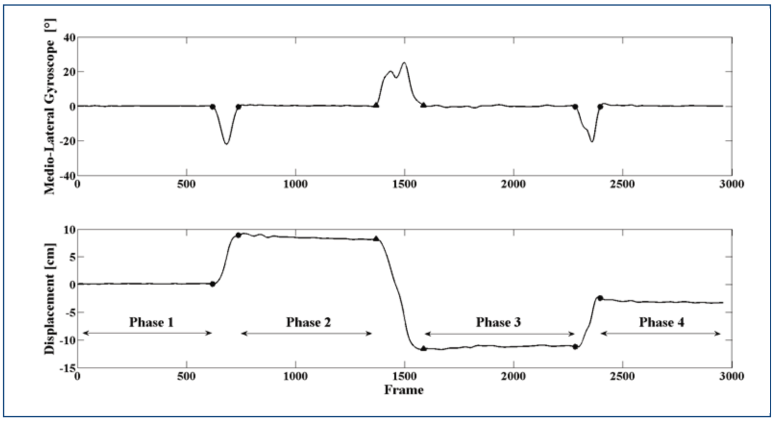

Figure 2 Example of signal processing

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RADIOGRAPHIC EVALUATION OF AN ENHANCED TRUNK MARKER SET IN PATIENTS WITH ADOLESCENT IDIOPATHIC SCOLIOSIS

S. Schmid (1,2), S. Lorenzetti (1), C.-C. Hasler (3), J. Romkes (3), W. R. Taylor (1), R. Brunner (3)
(1) ETH Zurich, Institute for Biomechanics, Zurich, Switzerland
(2) Bern University of Applied Sciences, Health Division, Discipline of Physiotherapy, Bern, Switzerland
(3) University Children's Hospital Basel, Orthopedic Department, Basel, Switzerland

Main topics: 1) Orthopaedics, 2) Technical developments in movement science

INTRODUCTION and AIM

Standard optical marker sets used for clinical gait analysis (e.g. Plug-in gait) do not allow the quantification of spinal movement. In order to be able to better evaluate pathologies affecting the spine, a previously developed enhanced marker set [1] has been introduced. Due to rotational deformities such as those seen in adolescent idiopathic scoliosis (AIS), however, spinal curvature might be underestimated when derived from the spinous processes [2]. In addition, inaccurate marker placement might further influence curvature estimation. Therefore, the aims of this study were to evaluate 1) the precision of marker placement and 2) the accuracy of sagittal and frontal curvature estimation in the lumbar and thoracic spine.

MATERIALS and METHODS

Eight patients with AIS (age: 14.9±1.4 years; height: 1.67±0.08 m; mass: 57.3±12.6 kg, Cobb angle: 44.5±16.1 degrees) participated in this study. Selected thoracic (T3, T5, T7, T9, T11) and lumbar (L1-5) spinous processes were marked directly on the skin with radio-opaque markers while participants underwent a standard biplanar radiographic examination. Positions of markers, vertebral bodies and spinous processes were extracted using the software ImageJ. Spinal curvature was calculated using a custom-built MATLAB routine. Marker placement error in the horizontal and vertical directions was evaluated using descriptive statistics (median and interquartile range), whereas the accuracy of the curvature estimation was investigated using linear regression analysis.

RESULTS

Marker placement analysis showed horizontal and vertical median deviations of -2.4 mm (IQR: 3.9) and -0.4 mm (IQR: 6.7) for the thoracic and 2.6 mm (IQR: 5.8) and -0.9 mm (IQR: 9.5) for the lumbar spine, respectively (Figure 1). Thoracic curvature angles derived from the markers explained 74.9% (sagittal plane) and 55.3% (frontal plane) of the variance of the curvature angles derived from the vertebral bodies (Figure 2). Slope values of 0.775 and 0.590 further indicated a slight underestimation of the sagittal and moderate underestimation of the frontal curvature, respectively. Only weak estimation accuracy was found for the lumbar spine curvatures.

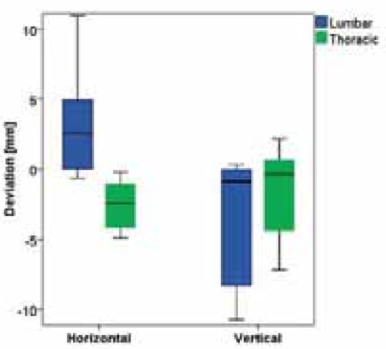

Figure 1: Placement errors of the lumbar and thoracic markers.

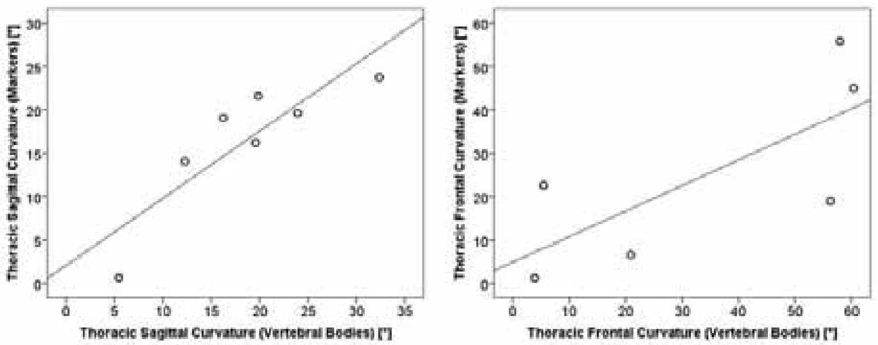

Figure 2: Estimation of the thoracic curvature angles in the sagittal and frontal planes.

DISCUSSION and CONCLUSIONS

Marker placement and curvature estimation were found to be more accurate in the thoracic than the lumbar spine. Possible explanations for the lower accuracy in the lumbar spine could be the amount of soft tissue in combination with the lordotic posture. As expected, the frontal curvatures derived from the spinous processes generally underestimated the actual curvature of the spine. These deviations might be corrected using additional radiographic information or by tracking the position of the ribs. In conclusion, the enhanced trunk marker set showed a great potential, especially for the non-invasive assessment of thoracic curvature.

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COORDINATION OF THE HIP AND LUMBAR SPINE DURING SIT-TO-STAND IN HEALTHY SUBJECTS

K. Widhalm (1), T. Stamm (1, 2), EJ. Hurkmans (1)
(1) FH Campus Wien, Vienna, Austria
(2) Medical University of Vienna, Vienna, Austria

Main topics: Motor control and motor learning, Analysis of gait and motor disorders

INTRODUCTION and AIM

The ADL task Sit-to-Stand (STS) has been a focus point in numerous studies [1]. Especially movement behaviour in low-back-pain patients has been investigated in depth. Variability in sagittal spine alignment has been hypothesized to be related with the occurrence of low back pain [2]. However, knowledge concerning different movement patterns in healthy subjects performing STS is missing, making it difficult to conclude whether or not movement patterns are different among low back pain patients. Therefore the objective of this study was 1) to examine the variation in the STS movement in relation to the hip and lumbar spine movements during the last 30% of the total task duration and 2) classifying movement patterns.

PATIENTS/MATERIALS and METHODS

49 healthy subjects (age 11-50 years) performed 6 trials of seat-height normalised STS. Kinematic data were obtained using a 6 camera Vicon system. Main outcome measure was the median of ratios of changes in degrees in sagittal hip and lumbar spine angles. The last 30% of the total movement was used for this study since in this phase it was expected to find variability differing from literature. For classifying movement patterns a hierarchical cluster analysis was applied. This analysis was applied among three age groups (10-18, 19-30, 31-50 years) to see whether these movement patterns are different between age groups.

RESULTS

The mean values and range for all subjects were 1.89 s [1.46-2.86] for the total task duration, 34.35 % [27.86-42.61] of total task duration for Lift-Off, 83.51° [69.3-101.3] for the hip and 25.1° [11.1-32.9] for the lumbar spine. As result of the hierarchical cluster analysis 3 main types of movement patterns and 3 outliers could be identified. Type I (n=39) is characterised by relatively high contribution of lumbar spine movement during the analysed phase, Type II (n=3) and III (n=4) are more dominated by the movement of the hip and the 3 outliers seem to be caused by measurement problems. These three types of movement were similar among all age groups and also quite similar distributed.

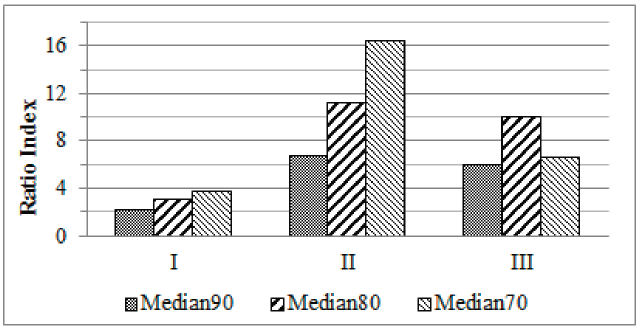

Figure 1: Median ratios of movement pattern type I-III of the last 90-100%, 80-90%, 70-80% of total task duration

Table 1: subject characteristics

age	f/m	MEAN age	MEAN BMI [kg/m²]
10-18	9/7	13.9 [11-18]	18.85 [14.61-21.15]
19-30	9/9	24.4 [19-30]	23.10 [19.72-28.52]
31-50	8/7	39.2 [31-50]	23.77 [19.02-28.25]

DISCUSSION and CONCLUSIONS

Although the calculation of the index didn´t take into account the differing amount of ROM used (hip : lumbar spine ≈ 3:1), it could be shown that healthy subjects perform STS in different ways. Including the difference of ROM for the Index calculation it can be stated that 80% of the subjects had an lumbar dominated extension in the last 30% of the STS task. Further studies are necessary to analyse factors associated with these different STS patterns and to find possible predictors for the onset of degenerative symptoms in the lower back.

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POST-ACUTE REHABILITATION AND FOLLOW-UP IN ISCHEMIC SPINAL CORD INJURY IN CHILDHOOD: A CASE REPORT.

Main topics: Analysis of clinical movement data, outcomes after clinical intervention

M.L. Salsano(1), A. Pisano(1), M. Petrarca(1), A. Maggi(1), G. Mosiello(1), E. Castelli(1).
(1) Department of Neuroscience and Neurorehabilitation, "Bambino Gesù" Children's Hospital, Rome, Italy

INTRODUCTION

Ischemic Spinal Cord Injury (SCI) in childhood is a rare condition. There are few reports in pediatric literature about etiology, diagnosis, treatments, post-acute rehabilitation and follow-up. The most common causes of SCI are obstruction of blood flow, cardiovascular compromise or malformation, iatrogenic or traumatic vascular injury, cerebellar herniation, thrombotic or embolic disease, infection and vasculitis. Though the cause of SCI in the absent of vertebral injury is unknown [1]. Functional outcomes in SCI depend on neurological level of the injury and can be classified using the American Spinal Injury Association (ASIA) Impairment Scale (AIS) [2]. Functional recovery can be assessed by comparing Spinal Cord Independence Measure (SCIM) score at admission with scores at discharge. We report the case of a young child with incomplete SCI admitted to inpatient post-acute rehabilitation.

METHODS

A healthy 7 years old girl started having headache at home and pain down her neck, followed by vomiting and inability to walk, after three days from a minor cervical trauma. Taken to Emergency Room, she was ventilated mechanically for progressive breathing difficulty. MR imaging revealed an irregular T2 hyperintensity in anterior spinal cord from bulbus to D5. Angiography revealed an abnormal morphology of the left vertebral artery. She was treated with steroids and anticoagulants. After 85 days she was admitted in our hospital for intensive post-acute rehabilitation program. ASIA Impairment Scale score was C6 C, ASIA Motor Score was 17,5/50 on the right side and 33,5/50 on the left side. Electrophysiological studies evidenced a SSEP normality and an altered MEP from bilateral quadriceps femoris and tibialis anterior muscles. Patient reported normal bladder and bowel sensitivity. Urodynamic test showed bladder low capacity with detrusor-sphincter dyssynergia. SCIM was 38/100. Intensive rehabilitation program was performed every day (except sunday) for three hours per day and consisted in: general muscle exercise, proprioceptive exercises, walking training on a treadmill, AFO and walker training, robotized platform training.

RESULTS

The outcomes after six months of intensive rehabilitation were ASIA score C6 D and ASIA Motor Score 33,5/50 on the right side and 42/50 on the left side. Electrophysiological control evidenced MEP improvement. Outcome SCIM was 82/100. Robotized platform training emphasized proprioceptive sensitivity and improved balance. Gait analysis showed enhanced bilateral ROM of the hip, knee and ankle in the sagittal plane. Cadence (D = 9s/m; p<0,001), stride time (D = 1,2s; p<0,004) and walking speed (D = 0,06m/s; p<0,001) were improved.

DISCUSSION

We observed that the intensive rehabilitation in incomplete ischemic spinal cord injury was essential for recovering ability to walk and for recovering functional independence in activities of daily living. The patient was able to walk in autonomy with AFO and walker. Furthermore the compensatory mechanism aimed at improving functional gait and walking stability, justifying an improvement of the kinematics data and demonstrating how patient was able to reorganize remaining abilities in the best way [3]. However the rehabilitative intervention in SCI should be prolonged even years after the injury to enhance functional outcomes.

Table 1- bilateral articular ROM

Index	**Admission**		**Discharge**		**D**	
	Dx	*Sn*	*Dx*	*Sn*	*Dx*	*Sn*
Hip ROM	6°	51°	31°	60°	+25°	+9°
Knee ROM	52°	58°	55°	70°	+3°	+12°
Ankle ROM	10°	35°	18,5°	33°	+8,5°	-2°

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EFFECT OF MONO - OR BISEGMENTAL SPINAL FUSION SURGERY (L3 – S1) ON TRUNK RANGE OF MOTION AND GAIT PERFORMANCE

F. Stief (1), M. Rickert (1), J. Wienand (1), M. Rauschmann (1), A. Meurer (1)
(1) Orthopedic University Hospital Friedrichsheim gGmbH, Frankfurt/Main, Germany

Main topics: Movement analysis in clinical practice; Outcomes after clinical intervention; Orthopaedics.

INTRODUCTION and AIM

Radiographs are routinely used to evaluate the outcome of spinal fusion surgery. However, there is a lack of research in quantifying functional changes in patients undergoing spinal fusion surgery. The aim of the present study was to assess the effect of a spinal fusion surgery in patients with symptomatic degenerative lumbar disease on trunk range of motion (ROM) and gait parameters. We hypothesized that (1) due to a reduction of low back pain, gait parameters would improve after a spinal fusion surgery and (2) are more similar to that observed in healthy controls at the same age. We also expected that the trunk ROM remains unchanged after surgery.

PATIENTS/MATERIALS and METHODS

Twenty-six patients with a radiological diagnosis of a degeneration process in the lumbar spine and a mean age of 59.3 (SD 10.1) years, as well as 20 healthy subjects at the same age were prospectively evaluated. Before and approximately six month after spinal fusion surgery (mono- or bisegmental interbody fusion between L3-S1) patients completed biomechanical assessments of gait analysis and trunk ROM during an upright position in the three principal planes of the body measured with a Vicon motion capture system. Differences before and after the surgical intervention as well as between groups were tested for significance using paired and unpaired Student's *t*-tests, respectively. The significance level was set at $p < 0.05$.

RESULTS

Results indicated a significantly increased walking speed, step length, and maximum hip extension during the stance phase of gait. Anterior pelvis and thorax tilt were significantly reduced after the surgery without significant differences compared to the control group (Table 1). Nevertheless, in comparison to healthy subjects at the same age, patients still walked at a slower speed and with a reduced step length after surgery. Regarding the trunk ROM during an upright position, maximum backward extension, lateral flexion, and rotation in the transverse plane remains unchanged after surgery. Nevertheless, we observed a decrease in maximum forward flexion and the fingertip-floor distance after surgery.

Table 1: Spatio-temporal, kinematic gait parameters during the stance phase of gait (mean with standard deviation in parenthesis), and p-values.

Parameter	Patients (n = 26)		Controls (n = 20)	p-Value	p-Value	p-Value
	Preoperative	Postoperative		Preoperative vs. Postoperative	Preoperative vs. Controls	Postoperative vs. Controls
Spatio-temporal parameters						
Walking speed (m/s)	0.98 (0.21)	1.06 (0.22)	1.31 (0.13)	0.011	≤0.001	≤0.001
Step length (m)	0.54 (0.11)	0.57 (0.10)	0.67 (0.06)	0.039	≤0.001	≤0.001
Angles (°)						
Hip max. extension	-8.25 (8.07)	-13.02 (11.17)	-15.44 (6.09)	0.022	0.002	0.388
Pelvis max. tilt anterior	7.33 (5.90)	4.61 (6.32)	5.76 (4.49)	0.038	0.330	0.493
Thorax max. tilt anterior	7.95 (4.24)	6.56 (4.74)	5.14 (3.72)	0.037	0.023	0.276

DISCUSSION and CONCLUSIONS

The results suggest that spinal fusion surgery is not disruptive for habitual functional activities such as walking. In contrast, the body center of mass was shifted in the posterior direction and thus the spinal fusion surgery normalized the sagittal alignment of the pelvis and thorax during walking. Regarding the trunk ROM during an upright position, the mobility of the fused spine to reach out for things down at the floor was restricted which could be explained with a closer look on anatomic mechanisms. The lumbar spine has its greatest degree of freedom in the ventral/dorsal flexion provided by its five motion segments [1]. The center of rotation of each segment is always the spinal disk which is removed and hardened with the spinal fusion and thus one or two motion segments lose their function. Accordingly, the flexion ability may be decreased. In conclusion, detailed gait assessment and trunk ROM will further our understanding of the functional ramifications of performing spinal fusion and may help clinicians predict and avoid development of additional problems.

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TEST-RETEST RELIABILITY OF THREE-DIMENSIONAL GAIT ANALYSIS IN CHRONIC LOW BACK PAIN INDIVIDUALS: A PRELIMINARY STUDY

R. Fernandes (1,2), V. Moniz-Pereira (1), A. P. Veloso (1), P. A. Armada-da-Silva (1)
(1) CIPER - LBMF – Faculdade de Motricidade Humana – Universidade de Lisboa, Lisboa, Portugal
(2) Departamento de Fisioterapia, Escola Superior de Saúde – Instituto Politécnico de Setúbal, Setúbal, Portugal

Main topics: Reliability and service development: Analysis of clinical movement data

INTRODUCTION and AIM

Three-dimensional (3D) gait analysis is commonly used in research and clinical settings. Nevertheless, there are numerous sources of variability affecting the testing procedure (instrumental errors, anatomical landmark misplacement and soft tissue artifacts) [1], as well as inherent variability in gait performance, particularly in pathological gait. Few quality studies have been conducted regarding test-retest reliability in chronic low back pain (CLBP) individuals. Thus, the aim of this study was to investigate test-retest reliability of 3D gait analysis in a sample of chronic low back pain (CLBP) individuals.

PATIENTS/MATERIALS and METHODS

A prospective test-retest study design was conducted with a convenience sample of 8 CLBP individuals (43.8±6.7 yrs; 69±15.5 kg; 164.9±8.4 cm). All participants underwent two assessment sessions with an interval of 6 to 9 days. Each session included pain intensity (Numerical Rating Scale), disability (Quebec Back Pain Disability Scale), kinesiophobia (Tampa Scale of Kinesiophobia), and gait assessments. The gait data collection was carried out using a 13-camera opto-electronic system (Oqus 300, Qualisys AB, Gothenburg, Sweden) at 200Hz. Participants were instructed to walk during a few minutes at their preferred velocity and 10 gait cycles were selected to be processed in Visual 3D software (v5.01.10, C-Motion, Inc). A GCVSPL filter was applied to kinematic data. The marker set selection was based on previous reports [2] and a 9 segments' model (feet, shanks, thighs, pelvis, lumbar and thoracic spine) was built and optimized through global optimization [3]. Peak values for lower limb and trunk joint angles were computed for each trial and averaged for each subject. Intraclass Correlation Coefficient (ICC2,1) and their 95% confidence intervals for the 2-way random-effects model were calculated (IBM SPSS Statistics 20, $p<.05$). Standard error of the measurement (SEM) and minimal detectable change (MDC) were also computed for each variable according to a previous study [4].

RESULTS

There were no statistically significant differences in pain intensity, disability, kinesiophobia and anthropometric variables between the two assessment sessions. Reliability of peak values (maximum and minimum) for joint angles was examined and the results are shown on table 1. The obtained ICC values show high reliability to all parameters, very low SEM values (<1º) and very low MDC values (<1º, except to right hip peak flexion).

DISCUSSION and CONCLUSIONS

The results of this study show excellent values of test-retest reliability for lower limb and trunk kinematics during gait in CLBP individuals, together with a clinical acceptable level of error. These results also demonstrate that a very low amount of change would be sufficiently greater than measurement error, supporting the use of this method in clinical assessments of patients' gait patterns.
This work was funded by FCT through CIPER and SFRH/PROTEC/67505/2010.

Table 1: Reliability of thorax, lumbar and hips joints peak angles over gait cycle

Kinematic Parameters	ICC	95% CI	SEM °	MDC °
Left Hip Angles				
Peak Flexion	0.88	0.42 - 0.98	0.10	0.27
Peak Abduction	0.93	0.67 - 0.99	0.07	0.20
Peak External Rotation	0.87	0.33 - 0.97	0.16	0.45
Peak Extension	0.94	0.72 - 0.99	0.09	0.24
Peak Aduction	0.97	0.85 - 0.99	0.04	0.11
Peak Internal Rotation	0.90	0.55 - 0.98	0.13	0.37
Lumbar Angle				
Peak Flexion	0.74	-0.05 - 0.95	0.09	0.25
Peak Left Lateral Bending	0.91	0.59 - 0.98	0.06	0.18
Peak Left Rotation	0.85	0.26 - 0.97	0.03	0.09
Peak Extension	0.66	-0.34 - 0.93	0.08	0.24
Peak Right Lateral Bending	0.78	-0.06 -0.96	0.09	0.24
Peak Right Rotation	0.83	0.14 - 0.97	0.05	0.13

Kinematic Parameters	ICC	95% CI	SEM °	MDC °
Right Hip Angles				
Peak Flexion	0.84	0.19 - 0.97	0.48	1.32
Peak Abduction	0.86	0.37 - 0.97	0.17	0.47
Peak External Rotation	0.89	0.49 - 0.98	0.29	0.80
Peak Extension	0.92	0.65 - 0.98	0.08	0.23
Peak Aduction	0.88	0.44 - 0.98	0.09	0.25
Peak Internal Rotation	0.93	0.68 - 0.99	0.12	0.33
Thorax Angles				
Peak Flexion	0.91	0.59 - 0.98	0.07	0.20
Peak Left Lateral Bending	0.90	0.51 - 0.98	0.10	0.27
Peak Left Rotation	0.81	0.10 - 0.96	0.14	0.39
Peak Extension	0.94	0.72 - 0.99	0.07	0.18
Peak Right Lateral Bending	0.91	0.59 - 0.98	0.07	0.21
Peak Right Rotation	0.81	0.12 - 0.96	0.12	0.33

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16:00-18:00	**Poster session and Coffee break**
P001	EFFECTS OF BILATERAL SUBTHALAMIC NUCLEUS DEEP BRAIN STIMULATION AND LEVODOPA ON SPATIOTEMPORAL VARIABLES OF GAIT IN PARKINSON'S DISEASE *D. Speciali, N. Mariana Luna, R. Brant, E. Talamoni Fonoff, M. Jacobsen, J. Maria D'Andrea Greve, W. Godoy, R. Baker, P. Roberto Garcia Lucareli*
P002	MOTOR STRATEGIES OF THE UNAFFECTED LOWER LIMB IN CHRONIC STROKE SURVIVORS *B. Nesi, B. Faraoni, A. Taviani, F. Benvenuti*
P003	MULTI-SEGMENT FOOT KINEMATICS AND PAIN INTENSITY COMPARISON IN WOMEN WITH AND WITHOUT PATTELOFEMORAL PAIN SYNDROME *B. Lima, L. Contani, C. Ferreira, N. Rabelo, A. Bley, A. Reis, L. Yi, P. Lucareli*
P004	POSTURAL STABILITY IN TRANSTIBIAL AMPUTEES ASSESSED BY LABORATORY AND CLINICAL TESTS *K. Ořechovská, Z. Svoboda, M. Janura, Z. Kováčiková*
P005	THE VALUE OF TRIDIMENSIONAL GAIT ANALYSIS IN FUNCTIONAL DIAGNOSIS OF LUMBAR SPINAL STENOSIS *S.A. Garbelotti Jr., P.R.G. Lucareli, W. Godoy, D.S. Speciali, A. Ramalho Jr., J.M.D. Greve*
P006	USABILITY STUDY OF A WEARABLE AUDIO-FEEDBACK SYSTEM FOR GAIT REHABILITATION IN PERSONS WITH PARKINSON'S DISEASE *A. Ferrari, P. Ginis, A. Mirelman, E. Gazit, A. Nieuwboer, M. Dorfman, J.M.. Hausdorff, L. Rocchi, L. Chiari*
P007	INFLUENCE OF TEMPORAL NORMALIZATION ON GAIT SCORES *S. Armand, A. Bonnefoy-Mazure, G. De Coulon, F. Leboeuf*
P009	GAIT ANALYSIS DRIVEN FINITE ELEMENT SIMULATIONS: TOWARDS THE USE OF OPENSIM OUTPUT AS BOUNDARY CONDITION *A. Scarton, W. Aerts, A. Guiotto, Z. Sawacha, I. Jonkers, J. Vander Sloten, C. Cobelli*
P010	DECOUPLING THE EXTRAPOLATED CENTRE OF MASS (XCoM) AND CENTRE OF PRESSURE (CoP) DURING GAIT INITIATION. INTRODUCTION OF A NEW VARIABLE *E.C. Prinsen, M.J. Nederhand, H.S. Rietman*
P012	STUDY OF MECHANICAL ENERGY RECOVERY IN PARKINSONIAN GAIT *M. Dipaola, A. Cattaneo, I.U. Isaias, C.A. Frigo*
P015	STRIDE FREQUENCY AND LENGTH ADJUSTMENTS IN POST-STROKE INDIVIDUALS; THE INFLUENCE ON THE MARGINS OF STABILITY *L. Hak, H. Houdijk, P. Van der Wurff, M.R. Prins, P.J. Beek, J.H. Van Dieën*
P016	CORRELATIONS BETWEEN 3D SUBJECT-SPECIFIC MUSCULOSKELETAL PARAMETERS AND GAIT ANAYSIS IN PATIENTS WITH CEREBRAL PALSY *A. Assi, A. Massaad, Z. Bakouny, C. Sauret, W. Skalli, I. Ghanem*

P017 EVALUATION OF THE INITIATION OF LEVEL WALKING AND STAIR ASCENDING IN PARKINSON'S DISEASE: AN INSTRUMENTED METHOD BASED ON INERTIAL SENSORS
G. Bonora, I. Carpinella, D. Cattaneo, L. Chiari, M. Ferrarin

P018 FUNCTIONAL AND RADIOGRAPHIC CONSIDERATION OF LOWER LIMB MALALIGNMENT IN CHILDREN AND ADOLESCENTS WITH IDIOPATHIC GENUA VALGA
A. Kranzl, S. Farr, E. Pablik, R. Ganger

P019 3D UNDERWATER GAIT ANALYSIS: COMPARISON AMONG 3 DIFFERENT PROTOCOLS
Z. Sawacha, F. Minelle, M. Cortesi, G. Gatta, C. Cobelli, S. Fantozzi

P020 SENSORIMOTOR CONTROL IS BILATERALLY ALTERED FOR SHOULDER ABDUCTION AND FLEXION IN CHRONIC HEMIPARETIC INDIVIDUALS
G. Lopes dos Santos, L. Fernanda Garcia Salazar, A.B. de Oliveira, A.C. Lazarin, G.G. Zanca, S.M. Mattiello, T. Luiz de Russo

P021 ASSESSMENT OF A MODEL-BASED METHOD FOR SCAPULA KINEMATICS MEASUREMENT
S. Duprey, S. Duprey, S. Duprey, P. Lagace, P. Lagace, T. Cresson, W. Skalli, N. Hagemeister

P022 EFFECT OF VISUAL, PROPRIOCEPTIVE, OR AUDITORY FEEDBACK ON KINEMATICS OF POURING WATER FROM KETTLE TO CUP
S. Portnoy, O. Halaby, D. Dekel-Chen

P023 EFFECTS OF ANKLE DEFORMITIES ON ACTIVITY AND PARTICIPATION LEVELS IN ADULT STROKE PATIENTS
M. Longhi, D. Mazzoli, A. Merlo, P. Prati

P024 PREVENTION OF GENU RECURVATUM IN POST STROKE PATIENTS
S. Portnoy, A. Frechtel, E. Raveh, I. Schwartz

P025 REPEATABILITY STUDY OF THE CAST MODEL FOR GAIT ANALYSIS
O. Pinzone, R. Baker , S. Preece, R. Jones

P027 FERRARI'S CLASSIFICATION OF DIPLEGIC FORMS OF CEREBRAL PALSY: VALIDATION BY MEANS OF ARTIFICIAL NEURAL NETWORKS
A. Ferrari, R. Neviani, D. Pandarese, A. Ferrari

P028 MUSCLE CONTRIBUTIONS TO CENTRE OF MASS ACCELERATION DURING TURNING GAIT IN TYPICALLY DEVELOPING CHILDREN: A SIMULATION STUDY
P.C. Dixon, K. Jansen, I. Jonkers, J. Stebbins, T. Theologis, A.B. Zavatsky

P029 EVALUATION OF MEDIAL LONGITUDINAL ARCH HEIGHT OF JUVENILE IDIOPATHIC ARTHRITIS INDUCED PES PLANOVALGUS DURING GAIT
J. Merker, M. Hartmann, F. Kreuzpointner, J. Haas, A. Schwirtz

P030 COMPARISON BETWEEN SELF-PACED AND FIXED VELOCITY GAIT IN AN IMMERSIVE VR ENVIRONMENT
A.C. Turconi, E. Biffi, C. Maghini, L. Piccinini

P031 MUSCLE STRENGTH AND POSTURAL CONTROL DURING SIT-TO-STAND MOVEMENT IN CHILDREN
S.L. Pavão, A.N. dos Santos, N.A.C.F. Rocha

P032 CRAWLERS VERSUS BOTTOM SHUFFLERS: DIFFERENCES IN CONTROL OF THE TRUNK
A. Hallemans, P. Van de Walle, E. Verbecque, N. Op de Beeck, L. Vereeck, P. Aerts

P033 DIFFERENCES IN JOINT MOMENT AND POWER IN CHILDREN WITH CEREBRAL PALSY AND LEG LENGTH DISCREPANCY
R. Zügner, R. Tranberg, I. Stefansdottir, M. Nyström-Eek

P034 UTILITY BELT OR LOAD BEARING VEST- AN ANALYSIS OF PELVIC KINEMATICS IN SWEDISH POLICE
L. Bæk Larsen, R. Tranberg, N. Ramstrand

P035 EFFECT OF SUBJECT-SPECIFIC MUSCULOSKELETAL MODELLING ON KINEMATICS AND DYNAMICS OF JUMPING IN POWER ATHLETES
S. Van Rossom, L. Bosmans, A. Van Campen, F. De Groote, J. De Schutter, I. Jonkers

P036 LOWER LIMB JOINT MOMENTS DURING STAIR ASCENT IN OLDER ADULTS WITH DIFFERENT FUNCTIONAL FITNESS LEVELS
V. Moniz-Pereira, S. Cabral, F. Carnide, A.P. Veloso

P037 ESTIMATION OF THE ANKLE STIFFNESS OF PEOPLE WITH TRANSFEMORAL AMPUTATION DURING SLOPE AND STAIR WALKING
H. Pillet, X. Drevelle, C. Villa, X. Bonnet, B. Dauriac, I. Loiret, F. Lavaste

P038 GAIT DEVIATIONS IN THE INTACT SIDE OF PATIENTS AFTER POLYTRAUMA WITH LOWER LIMB INJURES CONSEQUENCES
R. Jakusonoka, Z. Pavare, A. Jumtins, T. Ananjeva, A. Smolovs, J. Vinogradova

P039 THE IMPACT OF VISION ON THE DYNAMIC CHARACTERISTICS OF THE GAIT: STRATEGIES IN CHILDREN WITH CONGENITAL BLINDNESS
S. Gazzellini, M.L. Lispi, E. Castelli, A. Trombetti, G. Vasco, S. Carniel, M. Petrarca

P040 INT-/EXTERNAL ROTATION OF BILATERAL SHOULDER AB-/ADDUCTION AND ANTE-/RETROVERSION MOVEMENTS DESCRIBED AS CONJUNCT AND ADJUNCT ROTATION
O. Rettig, B. Krautwurst, S. Wolf

P041 ACCLIMATIZATION OF THE WALKING PATTERN WITH A NEW ANKLE FOOT ORTHOSIS IN CHILDREN WITH CEREBRAL PALSY
K. van Hutten, Y. Kerkum, A. Buizer, J. Harlaar, J. van den Noort, M.A. Brehm

P042 STATISTICAL PARAMETRIC MAPPING TO IDENTIFY GAIT PATTERN FEATURES IN CHILDREN WITH CEREBRAL PALSY
A. Nieuwenhuys, D. Monari, K. Deschamps, T. De Laet, G. Molenaers, K. Desloovere

P043 THE CROSS-TRAINING EFFECT ON MUSCLE PERFORMANCE IN PATIENTS WITH MULTIPLE SCLEROSIS: A PILOT STUDY
A. Manca, M.P. Cabboi, E. Ortu, D. Dragone , A. Peruzzi, A. Cereatti , G. Mureddu, G. Bua, F. Deriu

P044 MONITORING FREEZING OF GAIT WITH A SMARTPHONE
L. Pepa, F. Verdini, M. Capecci, F. Maracci, M.G. Ceravolo, T. Leo

P045 OBJECTIVELY ASSESSED SPASTICITY OF THE CALF VERSUS IMPEDING MUSCLE ACTIVITY DURING GAIT IN SPASTIC CEREBRAL PALSY
L. Sloot, M. van der Krogt, E. de Vlugt, J. Harlaar

P046	FUNCTIONAL EVALUATION OF FLAT FOOT IN CHILDREN: COMPARISON OF TWO DIFFERENT BIOREABSORBABLE IMPLANTS FOR SURGICAL TREATMENT *L. Berti, G. Lullini, P. Caravaggi, A. Leardini, S. Tamarri, V. Persiani, S. Giannini*
P047	LUMBAR REPOSITIONING IS INFLUENCED BY NONSPECIFIC LOW BACK PAIN, TEST SETUP AND BODY MASS INDEX *C. Bauer, M. Ernst, F. Rast, S. Schelldorfer, A. Meichtry, J. Kool, J. Suni, M. Kankaanpää*
P048	GAIT ANALYSIS IN CHILDREN WITH HEMIPLEGIC CEREBRAL PALSY: FOOT-FLOOR CONTACT AND EMG ACTIVATION PATTERNS *V. Agostini, A. Nascimbeni, A. Gaffuri, M. Knaflitz*
P049	DYNAMIC MOTOR CONTROL PREDICTS TREATMENT OUTCOME IN CHILDREN WITH CEREBRAL PALSY *M.H. Schwartz, A. Rozumalski, K.M. Steele*
P050	A NOVEL DEVICE FOR TESTING THE DYNAMIC PERFORMANCE OF IN SITU FORCE PLATES *R. East*
P051	KINEMATIC DIFFERENCES EXIST BETWEEN TRANSTIBIAL AMPUTEE FALLERS AND NON-FALLERS DURING DOWNWARDS STEP TRANSITIONING *N. Vanicek, S. Strike, R. Polman*
P052	CLINICAL VALIDATION OF A NOVEL PROTOCOL FOR DYSTONIA ASSESSMENT USING MIMU SENSORS *A. Pisano, E. Palermo, L. Cantonetti, M. Petrarca, S. Rossi, S. Gazzellini , C.E. Marras, P. Cappa, E. Castelli*
P053	IMMERSIVE VR PLATFORM FOR REAL TIME GAIT ANALYSIS *L. Piccinini, E. Biffi, C. Maghini, A.C. Turconi*
P054	IMPROVEMENTS IN KNEE KINEMATICS DURING WALKING ARE CORRELATED WITH CHANGES IN PHYSICAL ACTIVITY AND USE OF TIME IN FREE LIVING CONDITIONS AFTER TOTAL KNEE ARTHROPLASTY *J. Arnold, S. Mackintosh, T. Olds, S. Jones, D. Thewlis*
P055	EVOLUTION OF VAULTING STRATEGY DURING TRANSFEMORAL AMPUTEE LOCOMOTION ON SLOPES AND CROSS-SLOPES COMPARED TO LEVEL WALKING *C. Villa, X. Drevelle, X. Bonnet, I. Loiret, P. Fode, F. Lavaste, H. Pillet*
P056	KINEMATIC GAIT PATTERN IN CHILDREN WITH CEREBRAL PALSY AND LEG LENGTH DISCREPANCY - EFFECT OF AN EXTRA SOLE *M.N. Eek, R. Zügner, I. Stefansdottir, R. Tranberg*
P057	ANALYSIS OF THE COEFFICIENT OF FRICTION DURING THE PARKINSON GAIT *A. Kleiner, M. Galli, P. Sale, F. Stochi, M. Franceschini, G. Albertini, R.M.L. Barros*
P058	DESIGN AND CONSTRUCTION OF A PATIENT-SPECIFIC 3D-PRINTED WRIST SPLINT WHICH INDUCES MOVEMENT IN THE DART THROWING MOTION PLANE *S. Portnoy, Y. Kaufman-Cohen, A. Sayapin, G. Yaacoby, N. Doron, Y. Levanon*
P059	CHILDREN WITH SPASTIC HEMIPLEGIA AND BILATERAL INVOLVEMENT: DO THEY REQUIRE UNI OR BILATERAL MANAGEMENT? *H. Böhm, M. Armbruster, M. Hösl, L. Döderlein*

P060 CLASSIFICATION OF GAIT PATTERN IN STROKE PATIENTS TO OPTIMISE ORTHOTIC TREATMENT AND INTERDISCIPLINARY COMMUNICATION
D. Sabbagh, J. Fior, R. Gentz

P061 CORRELATION BETWEEN PREOPERATIVE PARASPINAL MUSCLE STATUS AND SEVERITY OF DEGENERATIVE FLAT BLACK AND DEGREE OF IMPROVEMENT AFTER CORRECTIVE FUSION SURGERY
J.H. Lee, S. Lee

P062 JOINT LOADING DURING GRADED WALKING WITH DIFFERENT PROSTHESES – A CASE STUDY
N. Alexander, G. Strutzenberger, J. Kroell, J. Christian, T. Wunsch, H. Schwameder

P063 INFLUENCE OF ALTERED GAIT KINEMATICS ON THE RISK OF EDGE LOADING IN THE HIP
M. Wesseling, F. de Groote, C. Meyer, K. Corten, J. Simon, K. Desloovere, I. Jonkers

P064 USE OF THE OS-STRETCH TO PROVIDE A PROGRESSIVE STRETCH IN STANDING TO THE CALF MUSCLES IN IDEOPATHIC TOE WALKERS AND CHILDREN WITH CEREBRAL PALSY
S. Jarvis, C. Stewart, N. Postans, A. Roberts

P065 MOTOR CONTROL INDEXES IN REHABILITATION: EFFECT OF THE SAMPLING FREQUENCY
A. Scano, M. Caimmi, M. Malosio, L. Molinari Tosatti

P066 MORE PROFOUND BALANCE IMPAIRMENT AT FAST PLATFORM SHIFT OCCURS IN LATERAL THAN ANTERIOR-POSTERIOR DIRECTION
Z. Kováčiková, E. Zemková, M. Jeleň, T. Vilman

P067 GROUND REACTION FORCE COMPUTATION USING ZERO MOMENT POINT
E.J. Dijkstra, E.M. Gutierrez-Farewik

P068 CATCH EVENT IDENTIFICATION BASED ON MUSCULOSKELETAL ANALYSIS: PILOT STUDY
M. Cognolato, D. Conte, L. Modenese, E. Carraro, C. de Conti, E. Trevisi, N. Petrone

P069 Py3DFreeHandUS: A PURE PYTHON LIBRARY FOR 3D VOXEL-ARRAY RECONSTRUCTION BY USING 3D FREEHAND ULTRASOUND
D. Monari, F. Cenni, E. Aertbeliën , K. Desloovere

P070 ANALYSIS OF THE SIT TO STAND TASK IN TRANSTIBIAL AMPUTEES USING MAGNETO-INERTIAL SENSORS
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P071 COMPARISON OF JOINT TORQUE DURING ISOMETRIC MUSCLE CONTRACTION TO JOINT TORQUE DURING WALKING AT DIFFERENT VELOCITIES
M. Goudriaan, C. Bruyninckx, A. Nieuwenhuys, K. Delanghe, J. Casie, D. Monari, K. Desloovere

P072 A TRACTABLE CLOUD-BASED FRAMEWORK FOR HUMAN MOVEMENT ANALYSIS AND CLASSIFICATION
R. Matias, J. Rosa, H. Silva, A. Fred, A. Veloso

P073 A QUANTITATIVE PERFORMANCE EVALUATION DURING ROBOTIC REHABILITATION TREATMENT
E. Biffi, E. Peri, C. Maghini, F. Servodio Iammarrone, C. Gagliardi, C. Germiniasi, A. Pedrocchi, A.C. Turconi, G. Reni

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P193 PARTICULARLY IN SPASTIC CHILDREN FOOT PLATE ANGLE IS NOT A VALID ESTIMATOR OF TALO-CRURAL JOINT ANGLE: 3D-ULTRASOUNDIMAGING AND X-RAY ANALYSIS OF GASTROCNEMIUS LENGTH
P.A. Huijing, M.R. Bénard, J. Harlaar, R.T. Jaspers, J.T. Becher

P194 NOVEL FUNCTIONAL KINEMATIC ANALYSIS FOR CLINICAL EVALUATION OF THE UPPER LIMB REACHING TASK IN SUBJECTS WITH NEUROLOGICAL DISORDERS: THE 5P TEST
P. Gaffurini, L. Bissolotti

P195 MONITORING PHYSICAL ACTIVITY OF CHILDREN WITH CEREBRAL PALSY: DOES VELOCITY INCREASE SPASTICITY?

P196 THE EFFECT OF FUR INSOLE ON PLANTAR PRESSURE DISTRIBUTION OF YOUNG LADIES DURING NORMAL WALKING
S. Yan, L. Yang, S. Li, J. Zhou

P197 DYNAMICAL ASYMMETRY INDEX IN PATIENTS AFTER UNILATERAL TOTAL HIP REPLACEMENT
S. Winiarski, K. Aleksandrowicz

P198 COMPARING THE EFFECT OF A DORSAL-LEAF-SPRING AFO AND A SPRING-HINGED AFO ON GAIT CHARACTERISTICS IN PLANTARFLEXOR WEAKNESS – A PILOT STUDY
H.E. Ploeger, M.A. Brehm, S.A. Bus, F. Nollet

P199 CHANGES IN GAIT FOLLOWING TAPPING OF CEREBROSPINAL FLUID FOR THE ASSESSMENT OF NORMAL PRESSURE HYDROCEPHALUS
D. Speciali, M. Barreto, W. Godoy, S. Lacerda, A. Vacari, I. Hideyo, C. Tanuri, P. Lucareli

16:00-17:00
Aula Minor

ESMAC AGM

17:00-18:00
Aula Major

SIAMOC AGM

18:00-20:00
Aula 2

Vicon User meeting

Vicon update from Sales Director
Andy Ray

Overview of Nexus 2.1 from Product Manager
Derek Potter

Feature Focus with local Vicon Representative
Gabriele Paolini

Q&A

9:00-9:40
Aula Major

FROM POSTURE EVALUATION TO MOVEMENT AND THREE-DIMENSIONAL ANALYSIS OF THE SPINE AND TRUNK

Stefano Negrini
University of Brescia, Brescia, Italy – IRCCS Don Gnocchi Foundation, Milan, Italy

e-mail: stefano.negrini@med.unibs.it

ABSTRACT. In the last decades, assessment of trunk posture and motion has gained importance in clinical practice, and several instrumental non-invasive techniques have been developed to overcome limitations of manual and radiological methods. Despite the large effort spent in improving the underlying technologies, the actual role of these measures in the clinical setting remains still undefined due to a variety of issues. The main question concerns the provision of parameters providing a significant contribution to the clinical decision making. A well-defined clinical role is established for surface topography in the follow-up of spine sagittal plane deformities, adulthood scoliosis and spine disorders involving the spino-pelvic alignment. Conversely, further studies are required to identify reliable key parameters for use in the clinical (adolescent scoliosis, back and neck pain), occupational (measurement of spine exposure to mechanical loads) and forensic (assessment of segmental functional impairments) fields. The new frontiers include evaluation of the moving spine and trunk, focusing on the stability function and not only on range of motion.

9:40-10:30
Aula Major

BIOMECHANICS
Chairs: Ilse Jonkers, Ugo Della Croce

9:40-9:50
A COMPREHENSIVE EVALUATION OF THE CROSS-TRAINING EFFECT IN ANKLE DORSIFLEXOR MUSCLES OF HEALTHY SUBJECTS
A. Manca, E. Ortu, F. Pisanu , F. Ginatempo, B. Mercante, D. Dragone , E. Tolu , F. Deriu

9:50-10:00
HOW ACCURATE IS THE KNEE JOINT CENTRE AND AXIS CALIBRATION?
C. Sauret, H. Pillet, W. Skalli, M. Sangeux

10:00-10:10
COMPARISON OF THE EMG PROFILES DETECTED BY MULTIPLE FINE WIRE ELECTRODES DURING GAIT OF THE SELECTED LOWER LIMB MUSCLES
P. Onmanee, R. Baker, R. Jones, K. Hollands

10:10-10:20
VALIDATION OF A MULTI-BODY OPTIMIZATION WITH A KNEE MODEL INCLUDING DEFORMABLE LIGAMENTS
X. Gasparutto, N. Sancisi, E. Jacquelin, V. Parenti-Castelli, R. Dumas

10:20-10:30
MODEL-DRIVEN EUROPEAN PAEDIATRIC DIGITAL REPOSITORY (MD-Paedigree)
J. Harlaar

10:30-11:00
Coffee break

A COMPREHENSIVE EVALUATION OF THE CROSS-TRAINING EFFECT IN ANKLE DORSIFLEXOR MUSCLES OF HEALTHY SUBJECTS

A. Manca[1], E. Ortu[2], F. Pisanu, F. Ginatempo[1], B. Mercante[1], D. Dragone[1], E. Tolu[1] and F. Deriu[1]
(1) Dept. of Biomedical Sciences – University of Sassari, Sassari, Italy
(2) O.U. of Neurology, «A. Segni» Hospital - ASL n. 1 Sassari, Italy

Main topics: Rehabilitation; Outcomes after clinical intervention.

INTRODUCTION and AIM

The Cross-Training (CT) effect is the performance improvement in the unpracticed limb after unilateral exercise training[1]. The reported magnitude of the strength transfer typically ranges from 5 to 25%, which has been shown to have clinical implications in pathological asymmetric conditions[2]. CT studies have merely focused on parameters describing maximal strength, such as isokinetic peak torque (PT) and isometric maximal voluntary contraction (MVC). No data are currently available on a contralateral transfer of muscle performance also in terms of muscular work (MW) and total work (TW). These parameters are considered better indicators of the function of a muscle group than PT and MVC, as they provide information regarding average force and endurance[3]. Additionally, nervous mechanisms underlying the CT-effect are still debated[1]. Therefore, the present study proposes to evaluate the CT-effect on a more comprehensive muscle performance of the ankle dorsiflexors and the parallel neural adaptations.

PATIENTS/MATERIALS and METHODS

Thirty healthy, recreationally active volunteers (21 males, 9 females; 26.7±4.6 y.o.; 70.5±12.0 kg) participated in this study. Design was set as a parallel-group case-control study. Participants were randomly assigned to an intervention (CT; n = 15) or to a non-intervention control group (n = 15). Intervention consisted of a 4-week unilateral isokinetic/concentric training (4 times/week for a total of 16 sessions at 90 and 45°/s) of the stronger tibialis anterior muscle (TA). PT, MW and TW were measured on a Biodex isokinetic dynamometer. Transcranial magnetic stimulation was used to probe motor-evoked potentials (MEP), resting motor threshold (RMT) and cortical silent period (cSP) at two stimulation intensities (120% and 150% of RMT) from the untrained TA; the M-wave and the volitional V-wave of the unpracticed side were also recorded and the V/M ratio calculated. Isokinetic and neurophysiological assessments were performed before (PRE) and after (POST) the 4-week intervention/non-intervention period. A repeated-measures analysis of variance along with post hoc comparisons (Bonferroni) was employed to process data.

RESULTS

Dynamometric parameters - Only in the CT group, the untrained side showed a significant increase of muscle performance from PRE to POST for all angular speeds tested in *PT* (90°/s: +27.7%; p<0.0005; effect size r=0.42; 45°/s: +21.9%; p<0.001; effect size r=0.45), *MW* (90°/s: +40.1%; p=0.005; effect size r=0.47; 45°/s: +56.5%; p<0.0005; effect size r=0.56) and *TW* (30 repetitions at 180°/s: +81%; p<0.0005; effect size r=0.49).
Neurophysiological parameters – Only in the CT group, the untrained side showed a significant reduction in the cSP duration at both TMS intensities (150% RMT: PRE=281ms; POST=243ms; p<0.0005; 120% RMT: PRE=175ms; POST=143ms; p<0.001) as well as an increase of the V/M ratio (PRE=0.06; POST=0.14; p<0.05).

DISCUSSION and CONCLUSIONS

Cross-Training resulted in a significant transfer to the untrained side, not only of maximal strength but also of muscle work capability and total work endurance. Muscle performance changes were paralleled by: *i)* a reduction of the cortical silent period duration, which accounts for an increased cortical excitability and *ii)* an increase of the V/M ratio suggesting an augmented cortico-spinal drive to the contralateral untrained limb.
Considering other parameters of strength along with PT may provide valuable additional information in the rehabilitation setting for those conditions where unilateral muscle weakness does not allow or makes difficult performing a conventional strength training of the weaker limb.

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HOW ACCURATE IS THE KNEE JOINT CENTRE AND AXIS CALIBRATION?

C. Sauret (1), H. Pillet (1), W. Skalli (1), M. Sangeux (2)
(1) Laboratoire de Biomécanique, Arts et Métiers ParisTech, Paris, France
(2) Hugh Williamson Gait Analysis Laboratory, The Royal Children's Hospital, Melbourne, Australia

Main topics: Musculoskeletal imaging**,** Musculoskeletal modelling, Analysis of gait and motor disorders

INTRODUCTION and AIM

The kinematics of the knee joint is widely studied during gait. Marker placement errors [1] affect the femoral frame definition which, in turn, affects kinematic results. A few studies have compared medical image based and skin marker based knee kinematics during gait (e.g. [2]). However, these studies do not differentiate between static anatomical frame definition error and soft tissue artefact effect on the kinematics. The aim of this study was to quantify the accuracy of knee joint centre and axis definition during static calibration against a medical image based reference.

PATIENTS/MATERIALS and METHODS

Eleven subjects participated in this study. Subjects were equipped with skin markers including 4 markers on the anterior and lateral parts of the thigh and 2 markers on the medial and lateral epicondyles of the knee to define the knee joint axis (KJA) and joint centre (KJC). Static calibration was performed with a motion capture system (Vicon, Oxford metrics, UK) and bi-planar radiographs were obtained with the EOS system (EOS Imaging, France) before markers removal [3]. The 3D bone geometry was registered to the skin markers [4] to superimpose EOS and VICON based position of the knee axis and centre. Besides, 6 femurs were reconstructed by 2 operators to assess the reproducibility of the image-based results.

RESULTS

Inter-observer reproducibility (2 SD) was 1.5 mm for the KJC and 1.7° for the KJA. Image-based KJC and skin-based KJC differed from 12 ± 7.6 mm (range: 4 – 34 mm). KJA exhibited 3D orientation differences of 15 ± 4° (range: 7 – 21°), mainly in the transverse plane (affecting internal/external rotations)

DISCUSSION and CONCLUSIONS

Results showed that knee joint centre and axis obtained from marker based static calibration greatly differs from the EOS medical image based benchmark. It appears that errors during static calibration have similar or greater magnitude than soft tissue artefact [3] during gait. Future work will focus on their impact on the knee and hip kinematics during gait. Further research is also warranted to improve the accuracy of the femoral anatomical frame definition during static calibrations for gait analysis.

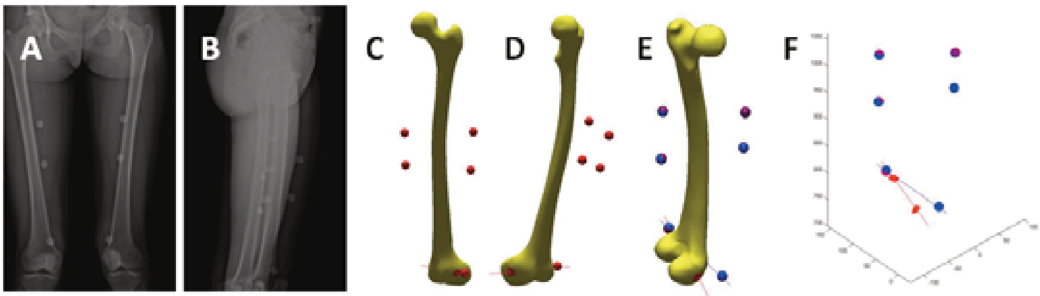

Figure 1: (A and B) Front and lateral radiographs; (C and D) representation of the reconstructed femur, markers (red) and image-based KJA; (E) fusion of Vicon data (blue markers) during static calibration and the skin-based KJA; (F) axes and markers obtained from (E) by removing the femur reconstruction.

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COMPARISON OF THE EMG PROFILES DETECTED BY MULTIPLE FINE WIRE ELECTRODES DURING GAIT OF THE SELECTED LOWER LIMB MUSCLES

P.Onmanee, RJ. Baker, RK.Jones, K.Hollands
University of Salford, Salford, United Kingdom

Main topics: experimental studies in human movement science, reliability and service development

INTRODUCTION AND AIM

Fine-wire (FW) sensors are the only method for detecting EMG in tibialis posterior (TP) which controls the sub-talar and other joints within the foot. The FW sensors are directly inserted in the muscles detecting electrical potential within a small volume which may not adequately represent the whole muscle. There have, however, been no previous studies to determine how sensitive fine wire signals are to electrode locations on TP. This study aims to measure differences between two sites within TP, medial gastrocnemius (MG) and tibialis anterior (TA) on different occasions.

PARTICIPANTS and METHODS

11 healthy adults (age 35±6 years, 4 females, height 1.67±0.10 m, weight 71±12 kg) who were self-reported to be free from any neurological or musculoskeletal disease gave consent to participate in the study. 9 completed two sessions two weeks apart. Fine wire EMG from two sites (one 2cm distal to the other) within TP, TA and MG were recorded simultaneously at self-selected walking speed following published guidelines [1, 2].

Root mean square (RMS) differences between EMG profiles (normalised to peak value within gait cycle) were averaged over a minimum of 5 gait cycles and the RMS difference between sensors and between sessions calculated for each participant.

RESULTS

Table 1 Average RMS difference as % of peak value within cycle (with standard deviation)

Comparison	Tibialis posterior	Medial Gastrocnemius	Tibialis anterior
Different site, same session	2.7 (3.1)	3.6 (3.0)	5.5 (3.7)
Same site, different session	5.2 (3.6)	4.4 (2.9)	4.8 (5.4)

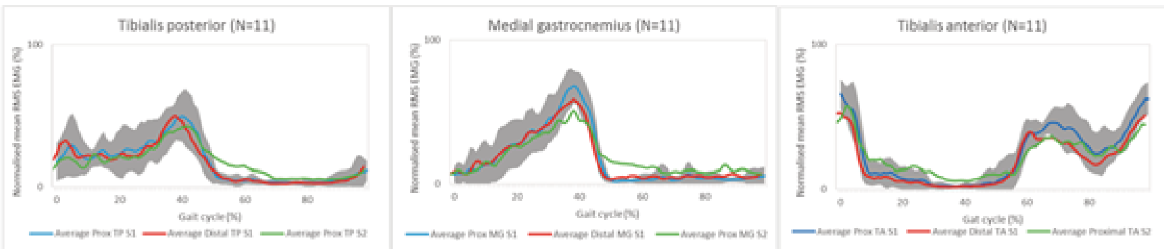

Figure 1 Normalised mean (±SD) muscle EMG RMS -time curve

DISCUSSION and CONCLUSIONS

The RMS differences between electrode sites and testing sessions for all muscles are below 5%. This indicates that the FW sensors from different sites within the same muscles detect similar EMG signal and there is good test re-test reliability of the signal in healthy adults. Also, EMG waveforms from MG and TA are similar to previous reports using both FW and surface sensors [2, 3]. This similarity suggests that the fine wire sensors adequately represents the muscle activity even though a FW sensor measures action potentials from an effective number of motor units within a relatively small detection volume [3]. Murley et al. [2] shows a similar pattern of TP EMG profile. Therefore the EMG profile from FW sensors represent the activity of TP during gait.

In conclusion, despite the small detecting volume, EMG signals detected by a FW sensor can be taken as representative of activity of the entire muscle in TP, MG, and TA. The result is also repeatable in healthy adults.

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VALIDATION OF A MULTI-BODY OPTIMIZATION WITH A KNEE MODEL INCLUDING DEFORMABLE LIGAMENTS

X. Gasparutto (1), N. Sancisi (2), E. Jacquelin (1), V. Parenti-Castelli (2), R. Dumas (1)
(1) Université de Lyon, IFSTTAR, UMR_T9406, LBMC, Université Lyon 1, Lyon, France
(2) Università degli Studi di Bologna, DIN, Bologna, Italy

Main topics: Analysis of clinical movement data, Technical developments in movement science.

INTRODUCTION and AIM

Soft tissue artefact introduces large errors in the joint kinematics estimated from skin markers. Multi-body optimization (MBO) methods have been proposed to reduce these errors. However, the validation of MBO methods using spherical or hinge knee kinematic models showed their inefficiency to estimate accurately the *in vivo* kinematics [1, 2]. A knee kinematic model with deformable ligaments has been developed on the basis of a previously proposed parallel mechanism [3, 4]. The objective of the study is to validate the model-based kinematics obtained with a MBO method using this knee kinematic model, against the kinematics measured in-vivo by bone pins.

PATIENTS/MATERIALS and METHODS

The knee kinematic model is based on *in vitro* studies [4]. The model geometry is calibrated on *in vitro* data in order to obtain the best fit parallel mechanism (isometric ACL, PCL, MCL, and most isometric LCL fibres) during passive flexion. The MBO framework of [5] is used with a penalty-based method to minimize the ligament length variations. The data of [6] are used for this validation study. The MBO method is applied to the skin markers and the model-based kinematics is compared to the bone-pin kinematics.

RESULTS

Over the three subjects and five running trials, the root mean square errors are below 2°, 2.2°, 2.5°, for the extension-flexion, abduction-adduction, internal-external rotations, respectively, and below 3 mm, 4.1 mm, 1.9 mm, for the medial-lateral, anterior-posterior, proximal-distal displacements, respectively. However, the correlation coefficients R^2 remain generally under 0.5.

DISCUSSION and CONCLUSIONS

The model-based kinematics obtained by the MBO method using a knee kinematic model with deformable ligaments demonstrated reliable results for the curve amplitudes but not for the curve patterns. The errors are lower than the errors reported for the model-based kinematics obtained by MBO methods using spherical or hinge knee kinematic models, e.g., in the order of 10° and 10–15 mm [2].
Therefore, this study presents encouraging results for the introduction of a knee kinematic model with deformable ligaments in MBO. As this study used a knee kinematic model based on cadaver data, personalization of the geometry should be considered for further improvements of the estimation of the model-based kinematics from skin markers.

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11:00-12:30 **OUTCOME STUDIES**
Aula Major ***Chairs: Jaap Buurke, Kaat Desloovere***

11:00-11:10 LONG TERM FOLLOW UP OF CHILDREN POST SELECTIVE DORSAL RHIZOTOMY (SDR) – THE EFFECT OF THE ADOLESCENT GROWTH SPURT ON GAIT
J. McFall, C. Stewart, V. Kidgell, N. Postans, S. Jarvis, R. Freeman, A. Roberts

11:10-11:20 RESPONSIVENESS OF GAIT PARAMETERS TO CHANGES IN LOCOMOTOR IMPAIRMENTS INDUCED BY CMT DISEASE: A 12 MONTHS FOLLOW-UP STUDY
T. Lencioni, M. Rabuffetti, I. Moroni, E. Pagliano, D. Pareyson, G. Piscosquito, M. Ferrarin

11:20-11:30 QUANTIFYING FUNCTION BEFORE AND AFTER TOTAL JOINT REPLACEMENT SURGERY IN PATIENTS WITH HIP OSTEOARTHRITIS
J.E. Naili, A. Esbjornsson, M.D. Iversen, M.H. Schwartz, C. Häger, E.W. Brostrom

11:30-11:40 GAIT ANALYSIS PRE/POST TAP-TEST TO PROGNOSTICATE SHUNT RESPONSIVENESS IN NORMAL PRESSURE HYDROCEPHALUS
V. Agostini, M. Carlone, M. Campagnoli, I. Azzolin, R. Scarafia, G. Massazza, M. Lanotte, M. Knaflitz

11:40-11:50 THE EFFECT OF COMBINING TOTAL ANKLE ARTHROPLASTY WITH A CORRECTION FOR HINDFOOT MISALIGNMENT USING TRIPLE ARTHRODESIS – A KINEMATIC ANALYSIS
J. Burg, S. Duerinck, G. Dereymaeker, S. Van Bouwel, J. Vander Sloten, I. Jonkers

11:50-12:00 ROBOTIC ON SITE GAIT TRAINING IN CHILDREN WITH DIPLEGIA
A. Colazza, S. Carniel, N. Riccioli, M. Petrarca, E. Castelli

12:00-12:10 KINEMATIC AND KINETIC ANALYSIS OF THE EFFECTS OF A HIGH INTENSITY CROSS-TRAINING ON GAIT IN PATIENTS WITH MULTIPLE SCLEROSIS
V. D'Angeli, A. Cereatti, A. Peruzzi, G. Paolini, A. Manca, F. Deriu, G. Bua, U. Della Croce

12:10-12:20 CLINICAL AND FUNCTIONAL EVALUATION OF THREE DIFFERENT SURGICAL SOLUTIONS FOR ANKLE ARTHROSIS AT FIVE YEARS FOLLOW UP: ARTRHODESIS, TOTAL ANKLE REPLACEMENT AND OSTEOCHONDRAL ALLOGRAFT TRANSPLANTATION
A. Leardini, G. Lullini, P. Caravaggi, F. Vannini, S. Giannini, L. Berti

12:20-12:30 WHAT POST-OPERATIVE SHOE AFTER FOREFOOT SURGERY? BIOMECHANICAL EVALUATION OF TWO DIFFERENT FOREFOOT RELIEF SHOES
G. Lullini, A. Giangrande, L. Berti, P. Caravaggi, S. Giannini, A. Leardini

LONG TERM FOLLOW UP OF CHILDREN POST SELECTIVE DORSAL RHIZOTOMY (SDR) – THE EFFECT OF THE ADOLESCENT GROWTH SPURT ON GAIT

J. McFall (1,2), C.Stewart (1), V.Kidgell (1), N. Postans (1), S. Jarvis (1), R. Freeman (1), A. Roberts (1)
(1) ORLAU, RJAH Orthopaedic Hospital, Oswestry, UK
(2) School of Medicine, Cardiff University, UK

Main topics: Analysis of clinical movement data, Outcomes after clinical intervention, Rehabilitation

INTRODUCTION and AIM

The RJAH Orthopaedic Hospital has been performing Selective Dorsal Rhizotomy (SDR) procedures for children with cerebral palsy for almost 20 years. Children undergoing SDR have been followed up at regular intervals, including before and after the adolescent growth spurt. Our previously published 18 month follow up [1], showed positive outcomes as a result of careful patient selection. Many patients are now adults and we are reporting the durability of the outcomes through the period of rapid growth experienced during adolescence.

PATIENTS/MATERIALS and METHODS

A cohort of 17 ambulant adults was identified, who had an SDR during childhood (average age 8.4). All patients had been assessed at three time points, preoperatively (PRE) and at two time points postoperatively (POST1 and POST2). POST1 was performed at age 10 for girls and 12 for boys (pre-pubertal) and the POST2 at 16 for girls and 18 for boys (post-pubertal). At each time point instrumented 3D gait analysis was performed, along with a full clinical examination. Within subject analysis of variance was determined using Friedman and Wilcoxon signed ranks tests at a significance level of p=0.05 (2-tailed).

RESULTS

Table 1: Changes in key gait parameters from pre-op to post adolescence (* significant results)

Parameter	PRE	Change (PRE to POST2)	Change (POST1 to POST2)
GPS	14.7 +/- 3.6	-3.2 +/- 1.0 *	0.3 +/- 1.1
Walking Speed (m/s)	0.77 +/- 0.29	0.24 +/- 0.1 *	0.01 +/- 0.1
Normalised step length (% height)	24.3 +/- 12.8	10.1 +/- 3.4 *	1.9 +/- 2.8
Mean Pelvic Tilt	15.0 +/- 5.6	5.5 +/- 2.7 *	-0.9 +/- 2.8
Minimum Hip Flexion in Stance (◦)	5.4 +/- 7.9	2.4 +/- 3.3	-0.5 +/- 3.8
Minimum Knee Flexion in Stance (◦)	23.7 +/- 10.1	-2.6 +/- 5.0	1.1 +/- 5.6
Knee Flexion at Initial Contact (◦)	40.3 +/- 7.1	-8.7 +/- 3.9 *	-1.5 +/- 4.3
Max Rate of Knee Flexion in Swing (°/s)	129.1 +/- 41.7	105.3 +/- 23.7 *	33.1 +/- 29.5 *
Maximum Dorsiflexion in Stance (◦)	-2.2 +/- 20.7	16.8 +/- 5.5 *	-0.7 +/- 3.1

DISCUSSION and CONCLUSIONS

We are reporting the durability of SDR through the adolescent growth spurt and into adulthood, with an average follow up time at POST2 of 9.7 years post op.

The second column in Table 1 compares pre-operative gait data with the outcome post-adolescence. Statistically significant positive changes are observed in many parameters, including the global measures of gait function (GPS and walking speed). The greatest changes are observed in the parameters most directly linked to spasticity, for example an increased Maximum Rate of Knee Flexion in Swing as a result of reduction in rectus femoris spasticity. The only negative change observed is an increase in anterior pelvic tilt. Positive changes were also seen in clinical examination measures (not reported here).

The third column in the table shows the changes during the adolescent growth spurt. Little change is observed during this period, though patients did continue to improve their swing phase knee flexion rate. These results show that patients are not experiencing the negative effects of growth on their gait function, which might have been predicted.

None of the patients in this group required further soft tissue surgery post-SDR though some additional procedures were performed including botulinum toxin injections (3 patients), femoral derotation osteotomies (5 patients), tibial derotation osteotomies (4 patients) and foot stabilisation surgery (3 patients).

Further work is now required to analyse the pre-operative characteristics of patients which lead to a positive outcome at skeletal maturity, the ultimate goal of the SDR procedure.

Selective dorsal rhizotomy has a positive outcome for children with cerebral palsy where rigorous selection criteria are applied [1]. These children maintain the benefits of the procedure through the rapid growth experienced during adolescence, achieving a better gait pattern in adulthood than seen pre-operatively.

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RESPONSIVENESS OF GAIT PARAMETERS TO CHANGES IN LOCOMOTOR IMPAIRMENTS INDUCED BY CMT DISEASE: A 12 MONTHS FOLLOW-UP STUDY

T. Lencioni(1), M. Rabuffetti(1), I. Moroni(2), E. Pagliano(2), D. Pareyson(2), G. Piscosquito(2), M. Ferrarin(1).
(1) IRCCS Fondazione Don Carlo Gnocchi Onlus, Polo Tecnologico, Milano, Italy
(2) IRCCS Fondazione Istituto Neurologico Carlo Besta, Milano, Italy

Main topics: Natural history of movement and ability, Analysis of gait and motor disorder, Responsiveness.

INTRODUCTION and AIM

Charcot-Marie-Tooth disease (CMT), the most frequent hereditary neuropathy, is a very slowly progressive disorder. Symptoms and signs on distal limbs are muscle weakness, skeletal deformities and sensory loss [1]. Responsive indexes, able to reliably detect changes in the clinical status with time, are needed for natural history studies and randomised clinical trials. However, the primary clinical scale currently used for the assessment of CMT disease, the CMTNS (CMT Neuropathy Score), shows a poor responsiveness (Standardized Response Mean, SRM <0.20) [1,2]. The lack of indexes able to quantify CMT disease progression and/or the effect of clinical therapies raises concerns. The aim of this study was to examine, in a 12-month time period, the responsiveness of parameters derived from instrumented analysis of locomotor tasks in CMT patients.

PATIENTS/MATERIALS and METHODS

57 CMT subjects (25.6±16.7 yrs, range 7-60, 45 CMT1A, 12 CMTX1) with a wide range of severity levels were recruited. All subjects underwent a clinical examination, assessment with CMTNS and CMT Examination Score (CMTES), and a complete gait analysis at baseline and after 12 months. The protocol, approved by the local Ethical Committee, included the instrumented analysis of walking at natural speed (NW), toe- (TW) and heel-walking (HW), stair ascending (SA) and descending (SD) [3]. Responsiveness of the main spatio-temporal, kinematic and kinetic gait parameters was examined by calculating the SRM (mean score change after one year/SD score change) and was defined small (0.2-0.49), moderate (0.5-0.79) or large (>0.8) according to [4].

RESULTS

Considering the whole CMT group, SRM values ranged from small to moderate, with a maximal values of -0.54. Looking for more responsive parameters, CMT subjects were then divided into three subgroups according to their primary deficits in level walking, related to disease progression [3]: normal like patients (NL, N=16), patients with food drop deficit only (FD=17), and patients with FD and push off deficits (FD&POD=24). Table 1 reports the SRM values of the parameters that showed the maximal value for each subgroup (evidenced in bold): Stride Length normalized to body height, peak of knee flexion during swing ($KMAX_{sw}$) and the difference between the mean flx/ext angle of the ankle joint during toe- and heel- walking ($T\text{-}H_{st}$) [3]. FD&POD patients were the most stable group between the two evaluations, in contrast to groups NL and FD, whose gait parameters showed a moderate-to-large responsiveness. Last column reports values for the whole CMT group.

DISCUSSION and CONCLUSIONS

At 12-month follow-up, some gait parameters showed higher responsiveness than clinical scales for CMT patients [1,2]. Different parameters showed a better sensitivity to the progression of the disease depending on the degree of locomotor impairment (NL, FD, FD&POD), possibly because at different CMT stages the worsening of locomotor function is related to different biomechanical factors. For example, for NL subjects a complex task such as SD, which requires a greater capacity of coordination and balance, is able to evidence motor deterioration more than level walking. Demanding tasks, such as star descending, toe and heel walking, highlight the functional changes related to disease progression even at the early and intermediate CMT stage. At a more advanced stage, responsiveness of specific gait parameters decreased, likely because of a floor effect, and stride length remained the only one still moderately sensitive to disease progression. The results of this study suggest that stage-specific gait parameters can be used as responsive outcome measures to assess the progression of CMT disease and/or the effect of possible drug therapies.

Table 1 SRM values for the gait parameters

Parameter	Task	NL	FD	FD&POD	All-CMT
StrideLengthNorm	SD	-0.62	-0.26	-0.48	-0.20
$KMAX_{sw}$	SD	-0.86	-0.68	-0.21	-0.54
T-Hst	TW-HW	-0.13	-0.91	-0.24	-0.38

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QUANTIFYING FUNCTION BEFORE AND AFTER TOTAL JOINT REPLACEMENT SURGERY IN PATIENTS WITH HIP OSTEOARTHRITIS

JE. Naili[1], AC. Esbjörnsson[1], MD. Iversen[1,2], MH. Schwartz[3], C Häger[4], EW. Broström [1]
[1]Dept of Women's and Children's Health, Karolinska Institutet, Stockholm, Sweden [2]Dept of Physical Therapy, Movement and Rehabilitation Sciences, Northeastern University, and Section of Clinical Sciences, Division of Rheumatology, Immunology & Allergy, Brigham & Women's Hospital, Harvard Medical School, MA, United States [3]Gillette Children's Specialty Healthcare, MN, United States [4]Dept of Community Medicine and Rehabilitation, Physiotherapy, Umeå University, Umeå, Sweden.

Main topics: Functional outcome measures in mobility, Movement deviation indexes, Orthopaedics

INTRODUCTION and AIM

In Sweden, hip osteoarthritis (HOA) is the cause of 16,000 hip joint replacements per year [1]. Common symptoms of HOA include joint pain, joint stiffness and impaired function. The goal of OA treatment is to reduce pain and improve physical function. Several methods to assess function exist. To our knowledge, there is no consensus regarding the best research tools to use when evaluating function in patients with HOA. This study aimed to quantify function in patients with end-stage HOA before and one year after total joint replacement (TJR) surgery, and to explore which combination of tests could provide a useful functional evaluation battery.

PATIENTS/MATERIALS and METHODS

23 patients with unilateral HOA, mean age 67 yrs (10), scheduled for TJR surgery within the following month, and 11 healthy control subjects, mean age 65 yrs (11), were included. All participants performed a 3D gait analysis (©Vicon Motion Systems Ltd), the timed up and go test (TUG, s), the five times sit to stand test (5STS, s), and the single limb mini squat test (SLMS) and completed the Hip disability and Osteoarthritis Outcome Score (HOOS) at baseline. Adults with HOA then repeated the test protocol one year after surgery. Kinematic gait deviations were calculated and described using the gait deviation index (GDI) [3]. Parametric and non-parametric statistics characterized the nature of data and were used to calculate differences between samples.

RESULTS

There were no significant differences in age or BMI between the HOA patients as compared to controls. Mean follow-up time after TJR surgery was 12.3(1.1) months. Among HOA patients, function improved significantly one year after TJR; GDI-scores increased, time taken to perform TUG and 5STS decreased and the number of SLMS performed in 30 s increased (Table 1). Values on all five subscales of HOOS increased after TJR (range 84-168%; p<0.001). When comparing HOOS scores of HOA post TJR with scores of controls, HOA patients rated their function significantly lower than controls in all subscales, except for the subscale "Pain" (p=0.054).

Table 1. GDI-scores, time taken to perform TUG and 5STS and number of SLMS in individuals with HOA and healthy controls.

	Control n=11 Mean(SD)	HOA pre-op n=23 Mean(SD)	HOA post-op n=23 Mean(SD)	Mean Δ Pre-op cf. to Post-op	p-value	Mean Δ Post-op cf. to Control	p-value
GDI	101.2(6.7)	85,8(8.3)	92.9(8.2)	7.1	0.007	8.2	0.008
TUG (s)	9.3(1.9)	12.6(2.6)	10.6(1.7)	2	<0.001	1.3	0.6
5STS (s)	10.3(3.1)	16.2(7.8)	10.9(2.3)	5.3	<0.001	0.6	0.927
SLMS (n of reps)	26.6(10.4)	19.7(6.8)	24.8(7.2)	5.1	<0.001	1.8	0.74

GDI, Gait Deviation Index; TUG, timed up and go; 5STS, five times sit to stand; SLMS, single limb mini squat; HOA, hip osteoarthritis; Δ, difference.

DISCUSSION and CONCLUSIONS

HOA patients demonstrated substantial functional impairments with low self-reported function, gait deviations and decreased performance-based function prior to TJR. One year after surgery, patients reported improved function and decreased pain. Their performance-based function improved to the level of healthy controls. Significant differences did remain between HOA patients and control subjects in self-reported hip function as well as in GDI-scores one year after TJR. In conclusion, both pain and performance-based function improved. Deviations in overall gait pattern remained and self-reported function was lower than healthy controls one year after TJR. Combining patient-reported outcome measures and kinematic measures of gait with performance-based measures of function provided information on characteristics of function that improved one year after TJR surgery, and revealed areas which require additional rehabilitation.

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GAIT ANALYSIS PRE/POST TAP-TEST TO PROGNOSTICATE SHUNT RESPONSIVENESS IN NORMAL PRESSURE HYDROCEPHALUS

V. Agostini (1), M. Carlone (2), M. Campagnoli (2), I. Azzolin (2), R. Scarafia (2), G. Massazza (2), M. Lanotte (3), M. Knaflitz (1)
(1) Dipartimento di Elettronica e Telecomunicazioni, Politecnico di Torino, Torino, Italy
(2) S.C. Medicina Fisica e Riabilitazione U., A.O. Città della Salute e della Scienza, Torino, Italy
(3) Dipartimento di Neuroscienze, Università di Torino, Torino, Italy

Main topics: •Analysis of clinical movement data •Analysis of gait and motor disorders •Functional outcome measures in mobility •Movement deviation indexes.

INTRODUCTION and AIM
Gait disturbance is a very common and disabling symptom of idiopathic normal pressure hydrocephalus (iNPH), and it is often the first sign to appear. The other classical symptoms are urinary incontinence and cognitive dysfunction [1]. Shunt surgery aimed at removing the excess of cerebrospinal fluid (CSF) may improve the iNPH patient condition, and it is routinely applied to selected patients after a careful clinical assessment of the potential risks and benefits following the surgery. To improve the patient selection for shunting, clinicians may perform a tap-test (TT), i.e., they remove 30-50 ml of CSF by lumbar puncture to obtain a temporary drainage. Improvements in gait after TT is often used to prognosticate shunt responsiveness. Patients are classified as tap-test responders or non-responders, depending on presence or absence of transient gait improvements after CSF removal. Gait improvements are usually evaluated by clinicians in a subjective way or performing the 10-m test. Instrumented gait analysis may be an important tool to assess gait changes after TT, thus helping the clinician in a better selection of the candidates for shunt surgery [2]. The aim of this study is to propose an objective method, based on gait data, to classify TT-responders and non-responders.

PATIENTS/MATERIALS and METHODS
We retrospectively analysed the gait, at self-selected speed, of 60 iNPH patients and 50 controls, matched for sex and age. For patients, gait data were collected both before and after tap-test. Thirteen of the 60 patients were shunted, and they were evaluated by gait analysis again 6 months after surgery. By means of foot-switches and knee goniometers (sagittal plane) we extracted 11 gait parameters: double support and, bilaterally, heel contact, flat-foot contact, push-off, swing, and dynamic knee Range of Motion. We used these parameters to calculate the Mahalanobis distance of each patient from the group of controls. This allowed us to score, through a single value, how much the patient's performance deviates from controls: a) pre tap-test, and b) post tap-test. Considering only those patients that showed basal conditions out of the range of normality (Mahalanobis distance greater than the mean + 3 standard deviations of the control group), we defined tap-test responders those patients whose Mahalanobis distance from controls decreased at least 10%.

RESULTS
Before TT, iNPH patients showed augmented double support and flat-foot contact, and reduced swing and knee dynamic ROM with respect to the control group. These parameters did not normalize after TT. We classified the iNPH patients in TT responders (n = 22) and non-responders (n = 38), as explained above. The increments/decrements of the 11 parameters after tap-test were globally different in the two groups (MANOVA test, $p = 0.03$). In the group of TT-responders, 9 patients were shunted: all of them improved their gait after shunt. In the group of non-responders, 4 patients were shunted: three of them did not improve, while one slightly improved after shunt.

DISCUSSION and CONCLUSIONS
We proposed a method to classify tap-test responders and non-responders in INPH patients. Although the number of shunted patients available to validate our results is small, the method is promising, both in terms of sensitivity and specificity.

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THE EFFECT OF COMBINING TOTAL ANKLE ARTHROPLASTY WITH A CORRECTION FOR HINDFOOT MISALIGNMENT USING TRIPLE ARTHRODESIS – A KINEMATIC ANALYSIS

J. Burg (1,4), S. Duerinck (2), G. Dereymaeker (1), S. Van Bouwel (3), J. Vander Sloten (1), I. Jonkers (4)
(1) Dept. of Mechanical Engineering, Biomechanics Section, Katholieke Universiteit Leuven, Belgium
(2) Dept. of Physiotherapy and Rehabilitation Sciences,Vrije Universiteit Brussel, Belgium
(3) Orthopaedic department, University Hospital Antwerp, Belgium
(4) Dept. of Kinesiology, Human Movement Biomechanics, Leuven, Belgium

Main topics: Prosthetics, Analysis of clinical movement data, Outcomes after clinical intervention

INTRODUCTION and AIM

As hindfoot alignment is of utmost importance to achieve maximal performance of a total ankle prosthesis (TAP), a misaligned hindfoot is often suggested as contra-indicative for TAP surgery.[1] However, results of clinical and radiological studies present a good outcome if hindfoot misalignment is corrected before TAP insertion[2], e.g. by means of a triple arthrodesis (TA). Nevertheless, no kinematic results were reported that compare the functional outcome after TAP insertion and after TAP in combination with TA. This study therefore provides a detailed kinematic analysis of the impact of both treatments on ankle-, foot, and lower limb function.

PATIENTS/MATERIALS and METHODS

Using integrated 3D motion capture (Vicon, Oxford Metrics, UK, 10 cameras), gait analysis results of 10 patients with a TAP combined with TA (COMBI) were compared to those of 15 patients with an isolated TAP and 15 control subjects. The use of a detailed multi-segment foot model allows calculating kinematics of the hindfoot, midfoot, forefoot and hallux. Both patients filled out the AOFAS and VAS scales indicating the self-reported pain and functionality level. Data were checked for normality using Kolmogorov-Smirnov, Lilliefors and Jarque-Bera tests. A non-parametric ANCOVA[3] was used to test for differences between the COMBI group and the isolated TAP group.

RESULTS

The COMBI group presents good scores regarding pain and functionality, but a significantly reduced walking compared to the isolated TAP group. Ankle kinematics are not significantly different from isolated TAP patients (figure 1). However, at the midfoot, increased dorsiflexion presents as well as decreased varus and external rotation. A compensatory increased plantarflexion and external rotation and a decreased valgus presents at the forefoot.

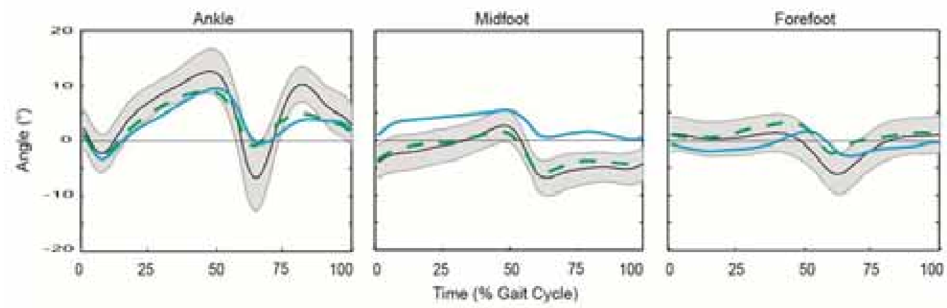

Figure 1: Sagittal plane kinematics of the ankle, midfoot and forefoot (plantarflexion: - / dorsiflexion: +). A blue full line indicates COMBI, a green dashed line the isolated TAP and a full black line the healthy controls. A grey zone represents one standard deviation from the mean of control values

DISCUSSION and CONCLUSIONS

An additional triple arthrodesis to correct for hindfoot misalignment prior to TAP insertion does not cause significant differences in ankle function, compared to an isolated TAP group. In contrast, differences do present in midfoot position and are compensated at the forefoot. Combined with the positive clinical and radiological results, our results are encouraging to perform TAP surgery in feet with a pre-operative hindfoot misalignment, provided that the misalignment is corrected.

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ROBOTIC ON SITE GAIT TRAINING IN CHILDREN WITH DIPLEGIA

A.Colazza(1), S.Carniel(1), N.Riccioli(1), M.Petrarca(1), E.Castelli (1)
(1) Movement Analysis and Robotics Laboratory, "Bambino Gesù" Children's Hospital, Santa Marinella(RM), Italy

Main topics: Robotic devices, Rehabilitation, Functional outcome measures in mobility

INTRODUCTION and AIM

The aim of this study was to explore how the robotic exoskeleton for walking on site could be useful for gait rehabilitation in children affected by Cerebral Palsy, diplegia. The SARA' system utilizes linear motors with an active control not only on the hip and the knee but also on the ankle. In literature was reported the evidence in the use of robotic systems for gait training [1,2], while the main aim of this work it's how we can establish the best goal in respect to the clinical assessment. The children were divided in two sub group, using the GMFCS classification, i.e., I-II and III-IV.

PATIENTS/MATERIALS and METHODS

Ten children with diplegia (age 8 ± 3), with Gross Motor Function Classification System (GMFCS) level included between I and IV were be involved in this study. The exclusion criteria are: injections of botulinum toxin in the last 6 months and lower limbs surgeries in the last year; all the children included in the study showed a good level of involvement. The intensive training with SARA' system consisted in two therapy sessions per day, each one of 45 minutes, for an amount of twenty sessions. During this period, the children didn't carry out other neuromotor therapies. At the beginning of the training, at its end and after six months assessment of the motor aspects with Gross Motor Functional Measure (GMFM), of the range of motion of the lower limbs (ROM) and with the gait analysis were performed.

RESULTS

The analysis of the data collected showed different areas of improvement in the two groups. The first group (FG), level I-II of the GMFCS (Figure1), reach a good improvement in the areas D, E (Walking, running and jumping); the second group (SG), level III-IV of the GMFCS (Figure2), point out modifications of other functional areas B and C (Sit down position and Crawling). Although the Passive ROM improved, differences in the gait analyses ROM were not observed. The Passive ROM evaluations in sagittal plane underlined an increase ROM at the articulations of knee, hip and ankle for the patients of the FG, while they showed a tendency to unchanged in SG. The FG patients showed in gait spatio–temporal parameters analyses an increase of walking velocity corresponding to an increase of cadence.

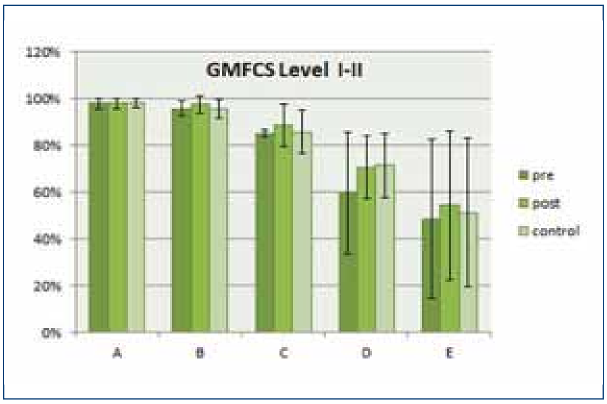

Figure 1 GMFCS Level I-II in four patients affected by Cerebral Palsy

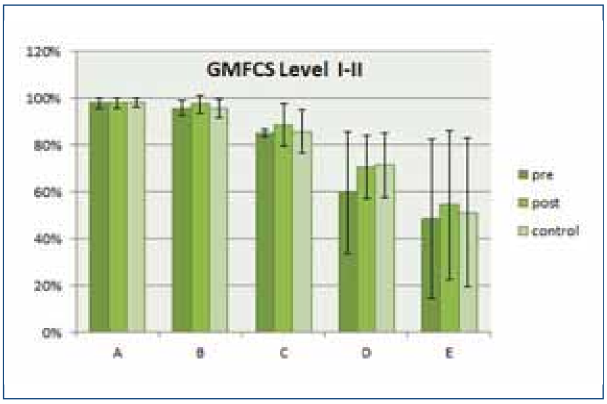

Figure 2 GMFCS Level III-IV in six patients affected by Cerebral Palsy

DISCUSSION and CONCLUSIONS

All patients show positive GMFM changes but there isn't significative modifications in gait analysis data. The robotic treatment SARA' has proved its efficacy in general mobility of the patients without specific effect on the walking function. It is then possible to hypothesize that the observed benefice on functional areas depends on the initial motor outline of the patients, while the nature of the specific training induced by robotic devices needs further investigations.

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KINEMATIC AND KINETIC ANALYSIS OF THE EFFECTS OF A HIGH INTENSITY CROSS-TRAINING ON GAIT IN PATIENTS WITH MULTIPLE SCLEROSIS

V. D'Angeli (1,2), A. Cereatti (1,2), A. Peruzzi (1,2), G. Paolini (1,2), A. Manca (3), F. Deriu (3), G. Bua (4), U. Della Croce (1,2)
(1) Information Engineering Unit, POLCOMING Department, University of Sassari, Sassari, Italy
(2) Interuniversity Centre of Bioengineering of the Human Neuromusculoskeletal System, Sassari, Italy
(3) Department of Biomedical Sciences, University of Sassari, Sassari, Italy
(4) O.U. of Neuromotor Rehabilitation – Policlinico Sassarese, Sassari, Italy

Main topics: Analysis of gait and motor disorders, Outcomes after clinical intervention

INTRODUCTION

Muscles weakness is a common symptom in Multiple Sclerosis (MS) and could result in an asymmetric loss of lower limbs strength. Standard resistance trainings (STs) focus on the most affected side and have shown to be effective in increasing strength [1]. However, to be administered, STs require a minimum level of strength and endurance. It has been proved that in orthopaedic and neurologically healthy subjects, training one limb induces strength improvements in the contro-lateral untrained limb (cross-training, CT). The latter consideration may open up a new perspective in the definition of the MS treatment. The aim of this preliminary study is to explore in MS individuals if the CT-induced improvements in gait are larger than those induced by a ST (control group).

METHODS

Eight MS patients (5 f, 3 m; age: 43±13 y.o.), with lower limb strength asymmetry, were randomized into a CT and a ST group. The Expanded Disability Status Scale mean scores were 5.4 and 4.7 for the CT and ST, respectively. For each subject, gait analysis data on both legs were collected during walking over-ground at self-selected speed, before (PRE) and after (POST) intervention. Both ST and CT interventions consisted in a unilateral dorsi-flexor high-intensity resistance training, but while the ST was performed on the most affected side (MA), the CT was performed on the least affected side (LA). Lower limb joint kinematics and kinetics were estimated using a 6-camera Vicon T20 system, synchronized with a Bertec force platform, and the Vicon Plug-in Gait marker set. Electrical activity of the rectus femoris, tibialis anterior and gastrocnemius medialis were recorded bilaterally using surface electromyography (Myon system). Five walking trials per side were acquired. Relevant gait parameters were extracted from the kinematics and kinetic patterns and averaged over groups [2]. MA and LA sides were analyzed separately.

RESULTS

The results found in PRE showed similar gait speed and stride length values for both groups (average value over groups: 0.9 ±0.1 m/s and 1.1 ±0.1 m). In the POST evaluation, no changes in the spatio-temporal parameters were observed for either groups. A large increase of the ankle dorsi/plantarflexion range of motion (Do/Pl RoM) for the LA side in the CT group was observed in POST. The maximum generated power peak at the ankle increased in both groups, however, the most significant improvement was found in the CT group for the MA side. An increased vertical ground reaction force peak (GRFp) at push-off was found in the CT group for the MA side. No changes were observed in the ST group (Table 1).

DISCUSSION

The most important changes in the gait pattern between PRE and POST were found at the ankle. The patients who underwent the CT intervention exhibited an increase of the power generated in the MA side more evident than the ST group. Furthermore, an increase in vertical GRFp was also observed in the MA side after the CT intervention. These preliminary results suggest that the CT was more effective than the ST in improving the MA push-off phase. A major limitation of the study is the limited number of patients analyzed. An experimental campaign to increase the sample size is ongoing.

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Table 1: Ankle Do/Pl RoM, maximum generated ankle power peak and maximum vertical GRFp at push-off, for the CT and the ST groups in PRE and POST.

	Ankle Do/Pl RoM [deg]				Ankle Power peak [W/kg]				GRFp [BW%]			
	CT		ST		CT		ST		CT		ST	
	LA	MA	LA	MA	LA	MA	LA	MA	LA	MA	LA	MA
PRE	22.7±2.6	25.6±6.3	25.3±2.5	24.3±3.0	2.1±0.5	1.2±0.7	1.7±0.7	1.2±0.5	103.1±6.9	93.8±1.8	99.6±2.6	100.1±5.3
POST	36.4±8.3	27.0±2.1	26.2±3.3	27.5±1.8	2.4±1.2	2.4±1.5	2.4±1.2	1.6±0.2	105.5±8.1	98.7±1.8	101.0±2.6	100.7±2.9

CLINICAL AND FUNCTIONAL EVALUATION OF THREE DIFFERENT SURGICAL SOLUTIONS FOR ANKLE ARTHROSIS AT FIVE YEARS FOLLOW UP: ARTRHODESIS, TOTAL ANKLE REPLACEMENT AND OSTEOCHONDRAL ALLOGRAFT TRANSPLANTATION

A. Leardini (1), G. Lullini (1), P. Caravaggi (1), F. Vannini (2), S. Giannini (2), L. Berti (1)
(1) Movement Analysis Laboratory, Istituto Ortopedico Rizzoli, Bologna, Italy
(2) Orthopaedic Clinic I, Istituto Ortopedico Rizzoli, Bologna, Italy

Main topics: Prosthetics, Analysis of Clinical Movement data

INTRODUCTION and AIM

Severe ankle arthrosis is a painful and life-limiting condition which often requires surgical intervention. Due to the traditional complications associated to joint reconstruction, arthrodesis remains the treatment of choice. More recently, the two reconstruction options, namely total ankle replacement (TAR) and bipolar fresh osteochondral allograft (BFOA) transplantation [1], showed to be viable alternatives in selected patients, particularly when arthrodesis is not desirable nor acceptable [2]. The aim of our study was to compare, at 5 years follow-up, clinical and functional results by gait analysis of three groups of patients with grade III ankle arthrosis that underwent one of these three surgical treatments.

PATIENTS/MATERIALS and METHODS

Thirty patients were enrolled in this study: 10 underwent arthrodesis, 10 underwent TAR (BOX Ankle ,) and 10 were treated with BFOA. Clinical evaluation was performed according to the AOFAS score system. Joint kinematics during gait were analysed using a eight-camera stereophotogrammetric system (M2, VICON 612, UK). Two dynamometric platforms were used to measure ground reaction forces and to compute joint moments. A surface EMG system (Zerowire, Aurion) recorded the activation times of the rectus femoris, biceps femoris, tibialis anterior, and gastrocnemius muscles. Joint angles and moments were determined according to the IOR gait gait protocol [3]. Control data were obtained from a group of 20 healthy subjects analyzed with the same protocol. Functional data of the three groups were assessed at 5 years after surgery.

RESULTS

AOFAS score was significantly higher in all groups at 5 years follow up compared to corresponding pre-operatory assessment, with BFOA patients showing the highest values (76.8 ± 12.3). Gait speed was found reduced in all patients ($p \leq 0.05$) compared to controls, but this was less evident after TAR. Stride length decreased in the three patient groups with respect to the healthy subjects ($p \leq 0.05$), whereas cadence and cycle time were not different from those in the control group ($p>0.05$). Ankle joint maximum dorsiflexion and the overall range of flexion were significantly decreased in all groups, whereas maximum plantarflexion was preserved. Joint motion in the coronal plane was significantly smaller after TAR and arthrodesis, but preserved after BFOA. Muscle activation patterns of TAR and BFOA at follow-up were strongly correlated with the corresponding control data.

DISCUSSION and CONCLUSIONS

Clinical outcomes were satisfactory in all groups. AOFAS score improvement was most evident in BFOA, however the latter was significantly the youngest group. Gait analysis revealed that none of these three surgical solutions is able to restore fully normal gait patterns. However, preservation of key parameters of joint function was achieved at medium-term by all three interventions. Ankle arthroplasty via artificial, i.e. TAR, or "biological", i.e. BFOA, reconstructions seems to be viable options in selected severe ankle arthritic patients besides the traditional joint fusion, i.e. arthrodesis.

Table 1: Main ankle kinematic parameters in the sagittal plane for the three surgical solutions and for the Control group. ANOVA was employed to determine statistical differences among the 4 groups

[deg]	Arthrodesis	TAR	BFOA	Control	ANOVA
Max Ankle Dorsiflexion	4.69 ± 7.2	8.09 ± 3.6	5.11 ± 3.1	15.89 ± 4.1	p= 0.001
Max Ankle Plantarflexion	6.02 ± 8.2	4.9 ± 3.4	10.33 ± 5.0	13.36 ± 6.0	p< 0.005
Ankle ROM sagittal plane	11.04 ± 1.8	13.10 ± 4.5	15.83 ± 4.7	29.36 ± 5.0	p< 0.005

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WHAT POST-OPERATIVE SHOE AFTER FOREFOOT SURGERY? BIOMECHANICAL EVALUATION OF TWO DIFFERENT FOREFOOT RELIEF SHOES

G.Lullini[1], A. Giangrande[1], L. Berti[1], P. Caravaggi[1], S. Giannini[2], A. Leardini[1]
(1) Movement Analysis Laboratory, Istituto Ortopedico Rizzoli, Bologna, Italy
(2) Orthopaedic Clinic I, Istituto Ortopedico Rizzoli, Bologna, Italy

Main topics: Orthotics, Analysis of Clinical Movement data

INTRODUCTION and AIM

After forefoot surgery, patients are usually required to wear forefoot relief shoes which are available in a variety of shoe designs providing different amounts of relief [1,2]. Gait ability and stability are also important factors in choosing the correct shoe design, and become critical in the elderly at increased risk of falls. Therefore accurate gait analysis is sought to quantify the overall performance of these shoes. The purpose of this study was to compare two post-operative forefoot relief shoes via state-of-the-art biomechanical measurements. The comparison was performed in terms of spatio-temporal gait parameters, lower limb kinematics and plantar pressure measurements.

PATIENTS/MATERIALS and METHODS

Twenty female patients (58.5 ± 9.2 years, 63.8 ± 14.1 kg), who underwent first metatarsophalangeal joint osteotomy for hallux valgus deformity, were enrolled in the study. Patients evaluation consisted in measuring lower limb kinematics and plantar pressure during walking at pre-op and one month after surgery. Patients were divided in two homogenous groups wearing one of two different post-operative shoe designs (Podartis,): WPS® with a talus outsole, and TD® with a full rigid outsole and the Zero® 8° talus insole. Each relief shoe was also compared to a comfortable shoe, as control, which was worn on the contralateral healthy foot. Pedobarographic data were obtained using the Pedar® system (Novel GmbH,). Gait analysis was performed using a 8-camera motion system (Vicon 612, Vicon Motion Capture, Oxford, UK) and two dynamometric platforms (Kistler Instrument; Einterthur, Switzerland). Joint moments and rotations were calculated according to Leardini et al. [3]. Kinetics and kinematics were compared to those of healthy population wearing the control shoes (28.2 ± 10.0 years, 55.1 ± 3.7 kg). Non-parametric Mann-Whitney test was used for statistical analysis, with significance level set at 0.05.

RESULTS

Stance time was longer in the relief shoes compared to the control. Pedobarographic analysis showed a reduction of peak pressure, pressure-time integral and force at forefoot in both shoes in comparison to the contralateral control shoe (Table 1). The TD showed pattern of sagittal-plane kinematics at the ankle more similar to the control compared to the WPS. The latter appeared to be more dorsiflexed than the other shoes from heel strike to around midstance.

DISCUSSION and CONCLUSIONS

The present forefoot relief shoes demonstrated a reduction of load under the forefoot, thus they both appear to be appropriate for the postsurgical treatment of patients undergoing forefoot surgery. While both shoes achieved significant pressure relief at forefoot, TD appeared to better preserve normal gait kinematics and thus should be recommended for elderly patients.

Table 1: Main pedobarographic parameters at rearfoot, midfoot and forefoot at post-op in the WPS and TD shoes. * denotes statistical difference with respect to the corresponding control value ($p<0.05$).

	Peak pressure [kPa]			Pressure Time Integral [kPa*s]			Force [%BW]		
	rearfoot	midfoot	forefoot	rearfoot	midfoot	forefoot	rearfoot	midfoot	forefoot
WPS post-op	173±34	93±26*	94±36*	79±32	37±8	32±14*	68±12	23±6	26±12*
Control	203±30	67±18	193±27	62±18	31±13	65±20	76±6	18±6	88±11
TD post-op	255±62*	86±32	94±34*	121±32*	39±22	41±19*	69±10	11±5	25±12*
Control	205±27	76±18	253±102	85±24	39±11	118±70	69±12	14±5	79±13

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11:00-12:30 **GAIT / MISCELLANEOUS PATHOLOGIES**
Aula Minor ***Chairs: Richard Baker, Marjolein van der Krogt***

11:00-11:10 PREFRONTAL CORTEX AS A COMPENSATORY FUNCTIONAL SUBSTRATE DURING ATAXIC OVERGROUND GAIT: A CORRELATION STUDY BETWEEN CORTICAL ACTIVITY AND GAIT PARAMETERS
C. Iacovelli, P. Caliandro, M. Serrao, G. Silvestri, C. Simbolotti, S. Mari, G. Reale, L. Padua, C. Casali, P.M. Rossini

11:10-11:20 INFLUENCE OF GAIT REHABILITATION ON MUSCLE SYNERGIES AND THEIR ACTIVATION PROFILES IN PERSONS WITH MULTIPLE SCLEROSIS
J. Jonsdottir, T. Lencioni, E. Gervasoni, A. Crippa, M. Rovaris, J. Ferrarin, A. Montesano, D. Cattaneo

11:20-11:30 DOES EXTERNAL LATERAL STABILIZATION REDUCE THE ENERGY COST OF WALKING IN LOWER LIMB AMPUTEES?
T. IJmker, S. Noten, C. Lamoth, W. Polomski, P. Beek, L. van der Woude, H. Houdijk

11:30-11:40 GAIT PATTERNS IN PAEDIATRIC PATIENTS SUFFERED FROM LEGG-CALVÉ-PERTHES DISEASE
K. Urbášek, J. Poul, J. Jadrný, M. Crhová

11:40-11:50 FOOT AND ANKLE ADAPTATIONS DURING GAIT IN CHILDREN WITH ACL INJURY
M. Ursei, M. Scandella, G. Knorr, F. Accadbled

11:50-12:00 OPTIMAL GAIT RETRAINING STRATEGIES IN PATIENTS WITH KNEE OSTEOARTHRITIS
T.A. Gerbrands, M.F. Pisters, P.J. Theeven, S.M. Verschueren, B. Vanwanseele

12:00-12:10 DOES ROTATIONAL MALALIGNMENT CAUSE KNEE PAIN? COMPARISON OF GAIT BETWEEN SYMPTOMATIC AND ASYMPTOMATIC CHILDREN AND ADOLESCENTS WITH ROTATIONAL PROBLEMS OF THE LEGS
H. Böhm , M. Hösl, L. Döderlein

12:10-12:20 A EUROPEAN CONSENSUS PROTOCOL FOR CLINICAL GAIT ANALYSIS
M. van der Krogt, M. Goudriaan, M. Petrarca, A. Balemans, M. Piening, G. Vasco, E. Castelli, K. Desloovere, J. Harlaar

12:20-12:30 AGE-RELATED CHANGES IN ARM MOVEMENTS DURING TYPICAL WALKING
P. Van de Walle, J. De Rijck, J. Kenis , P. Meyns, K. Desloovere, D. Monari, A. Hallemans

12:30-13:30 Lunch

PREFRONTAL CORTEX AS A COMPENSATORY FUNCTIONAL SUBSTRATE DURING ATAXIC OVERGROUND GAIT: A CORRELATION STUDY BETWEEN CORTICAL ACTIVITY AND GAIT PARAMETERS

C. Iacovelli (3), P. Caliandro (1), M. Serrao (2), G. Silvestri (1), C. Simbolotti (3), S. Mari (3), G. Reale (1), L. Padua (1,3), C. Casali (2), PM. Rossini (1,4)

(1) Department of Geriatrics-Neuroscience-Orthopaedics-Physiatrics,Institute of Neurology, Catholic University, Rome -Italy
(2) Department of Medical and Surgical Sciences and Biotechnologies, University of Rome, Italy
(3) Don Carlo Gnocchi Onlus Foundation, Rome – Italy
(4) IRCSS S. Raffaele Pisana Roma and Casa di Cura S. Raffaele Cassino, Rome – Italy

Main topics: Movement analysis in clinical practice, Central and peripheral resources for the movement

INTRODUCTION and AIM

The role of prefrontal cortex (PFC) during an attention demanding task performed while a healthy subject is walking has been demonstrated in recent studies evaluating the cortical control of gait [1]. Few data are available on the behavior of the PFC in neurological conditions affecting gait. PFC has a role in recovery after infratentorial stroke causing ataxic gait and its activation is correlated with the severity of the clinical picture in patients with chronic neurodegenerative ataxia. However, no information is available on the relationship between PFC activity and biomechanical features of gait. Our study aimed at investigating whether the activation of PFC in ataxic patients is linked to compensatory mechanisms or to gait parameters more specifically related to the functional role of the cerebellum in gait control.

PATIENTS/MATERIALS and METHODS

Nineteen patients with chronic gait ataxia and fifteen age/sex matched healthy subjects participated in the study. The subjects were requested to walk along a straight distance of 6 meters while PFC metabolic profile and the time–distance and kinematic parameters were assessed. PFC metabolism was evaluated by a 2-channel functional near-infrared imaging system (NIRO-200, Hamamatsu Phtotonics KK, Japan), while gait analysis was performed using the SMART-D500 stereophotogrammetric system (BTS, Milan, Italy) and using Davis protocol. In order to investigate the intra-subject variability of gait, we calculated the coefficient of variation (CV) for each discrete parameter and the coefficient of multiple correlation (CMC) for the continuous kinematic features [2].

RESULTS

In the patient group we found increases in [O2Hb]t compared to [O2Hb]b for both channels ($p=0.04$ for both right and left PFC) while no activation was found in the healthy subjects. [O2Hb]c was higher in the patient than in the healthy group ($p=0.03$ for the right PFC and $p=0.04$ for the left PFC). We found a strong positive correlation between the clinical picture as measured by the two scores of the SARA scale and the level of PFC activation as measured by [O2Hb]c in the ataxic patients. A positive correlation was observed between [O2Hb]c of both PFCs and the step width of the ataxic patients (the correlation coefficient was r:0.54 $p=0.02$ for the right PFC, and r:0.50 $p=0.03$ for the left PFC). No correlation was found between the PFC metabolic activity and the other time–distance parameters, or with the mean values of kinematic parameters and the values of CV and CMC.

DISCUSSION and CONCLUSIONS

During over ground gait, SCA patients have a bilateral activation of PFC. This metabolic pattern of PFC is influenced by the clinical severity of ataxia being evident only in patients with severe balance deficits. PFC activation seems to be linked to the compensatory mechanisms (i.e. step width) instead of the primary deficits (i.e. gait variability) of the pathology. In conclusion, the message of our study is that PFC activation during ataxic gait correlates with step width and therefore it seems involved in maintaining compensatory strategies rather than due to primitive cerebellar deficits.

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INFLUENCE OF GAIT REHABILITATION ON MUSCLE SYNERGIES AND THEIR ACTIVATION PROFILES IN PERSONS AFFECTED BY MULTIPLE SCLEROSIS

Jonsdottir J, Lencioni T, Gervasoni E, Crippa A, Rovaris, M. Ferrarin, M, Montesano A, Cattaneo D.
Fondazione Don Gnocchi Onlus IRRCS, Milan, Italy

Main topics: Analysis of gait and movement disorders; Outcomes after clinical intervention

INTRODUCTION and AIM

Muscle synergies are hypothesized to reflect the connections among neuromotor neurons in the spinal cord activated by temporal patterns of central commands and sensorial feedback [1]. Identification of these basic patterns of motoneuron activity may elucidate the nature of neuromotor recovery in persons with multiple sclerosis (PwMS) in response to gait rehabilitation. The number and composition of motor synergies accounting for lower extremity EMG during walking were investigated in PwMS pre and post rehabilitation and compared to those of same age healthy adults.

PATIENTS/MATERIALS and METHODS

Eight ambulating persons with MS were recruited and EMG, kinematic and ground reaction force data were collected pre- and post 20 gait therapy sessions. Normative data was collected on 18 age-and speed-matched healthy subjects (HC). Non-negative matrix factorization (NNMF) was used to identify muscle synergy modules and their activation profile. Pearson's correlation coefficient (ρ) was used to compare the activation profiles between each MS patient and the controls, while for the composition of each muscle synergies module, the scalar product (SP) was used. All data were time normalized to 100% of the gait cycle.

RESULTS

Gait speed normalized to height of the PwMS (mean age 49,3 years) pre gait therapy was 42.26+22,11 and post 50,95+18.06. Seventy two % of HC (mean age 46,9 years) had three muscle synergies, while the remaining 28% had four muscle synergies. Five PwMS had four modules, both pre- and post-therapy, with a significant improvement in the muscle synergy related to early stance C1 (ρ: pre 0.09 ± 0.10 $p<0.001$ with respect to HC, post 0.11 ± 0.34 $p>0.05$ with respect to HC; SP: pre 0.48 ± 0.21 $p<0.05$ with respect to HC, post 0.71 ± 0.06 $p>0.05$ with respect to HC). Two PwMS had four muscle synergies pre- and three post-therapy. One PwMS had five muscle synergies pre- and four post-therapy

DISCUSSION and CONCLUSIONS

Number of muscle synergy modules in PwMS was similar to that of HS. In some PwMS improvement in gait speed after rehabilitation coincided with a reduction in module number. In PwMS with no change in number of modules there were changes in the muscle synergy related to early stance (C1) in response to gait rehabilitation indicating better motor control at ground contact following rehabilitation [2] .

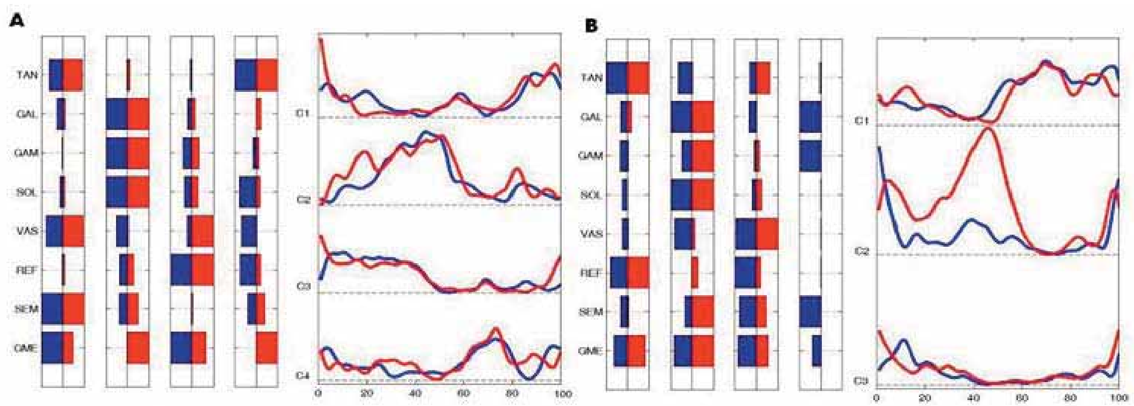

Fig. 1 Muscular synergy modules and activation indexes of 2 subjects with MS pre and post therapy

Pre rehabilitation: left/blue line; Post rehabilitation: right/red line; Subject **A** had 4 modules pre and 4 modules post with no change in normalized gait speed following rehabilitation (pre 42,28, post 42,39)); Subject **B** had 4 modules pre and three post rehabilitation with an increase in gait speed (pre 73,28, post 84,18). The biggest change was in module C2 that relates to push off impulse.

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DOES EXTERNAL LATERAL STABILIZATION REDUCE THE ENERGY COST OF WALKING IN LOWER LIMB AMPUTEES?

T. IJmker (1,2); S. Noten (1); C.J.C. Lamoth (3); W. Polomski (2); P.J. Beek (1,4); L.H.V. van der Woude (3); H. Houdijk (1,2);
(1) MOVE Research Institute Amsterdam, Faculty of Human Movement Sciences, VU University Amsterdam, Amsterdam, the Netherlands
(2) Heliomare Research & Development, Wijk aan Zee, the Netherlands
(3) University of Groningen, University Medical Center Groningen, Center for Human Movement Sciences, Center for Rehabilitation, Groningen, the Netherland
(4) Brunel University, School of Sport and Education, Uxbridge, UK

Main topics: Analysis of gait and motor disorders, Prosthetics, Experimental studies in human movement science.

INTRODUCTION and AIM
The energy cost of normal walking can partly be attributed to the effort required to control balance in the mediolateral direction. Previous studies have shown that providing external lateral stabilization decreases the energy cost of walking in healthy adults by 3-7%[1-2]. As prosthetic gait is characterized by reduced mediolateral balance control and increased energy cost, we hypothesized that external stabilization would lead to larger reductions in energy cost for amputees than for able bodied controls. Thus, the purpose of this study was to investigate the effect of external lateral stabilization on the energy cost of walking.

PATIENTS/MATERIALS and METHODS
15 transtibial (TT) and 12 transfemoral amputees (TF), and 15 able bodied controls (CO) walked on a treadmill with and without external lateral stabilization. Stabilization was provided via spring like chords attached to the waist. The effect of this manipulation on energy cost ($J \cdot kg^{-1} \cdot m^{-1}$), mean and variability of step length and step width, mediolateral pelvic displacement were assessed between groups.

RESULTS
No significant effects of external stabilization on energy cost were found in any of the groups, although on average CO and TT showed a decrease in cost (3% and 4% respectively), while TF showed an increase in cost (6.5%) with stabilization. Step width, step width variability, and mediolateral pelvic displacement decreased significantly with stabilization in all groups.

DISCUSSION and CONCLUSIONS

Figure 2: Boxplot of change in energy cost due to stabilization (positive values reflect an increase, negative values reflect a decrease)
In contrast to our expectations, external stabilization did not result in a significantly larger decrease in the energy cost of walking for amputees than for able-bodied subjects. On the contrary, for transfemoral amputees the energy cost of walking even tended to increase with stabilization. We speculate that restraining the mediolateral motion of the pelvis impedes movement adaptations necessary when walking with a (transfemoral) prosthesis, negating any beneficial effects with respect to balance control. Therefore the energy cost of balance control during walking in amputees remains to be determined.

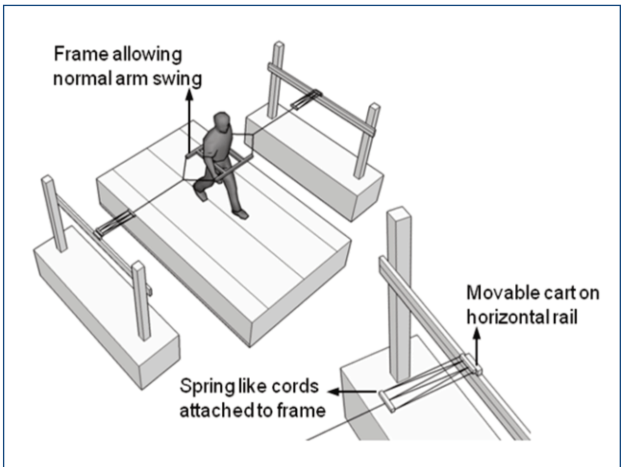

Figure 1: Schematic representation of experimental set-up

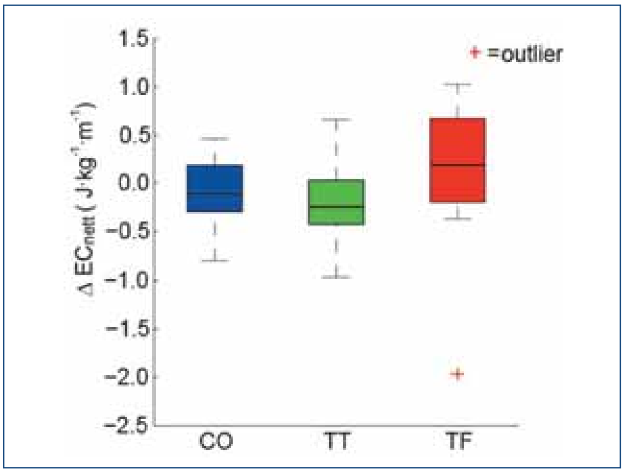

Figure 2: Boxplot of change in energy cost due to stabilization (positive values reflect an increase, negative values reflect a decrease)

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GAIT PATTERNS IN PEDIATRIC PATIENTS SUFFERED FROM LEGG-CALVÉ-PERTHES DISEASE

Karel Urbasek, Jan Poul, Jan Jadrny, Martina Crhova
University hospital Brno, Brno, Czech Republic

Introduction and Aim: The aim of this study was to look at gait parameters in pediatric patients suffered from Legg-Calve-Perthes disease (LCPD) and recognize gait abnormalities in laboratory conditions. 64 children were examined clinically and using computerized gait analysis. This study brings different view on outcome in pediatric patients suffered from LCPD. And show different patterns of hip loading.

Patients and Methods: There were 136 patients treated with LCPD in our clinic since 2002 till 2010. This study included patients who fulfilled following conditions: 1. they were examined in gait lab at least 1 year after completion of treatment. 2. patients with bilateral LCPD were excluded. 3. all patients were treated in University hospital Brno. X-rays of both hips were obtained before motion analysis in order to evaluate hip join morphology according to Stulberg classification. There were 64 patients who fulfill this criteria, 41 boys, 23 girls, 32 right, 32 left lower limbs, age 6,5-19,7 (mean 13,7) In the time of motion analysis. All patients underwent 3D motion analysis (8x Vicon MX T020, 2x AMTI OR6-7-2000, Full body model). Kinematic and kinetic parameters of hip joint and temporal spatial parameters were evaluated. We focused mainly on hip join loading patterns, representing by frontal hip moment. These parameters were compared to normative database and contralateral limb.

Results: It could be recognize 5 different hip loading patterns. 1. normal shape and magnitude of frontal hip moment. 2. decrease magnitude of frontal moment in whole single support phase, 3. increase magnitude of frontal moment in whole single support with overloading of the hip joint, 4. normal pattern in first half of single support with following rapid decrease of moment in second half of single support phase. 5. late onset of increasing hip moment in second half of single support phase with normal magnitude in the end of this phase. Only 20% of patients had normal hip loading pattern. Worse degree in Stulberg classification is not contributed automatically with more severe gait abnormality. Despite of good X-ray result (only 12 patients (18%) had Stulberg IV of V) in most of the patient were recognized different gait abnormalities.

Discussion and Conclusions: Only a few papers dealing with gait abnormality in the context of LCP disease based on 3D motion analysis were published. Only 20% of patients had normal hip join loading pattern. Stulberg classification is not predictor for magnitude of gait deviation. Understanding of hip joint loading could lead us to choose best rehabilitation program to restore normal gait pattern to avoid hip join overloading.

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FOOT AND ANKLE ADAPTATIONS DURING GAIT IN CHILDREN WITH ACL INJURY

Monica E. Ursei (1), Marino Scandella (2), Gorka Knorr(1), Franck Accadbled(1)
(1)- Service d'Orthopédie, Hôpital des Enfants, CHU Toulouse, France
(2)- Laboratoire d'analyse de la marche, Hôpital des Enfants, CHU Toulouse, France

Main topics: Movement analysis in clinical practice, Clinical decision making processes

INTRODUCTION: ACL injuries are common in adult population, resulting in knee instability, pain and increased risk of knee osteoarthritis. Several studies have demonstrated changes in gait pattern of subjects with this pathology. Once thought to be rare in paediatric population, ACL injury has received increased attention recently. ACL tears are becoming more frequent, as children are more involved in contact sports and better diagnostic techniques (such as MRI) are available. Few studies have examined changes in gait pattern of children with ACL injury and gait adaptations related to this pathology. The purpose of our study is to examine foot and ankle gait compensations in children with symptomatic ACL injury.

MATERIALS and METHODS: 42 children (12 girls, 30 boys; mean age 13,4 years [range 10-17]) with unilateral ACL injury were recruited from Children's Hospital, Toulouse, France. All of them presented knee pain, different degrees of swelling and knee instability. Diagnosis was confirmed by MRI scan. All the patients with neurological or congenital musculoskeletal condition or previous knee surgery were excluded. Each patient had undergone gait analysis and data were collected using Vicon 460 motion system. We analysed ankle kinematic parameters and foot progression. Comparisons were made between ACL injury patients and the reference normal gait data of our gait laboratory. For gait data, several parameters were measured: ankle position at initial contact, mid stance (25% of gait cycle GC), pre-swing (60% GC) and mid swing (83%GC). Foot progression was measured in stance and in swing.

RESULTS: All the patients except one had plantar flexion of the ankle at initial contact (between 2 and 15°, mean 4, 4°). For 23 (54%) patients ankle dorsiflexion was diminished in mid stance (mean 3,8°) compared to the reference value. Plantar flexion in pre-swing was increased (mean 19, 3°) in 38 (90%) patients. Ankle dorsiflexion was diminished in mid swing for 39 (92%) patients –mean 1,8° of plantar flexion. All the patients had increased external rotation of the foot both in stance (mean 11,2°) and in swing (mean 16,8°).

DISCUSSION AND CONCLUSION: During a gait cycle, children with ACL injury have modified ankle kinematics: plantar flexion at initial contact, diminished ankle dorsiflexion in stance and increased plantar flexion in pre-swing. All the patients walked with increased external rotation on the foot and decreased ankle dorsiflexion in swing. Modified kinematics seem to be an adaptation to avoid knee instability.

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OPTIMAL GAIT RETRAINING STRATEGIES IN PATIENTS WITH KNEE OSTEOARTHRITIS

T.A. Gerbrands (1,3), M.F. Pisters (1,2), P.J.R. Theeven (1), S.M.P. Verschueren (3), B. Vanwanseele (1,3)
(1) Fontys University of Applied Sciences, Eindhoven, The Netherlands
(2) University Medical Center Utrecht, Utrecht, The Netherlands
(3) KU Leuven, Leuven, Belgium

Main topics: Rehabilitation, Experimental studies in human movement science.

INTRODUCTION and AIM

Progression of knee osteoarthritis (OA) seems related to a high external knee adduction moment (EKAM) during gait[1,2], which can be reduced by gait retraining[3]. In healthy adults, lateral trunk lean and medializing the knee during gait reduce the EKAM effectively, although the optimal strategy seems individually dependent.[3] We aimed to determine which strategy reduces the EKAM most in patients with knee OA, and if the same strategy is most effective for all patients.

PATIENTS/MATERIALS and METHODS

Twenty-eight patients with radiographically diagnosed medial tibio-femoral knee OA underwent 3D gait analysis. Comfortable walking, lateral trunk lean towards the affected leg during the stance phase (Trunk Lean), and medializing the knee at initial contact (Medial Thrust) were investigated. Knee moments and kinematics of the knee and the trunk were calculated. Gait retraining strategies were assessed by comparison of EKAM peak and impulse relative to comfortable walking.

RESULTS

Most patients (age: 60.1±6.1 years, height: 1.71±0.10 m, weight: 77.9±12.7 kg, mean KOOS-score: 46.3, KOOS subscales: pain (55.5), symptoms (52.5), daily activities (60.8), sport/recreation (26.8), knee-related QoL (36)) could finish the protocol without reporting any difficulties. One patient could not perform Medial Thrust due to knee pain. Figure 1 shows the EKAM for all conditions. In both retraining strategies, EKAM was reduced significantly for early stance peak (MT: -0.07±0.01 Nm/Bw·Ht, TL: -0.08±0.01 Nm/Bw·Ht) and impulse (MT: -0.18±0.01 Nms/Bw·Ht, TL: -0.03±0.01 Nms/Bw·Ht). In 15 patients, Trunk Lean reduced overall EKAM peak the most (-0.09±0.04 Nm/Bw·Ht). In 12 patients this was true for Medial Thrust (-0.13±0.07 Nm/Bw·Ht). In the Medial Thrust group, leaning the trunk was significantly less effective than medializing the knee (p=0.005). In the Trunk Lean group, medializing the knee was significantly less effective than leaning the trunk (p=0.001). Changes in trunk angle and knee adduction angle as a result of retraining were similar between the groups (p>0.288).

DISCUSSION and CONCLUSIONS

Medial Thrust and Trunk Lean effectively reduce the early stance EKAM peak and impulse during gait in patients with medial tibio-femoral knee OA. Even if the gait retraining instructions are not executed differently, the effectiveness of gait retraining strategies in reducing peak EKAM depends on the individual. This should be taken into account when applied in clinical practise.

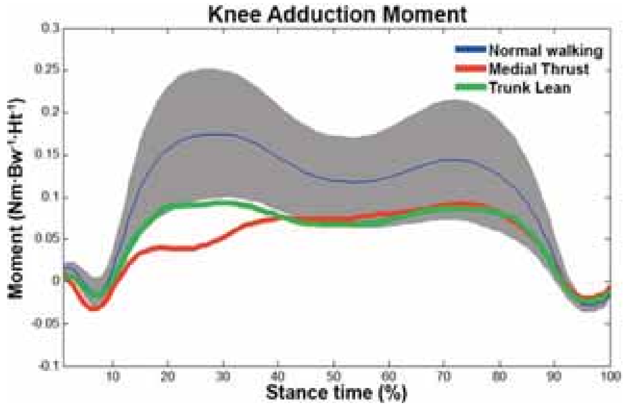

Figure 1: EKAM for all conditions. Grey areas represent 95% CI for Normal Walking.

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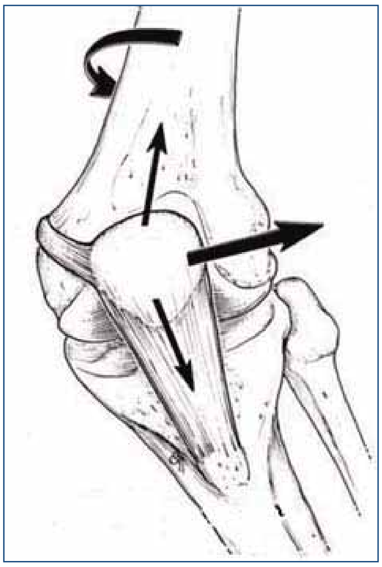
DOES ROTATIONAL MALALIGNMENT CAUSE KNEE PAIN? COMPARISON OF GAIT BETWEEN SYMPTOMATIC AND ASYMPTOMATIC CHILDREN AND ADOLESCENTS WITH ROTATIONAL PROBLEMS OF THE LEGS

H.Böhm(1), M. Hösl(1), L.Döderlein (1),
(1) Orthopaedic Hospital for Children, Aschau im Chiemgau, Germany

INTRODUCTION and AIM

Idiopathic in- or out-toeing gait may be caused by rotational bony deformities of the leg, e.g. by internal and/or external torsion of the tibia and/or femur. First, it may increase shoe wear and raise individual physical discomfort and cosmetic concerns. While during maturation reports about symptoms are sparse, in adulthood, knee- and hip arthritis were reported [1]. Yet, rotational deformities as risk factor of knee pain have widely been ignored. However, increased hip internal rotation during walking might increase the Q-angle that results in abnormal lateral patellofemoral loads [2] demonstrated in the figure. Therefore we hypothesized that among children with rotational deformities, in particular those with greater internal rotation of the hip during walking, anterior knee pain is a typical finding.



PATIENTS/MATERIALS and METHODS

58 patients with rotational malalignment of the femur and/or tibia, older than 8 years were prospectively recruited during outpatient visits in 2012 and 2013. Exclusion criteria were neuromuscular disorders, previous surgeries, cartilage defects, knee varus/valgus, hip- or foot deformities. A rotational profile of tibial torsion and femoral anteversion was determined with MRI scans. All patients were clinically examined and underwent a 3D gait analysis using a standard marker set optimized for transverse plane rotations [3]. Presence and location of pain were assessed. 20 typically developed children served as controls during gait studies. Mean hip and knee transverse plane rotations during the stance phase of gait and the foot progression angle were calculated. Patients with knee pain were opposed to patients without knee pain and controls.

RESULTS

15 of 58 patients reported knee pain after longer walking or running. Their mean age was 13.8 [11 - 17] years, and most of them were female (12/15). 13/15 had anterior, 1/15 medial and 1/15 overall knee pain. Compared to normative literature values, bony imaging profiles revealed that 7/15 had normal anteversion and an increased external tibial torsion, 5/15 had increased femoral anteversion with normal tibial torsion, 2/15 had increased femoral anteversion and increased external tibial torsion (also named miserable malalignment). For group comparison only asymptomatic patients with a similar age range were extracted (19/58). Gait analysis showed that mean hip internal rotation in stance was 13° SD=12° for patients with knee pain, while 5° SD=13° and 4° SD=11° for those without pain and controls. Hence, a significant increase of hip internal rotation could be exclusively noted in patients with knee pain ($p<0.001$). Knee rotation or foot progression did not reveal significant differences between symptomatic and asymptomatic patients.

DISCUSSION and CONCLUSIONS

A considerable amount of 26% of patients with congenital rotational leg deformities reported knee pain. Internal rotation of the hip during walking was increased exclusively in patients with pain therefore the hypothesis was true that hip internal rotational must be recognized as probable cause for patella overloading syndrome.

80 % of patients with knee pain were females at puberty. The reason might be that during puberty the pelvis broadens that increases the Q-angle. An increased Q angle in combination with internal rotation of the hip that further increases the Q-angle [2] risks anterior knee pain. Regarding the static rotational malalignment, a considerable amount (46%) of the patients with knee pain showed normal anteversion in combination with external torsion of the tibia. To compensate their external bony torsion these patients increased the internal rotation of the hip to obtain a natural foot progression angle. Therefore not only the increased anteversion was responsible for increased hip internal rotation. In conclusion the dynamic situation during walking was important for the development of knee pain and should be used as a potential indicator of therapy including derotation osteotomies.

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A EUROPEAN CONSENSUS PROTOCOL FOR CLINICAL GAIT ANALYSIS

M. van der Krogt (1), M. Goudriaan (2), M. Petrarca (3), A. Balemans (1), M. Piening (1), G. Vasco (3), E. Castelli (3), K. Desloovere (2), J. Harlaar (1)

(1) Department of Rehabilitation Medicine, VU University Medical Center, Amsterdam, The Netherlands
(2) KU Leuven, Biomedical Sciences Group, Department of Rehabilitation Sciences, Leuven, Belgium
(3) Movement Analysis and Robotic Laboratory (MARLab), Pediatric Neuro Rehabilitation Division "Bambino Gesù" Children's Hospital, IRCCS, Rome, Italy

Main topics: Analysis of gait and motor disorders; Analysis of clinical movement data.

INTRODUCTION and AIM

The EU-funded FP7 project MD-Paedigree aims to create a large-scale European database for four areas of paediatric diseases, consisting of clinical data and biophysical modelling outcomes. The 'Neurological and Neuromuscular Diseases' area focuses specifically on children with gait problems. For these patients, we aim to build a digital repository centred around gait analysis data, and to develop probabilistic modelling techniques enabling similarity searches and individualized treatment prediction. For this purpose, consistent datasets are required that rely on a harmonisation of methods and quality assurance protocols. The aim of this study was to reach consensus and develop a standardized measurement protocol for gait analysis including anamnesis and physical examination.

PATIENTS/MATERIALS and METHODS

An inventory was performed of 11 world-wide gait labs for investigation on protocols and procedures in use. In order to reach consensus, the clinical partners: VU University Medical Center Amsterdam, University Hospital Leuven and Bambino Gesù in Rome, evaluated the similarities and differences on the protocols used in clinical practice. After several dedicated meetings, consensus was reached regarding anamnesis, physical examination, marker placement, and operational gait analysis protocol for standardization of 3D gait analysis in children with Neurological and Neuromuscular Disease.

RESULTS

The proposed consensus protocol consists of the following standardized examinations: Anamnesis identifies family history, diagnosis based on international classification of diseases, birth problems and milestones, history of treatments perceived, walking aids, and other medical information. Physical examination includes investigation of functional strength, joint range of motion, spasticity, selective motor control, and bone deformities. Measurements of gait biomechanics is done while walking barefoot, with shoes only, and with the subject's current ankle-foot orthoses. Kinematic and kinetic data and EMG of gastrocnemius medialis, soleus, tibialis anterior, rectus femoris, vastus lateralis, semitendinosus, biceps femoris, and gluteus medius is collected. An advanced marker model is used that employs thirty-three anatomical, technical and virtual markers as shown in Figure 1. This marker set combines the Newington (PiG) [1] and CAST [2] models, which have a widespread use in the clinical community, to ensure compatibility. Finally, energy expenditure is measured during rest and comfortable walking.


Figure 1. Marker setup

DISCUSSION and CONCLUSIONS

This consensus protocol allows comparison of clinical gait analysis data for improved individualized clinical decision making in future. In the near future this protocol will be shared to enable standardized data collection throughout Europe.

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AGE-RELATED CHANGES IN ARM MOVEMENTS DURING TYPICAL WALKING

P. Van de Walle (1,2,3), J. Kenis (2), J. De Rijck (2), P. Meyns (2), K. Desloovere (2,3), D.Monari (3), A. Hallemans (1)
(1) Faculty of Medicine and Health Care, University of Antwerp, Belgium- (2) Faculty of Kinesiology and Rehabilitation Sciences, KU Leuven, Belgium - (3) Clinical Motion Analysis Laboratory, University Hospital Pellenberg, Belgium

INTRODUCTION and AIM

When toddlers learn to walk, they present with a typical high guard position of the arms (shoulder abduction and exorotation, elbow flexion). As gait matures, children soon develop a reciprocal arm-swing, which has been described as an important feature of typical gait, serving both to increase postural control and gait efficiency (1). Until now, there is only limited information about age-related changes in arm movements during walking (2,3,4). Furthermore, the information available at his point comes from age-related control groups and thus lacks a direct comparison between different age groups. The goal of this study was therefore to investigate age-related changes in arm movements during typical walking in a large cohort of children and adults from 3-35 years.

PATIENTS/MATERIALS and METHODS

102 children and adults (3-35 years) underwent full body 3D gait analysis at self-selected speed (Vicon, PlugInGait Marker Set). Kinematics of the shoulder in three planes, of elbow in the sagittal plane and of wrist in sagittal and coronal plane were analysed for 3 left and 3 right trials per participant. Participants were divided into five age groups: young children (G1: n=20; 3-6y) children (G2: n=24; 7-9y); pubertal children (G3: n=26; 10-13y); adolescents (G4: n=16; 14-18y) and adults (G5: n=16; 19-35y). Age-related changes in arm movement between groups was investigated by plotting mean and standard deviation per joint and per plane for all groups as well as by comparison of the mean position and the position at initial contact (IC) of the different joints, by GLM (group=fixed factor) and pairwise post hoc comparisons (Tukey HSD) with significance level at $p<0.05$.

RESULTS

Although overall movement patterns were similar (all joints, all planes), differences in magnitude and larger variability was seen in the youngest children compared to the older children and adults (i.e shoulder sagittal, figure 1). At the shoulder, G1 showed significantly more extension at IC compared G2-G5. Mean position was significantly more in extension for G1&G2 (-9.5°- -4.2°) compared to G3-G5 (0.0°–2.7°). No age-related differences were found for abduction. RoM of shoulder rotation was larger in adults (32.4±22.1°; $p<0.001$) compared to all other groups (21.2-26.5°; SD: 11.3-16.1°), but mean position did not differ between groups. Elbow flexion at IC was highest in G1 (38.7±11.5°), tended to decrease (not significant) between G2, G3 and G4 (31.98-33.6°; SD: 7.9-8.6°) and then further decreased to 27.4±5.8° in adults ($p<0.001$). At the wrist significantly more extension was found, both at IC and mean position, for G1-G2 compared to the other groups.

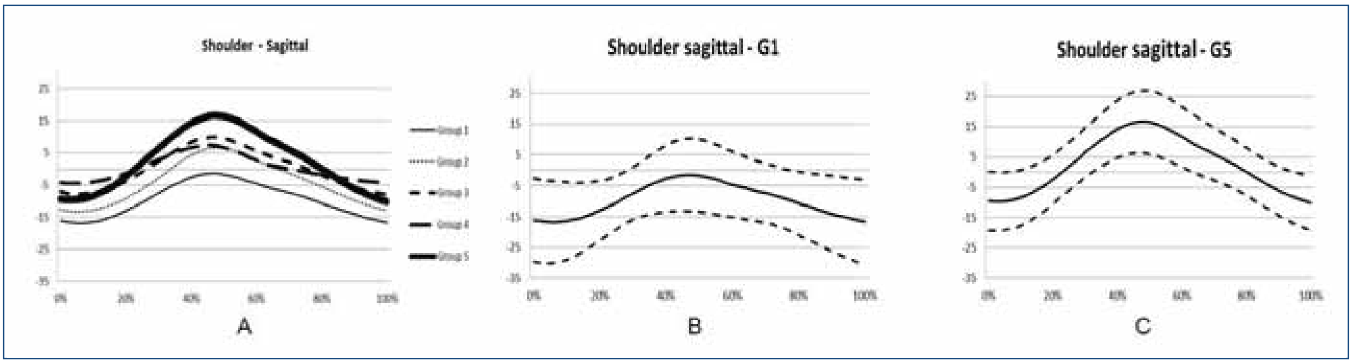

Figure 1: Changes in shoulder flexion (+) – extension (-) between the 5 age groups (A) and for G1 (B) and adults (C)

DISCUSSION and CONCLUSIONS

At the age of 3-6 years the overall movement patterns of typical mature arm swing were already recognizable for all joints in all planes. Although movement patterns were similar over age groups, age-related changes in both magnitude and variation were observed. The clearest age-related changes presented as increased shoulder extension and large elbow flexion at IC in the younger children that evolved to adult values over the other age groups. But also at the wrist joint changes were observed in extension at IC that decreased with age. These changes, along with the higher variation in the younger age groups, are most likely part of a learning process. It suggests that the onset of typical arm swing is followed by a fine tuning process, probably related to neuromotor control, before typical adult values are reached. In conclusion, the clear changes in arm swing that were observed from young children to adults, stress the need for the use of age-related reference data in clinical practice.

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13:30-14:10

PREDICTION OF UPPER ARM MOTION BASED ON COMPUTATIONAL MODEL

Yasuharu Koike
Tokyo Institute of Technology, Tokyo, Japan

e-mail: koike@pi.titech.ac.jp

ABSTRACT. The human neuromuscular system naturally modulates mechanical stiffness and viscosity to achieve proper interaction with the environment. We have been developing the computational musculo-skeletal model of upper arm to produce motion. Recently this model also produce force using same structure. Also we succeed to estimate the angle, torque, and stiffness of arm joints from muscle activity. In this talk, I introduce how to estimate upper arm motion from EMG or brain activities, and control robot which has musculo-skeltal properties using computational model.

14:10-15:00
Aula Major

FUNCTIONAL ASSESSMENT
Chairs: Jaap Harlaar, Andrew Roberts

14:10-14:20

EFFECTS OF SURGERY AND EARLY REHABILITATION TREATMENT ON EQUINO-VARUS FOOT DEFORMITY (EVFD). GAIT CHANGES AT ONE AND THREE MONTHS AFTER TREATMENT ASSESSED BY A TRI-AXIAL ACCELEROMETER
D. Mazzoli, E. Giannotti, A. Merlo, P. Zerbinati, M. Longhi, S. Masiero, P. Prati

14:20-14:30

GENDER EFFECT ON ADAPTATION STRATEGIES OF LEG AND JOINT STIFFNESS ACROSS DIFFERENT HOPPING CONDITIONS
I. Demirbüken, S. Angın, S.U. Yurdalan, P. Williams, K. Meijer

14:30-14:40

WALKING STRATEGIES IN SUBJECTS WITH CONGENITAL OR EARLY ONSET STRABISMUS
I. Aprile, M. Ferrarin, L. Padua, E. Di Sipio, C. Simbolotti, S. Petroni, C. Tredici, A. Dickmann

14:40-14:50

DYNAMIC KNEE STABILITY ESTIMATED FROM THE KNEE AXIS POSITION DURING HOPS TWENTY YEARS AFTER INJURY OF THE ANTERIOR CRUCIATE LIGAMENT
H. Grip, E. Tengman, C. Häger

14:50-15:00

PATHOLOGICAL FOOT KINEMATICS IN SUBJECTS WITH STAGE II TIBIALIS POSTERIOR DYSFUNCTION USING A MULTISEGMENTED FOOT MODEL
B. Callewaert, K. Deschamps, K. Desloovere, D. Monari, F. Staes, G. Matricali

EFFECTS OF SURGERY AND EARLY REHABILITATION TREATMENT ON EQUINO-VARUS FOOT DEFORMITY (EVFD). GAIT CHANGES AT ONE AND THREE MONTHS AFTER TREATMENT ASSESSED BY A TRI-AXIAL ACCELEROMETER.

D. Mazzoli (1), E. Giannotti (1,3), A. Merlo(1,4), P. Zerbinati (1,2), M. Longhi (1), P. Prati (1), S. Masiero (3)

(1) Gait & Motion Analysis Laboratory, Sol et Salus Hospital, Rimini, Italy
(2) Neuro-orthopaedic Service, MultiMedica Hospital, Castellanza (VA), Italy
(3) Department of Orthopaedic Rehabilitation, University of Padova, Padova, Italy
(4) LAM – Motion Analysis Laboratory – AUSL of Reggio Emilia, Italy

Main topics: Movement analysis in clinical practice, Functional outcome measures in mobility, Analysis of clinical movement data

INTRODUCTION and AIM
EVFD, the most characteristic deformity after stroke, compromises several prerequisites of walking with an important reduction of smoothness and symmetry during gait. In this work, we used an accelerometer to monitor the recovery of walking ability in stroke patients with EVFD surgically treated.

PATIENTS/MATERIALS and METHODS
Gait of a consecutive sample of 12 hemiplegic patients (52±11 yy, 6 Right, 4±2 yy from stroke, FAC 2-5, WHS 3-6, 6mWT 37-390 m) was assessed by a tri-axial accelerometer (GWalk, BTS, Milan) before, at 1 and 3 months after surgical correction of EVFD. Interventions were performed by a single surgeon and followed by a standardized rehabilitation protocol beginning at day 1 after surgery. Robust algorithms were developed to automatically identify gait events from the acceleration profiles of slow and very slow walking stroke patients. Step time, cadence, symmetry [1] and smoothness [2] indices were computed based on the fore-aft acceleration component.

RESULTS
Cadence improved at 1 month after surgery (from 61+/-24 step/min to 72+/-23, Wilcoxon test, $p<0.05$) and was maintained at 3 months. Smoothness (number of peaks per step) showed a progressive increase in time with statistical significative variation at 3 months after treatment ($p<0.05$, Figure 1). Symmetry index presented a different trend in our sample. At 1 month after surgery 9 patients had a variations towards normality and at 3 months 6 of these presented further improvement while 3 patients returned to asymmetric gait. In the rest of sample, 3 hemiplegic patients, we observed a worsening at 1 month with a partial recovery at 3 months after treatment (Figure 2). These 3 subjects presented at the evaluation before surgery the worst walking ability (unable to walk with either unassisted or without orthotic devices).

DISCUSSION and CONCLUSIONS
Surgery associated with early rehabilitation was effective in improving cadence and gait smoothness in patients with EVF at 3 months after treatment. All patients improved their walking smoothness, which is correlated with the energy expenditure. Conversely, the recovery in symmetry was variable in the sample and was influenced by the pre-operatory functional level. Accelerometer-based gait analysis may provide indicators of overall walking ability to monitor gait recovery in stroke patients.

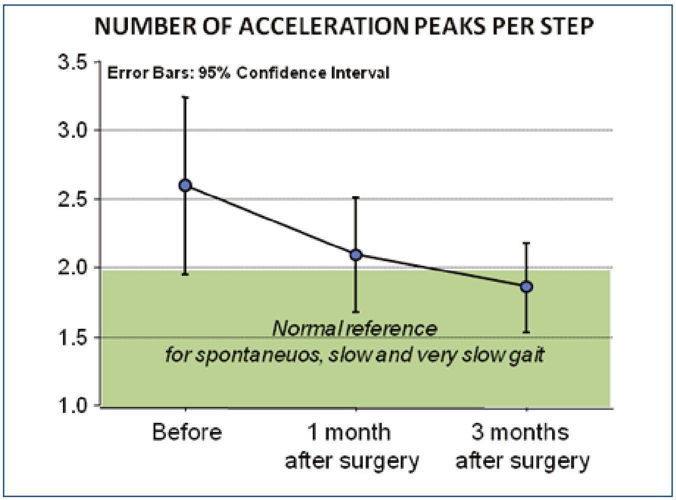

Figure 1. Time evolution of a smoothness index

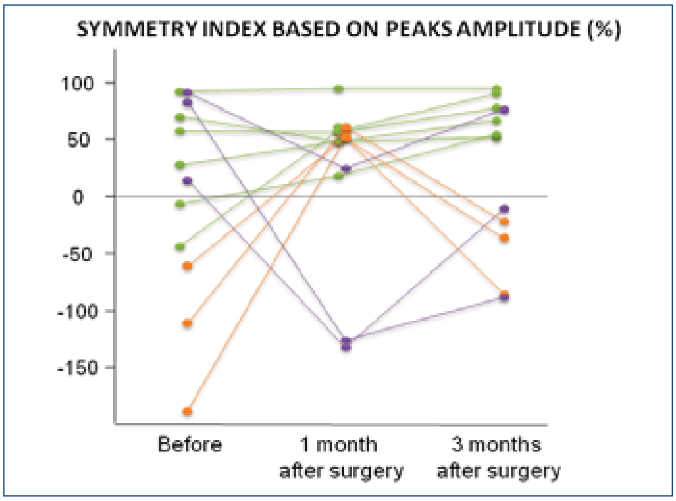

Figure 2. Time evolution of one of the symmetry indices in the sample. This index becomes negative in the case of large asymmetry (e.g.: PeakL/PeakR >3

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GENDER EFFECT ON ADAPTATION STRATEGIES OF LEG AND JOINT STIFFNESS ACROSS DIFFERENT HOPPING CONDITIONS

İlkşan Demirbüken (1), Salih Angın (2), Saadet Ufuk Yurdalan (1), Paul Williams (3), Kenneth Meijer (3)
(1)Marmara University, Faculty of Health Sciences, Dept. of Physiotherapy and Rehabilitation, İstanbul, Turkey
(2)Dokuz Eylul University, School of Physical Therapy and Rehabilitation, İzmir, Turkey
(3)Maastricht University, Dept. of Human Movement Science, Maastricht, The Netherlands

Main topics: Experimental studies in human movement science, Analysis of clinical movement data.

INTRODUCTION and AIM

Leg stiffness (K_{leg}), considered to be a regulated property of musculoskeletal system, and recently has received a great deal of attention in movement science researches. It is believed to considerably affect performance, functional ability and risk of injury in musculoskeletal structures of lower extremity [1]. Studies have shown that females are in a higher risk of sport injuries of lower extremity than their male counterparts. For instance females have higher rates of ACL injury in compared to males [2]. The difference in the rate of ACL injury between males and females is considered to be partly related with the differences in K_{leg} and its adaptation strategies to different conditions of functional tasks via determinants of K_{leg} (such as joint stiffness-K_{joint}) of males and females [3]. The purpose of the present study was to elucidate how females reacted different than males to adapt their K_{leg} and K_{joint} to higher demanding tasks as faster hopping conditions.

PATIENTS/MATERIALS and METHODS

Eleven healthy men and ten healthy women aged 18 to 35 years volunteered to participate in this study. Participants performed two-legged hopping on their bare feet. They were instructed to land with their right leg on the force platform (Kistler, 9082E, 100 Hz sampled). Three different hopping tasks were executed. Firstly they were asked to hop at their preferred frequency (the comfortable frequency), secondly they were asked to hop as fast as possible (fastest hopping frequency) and lastly, they hopped at a pace set by a metronome beat set at 3.0 Hz. Three trials were performed for each condition. 3D kinematics and kinetics were assessed by using the VICON motion capture system (VICON MX3, 100 Hz sampling rate) in combination with a force platform. Data was analyzed by custom-made software developed with MATLAB (Mathworks, version 7.1). K_{leg} was calculated as the ratio of vertical leg spring compression and peak vertical ground reaction force. The average K_{joint} of the ankle and knee determined from the ratio of the change in net moment to the joint angular displacement in the sagittal plane between the beginning of the ground-contact phase and the instant when the joints were maximally flexed. K_{leg} and K_{joint} of ankle and knee were normalized by dividing the participant's body mass to avoid body mass influence on K_{leg} values of males and females.

RESULTS

Subjects exhibited significant gender differences in weight (male: 73.2±7.1, female: 60.7±7.1), height (male: 182.4±6.7, female: 168.5±6.7), but demonstrated no significant differences in age (male: 23.7±2.6, female: 23.0±2.9). There were no significant differences in K_{leg} between males and females across three hopping rates ($p>0.05$). There was no statistical significance between K_{joint} of ankle of males and females at all hopping conditions ($p>0.05$).There was a significant differences in K_{joint} of knee values between the two groups at hopping with 3.0 Hz ($p<0.05$). K_{joint} of knee and ankle of both males and females were increased by increasing hopping frequency.

DISCUSSION and CONCLUSIONS

Our results have shown that females and males use different adaptation strategy to modulate their K_{leg} across different frequencies of hopping. Overall K_{leg} is adapting itself to different hopping frequencies in the same manner of K_{joint} of ankle. A primary difference between males and females was found to be in the adaptation of K_{joint} of knee to faster hopping frequencies especially at hopping with 3.0 Hz. Further understanding of determinants of K_{leg} in demanding conditions could help to design exercise prescriptions to protect the individuals from getting injured during sportive activities, especially for females.

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WALKING STRATEGIES IN SUBJECTS WITH CONGENITAL OR EARLY ONSET STRABISMUS

I. Aprile (1), M. Ferrarin (2), L. Padua (1,3), E. Di Sipio (1), C. Simbolotti (1), S. Petroni (4) , C. Tredici (5) and A. Dickmann (5)
(1) Don Carlo Gnocchi Foundation, SM Provvidenza Movement Laboratory, Rome, Italy
(2) Don Carlo Gnocchi Foundation IRCCS, Biomedical Technology Department, Milan, Italy
(3) Neuroscience Department of Catholic University, Rome, Italy
(4) Ophthalmology Department, Bambino Gesù Children's Hospital, Rome, Italy
(5) Institute of Ophthalmology, Catholic University, Rome, Italy

Main topics: Analysis of clinical movement data, Analysis of gait and motor disorders

INTRODUCTION and AIM

In the congenital strabismus, sensory adaptations will occur hampering the correct development of normal binocular vision. Stabismus can be classified according to the direction of deviation: (i) exodeviation, when the direction of the deviated eye is towards the temple; (ii) esodeviation, if the direction of deviation is towards the nose. A study investigated the effects of alterations in the optic flow field on spatio-temporal gait parameters and on joint kinematics [1]; other studies have evaluated gait in patients with visual deprivation [2, 3, 4]. In one study a significant influence of reversible visual deprivation on gait parameters has been observed in healthy subjects [5]. No studies on gait strategies adopted by patients in which the abnormal sensorial and motor cooperation (as in congenital/early onset strabismus) is irreversible and congenital, have been reported. The aim of this study is to investigate if patients with exotropic or esotropic, congenital or early onset, strabismus adopt different walking strategies with respect to healthy subjects. Our hypothesis is that the abnormal binocular cooperation, occurring in patients with exotropic or esotropic strabismus, could influence neurosensorial adaptation of the gait pattern.

PATIENTS/MATERIALS and METHODS

Twenty-five patients with strabismus were enrolled:19 with esotropic strabismus (ESO) and 6 with exotropic strabismus (EXO) and 27 of age-matched healthy subjects (HS). Both patients and healthy subjects have been subjected to a complete ophthalmological and orthoptic evaluation. Subjects with strabismus were divided, according to the direction of deviation, into two groups: patients with esotropic and patients with exotropic strabismus. Biomechanical data were collected using a stereophotogrammetric system and a force platform. Patients were equipped with 22 retro-reflective markers, according to Davis protocol [6]. Spatio-temporal, kinematic and kinetic parameters were considered. The statistical analysis was performed using the STATSOFT (Tulsa, OK, USA) package.

RESULTS

The comparison between patients with ESO and patients with EXO showed a lower maximal power at the knee and at the ankle in EXO group ($p<0.01$ and $p<0.05$, respectively). The step width was statistically different between ESO and EXO groups ($p<0.01$), it was lower in patients with ESO and higher in patients with EXO when they were compared with healthy subjects (not statistically significant). Furthermore, the deviation angle values showed a statistically significant relationship with the step width (at the near fixation $p<0.05$) and with the maximal power at the knee and at the ankle (at far fixation at the knee $p<0.001$ and at the ankle $p<0.05$; at near fixation at the knee $p<0.05$): in the patients with EXO the increased angle deviation is related to larger step width and to lower power at the knee and at the ankle. In the patients with ESO this relationship is less robust.

DISCUSSION and CONCLUSIONS

In conclusion it seems that patients with EXO and ESO adopt different strategies to compensate their difficulties in walking, and these different strategies are probably due to differences in an expanded visual field in patients with EXO and in a reduced visual field in patients with ESO.

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DYNAMIC KNEE STABILITY ESTIMATED FROM THE KNEE AXIS POSITION DURING HOPS TWENTY YEARS AFTER INJURY OF THE ANTERIOR CRUCIATE LIGAMENT

H. Grip (1), E.Tengman (1), C.Häger (1)
(1) Umeå University, Dept of Community Medicine and Rehabilitation; Physiotherapy, Umeå, Sweden

Main topics: Functional outcome measures in mobility, Analysis of clinical movement data

INTRODUCTION and AIM

A rupture of the Anterior Cruciate Ligament (ACL) is an injury that is common among athletes performing contact sports, and leads to decreased knee stability. Knee laxity is often measured in the clinics after a rupture, but is not necessarily related to functional outcome [1]. The knee axis position during knee demanding tasks (here defined by the position of the knee finite helical axis, FHA) may be a valid estimate of dynamic knee stability [2]. The aim was to test whether subjects, many years after a conservatively treated ACL injury, display a different knee axis position during highly demanding hops (side hops and drop jump).

PATIENTS and METHODS

This is a cross-sectional study of 33 persons with unilateral ACL-injury treated conservatively with physiotherapy. For comparison, a knee-healthy group of 33 age and gender matched controls was tested. Anterior tibial translation during external load was measured with a KT-1000 arthrometer (30lb). Self-rated knee function was assessed with the Lysholm score. Eight three-dimensional optical cameras (Oqus®, Qualisys Gothenburg, Sweden, 240 Hz) was used for motion registration. The anterior-posterior (A-P) position of the FHA of the shank relative to thigh was calculated for finite flexion steps of 20° (Matlab, Mathworks Inc). The Sidehop consisted of as many side hops as possible during 30 s on one leg, across two parallel lines on the floor, 40 cm apart, while both arms were held crossed over the chest. Hops in medial direction were analysed, as these were assumed to stress the dynamic stability of the knee the most. The Drop Jump was performed once for each participant, and consisted of a two-limb jump down from a height of 40 cm, immediately followed by a vertical jump. The phase between the first Landing and second Takeoff was analyzed. ANOVA was computed to test group differences. Within the ACL group, paired t-tests were used to test between-leg differences, and Spearman's correlation coefficient was used to test correlations to KT-1000 and Lysholm score.

RESULTS

The A-P FHA position was significantly more posterior during Sidehop in the ACL group compared to controls (non-dominant compared to injured, both phases $p<0.001$, and dominant compared to non-injured during Landing, $p<0.001$), Table 1. Also, the injured leg displayed a more posterior FHA position compared to the non-injured (TakeOff $p=0.029$, Landing $p=0.026$). Further, we found significant, negative correlations of the FHA position with Lysholm score (TakeOff phase, R= -0.47 injured leg, R= -0.36 non-injured leg). Preliminary results indicate a similar picture for the Drop Jump. A detailed analysis of this hop is currently under process.

Table 1: The A-P FHA position (group mean ± SD) during the Side Hop in the two groups.

FHA position (mm)	**ACL**		**CTRL**	
Condition	Injured leg	*Non-injured leg*	Non-Dominant leg	*Dominant leg*
Side Hop, Takeoff phase	15.1±14.6	8.7±1.2	4.2 (10.5)	5.0±8.4
Side Hop, Landing phase	37.9±22.2	29.8.40±14.8	18.1 (13.0)	14.8±10.5

DISCUSSION and CONCLUSIONS

A more posterior FHA position in the ACL participant's knees may be related to a larger forward translation of the shank during the hop. This could imply an impaired motor control of the knee. Indeed, a more posterior FHA position correlated to a lower self rated knee function. No correlation to knee laxity was found, indicating that this is not the most important factor for a well-functioning knee [1]. Large within-group variation may suggest that the variable is sensitive to skin tissue artefacts, something that is minimized by using finite intervals ≥ 20° when calculating FHA variables [2] and by using between-leg comparisons (as such effects should be equally large on both legs). A detailed kinematic analysis of the dynamic knee stability provides important information about function and should be part of a more comprehensive assessment after ACL injury.

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PATHOLOGICAL FOOT KINEMATICS IN SUBJECTS WITH STAGE II TIBIALIS POSTERIOR DYSFUNCTION USING A MULTISEGMENTED FOOT MODEL

B. Callewaert (1), K. Deschamps (1,2), K. Desloovere (1,2), D. Monari (4), F. Staes (2), G. Matricali (3)
(1) CMAL- University Hospital, Leuven, Belgium
(2) KU Leuven, Department of Rehabilitation Sciences, Belgium
(3) KU Leuven, Department of Development & Regeneration, Belgium
(4) KU Leuven, Department of Mechanical Engineering, Belgium

Main topics: analysis of clinical movement data, analysis of gait and motor disorders

INTRODUCTION and AIM

Little is reported regarding the dynamic interrelationship of segmental motion [1,2] and the establishment of the windlass mechanism during gait in subjects with stage II Posterior Tibialis Tendon Dysfunction (PTTD). The purpose of this study was to compare 3D foot kinematics of subjects with stage II PTTD with healthy controls during full gait cycle, using both a rigid one segment foot model and the Rizzoli 5-segment 3D foot model (R3DFM) [3].

PATIENTS/MATERIALS and METHODS

Twelve subjects with stage II PTTD (age: 54.7±8.6 years, BMI 29.5±3.7) and 12 healthy age and sex matched controls (age: 51.5±8.8 years, BMI 24.6±3.9) participated in this study. Marker placement was applied following the conventional Plug-in gait model (VICON, Oxford, UK) as well as the R3DFM [3]. Three-dimensional rotations between shank and calcaneus (Sha-Cal), calcaneus and midfoot (Cal-Mid), midfoot and metatarsus (Mid-Met) as well as calcaneus and metatarsus (Cal-Met) were calculated. The planar angle of the first metatarso-phalangeal joint, referred to as F2Ps, was also considered. With respect to the conventional gait model, the ankle kinematics (rigid foot) as well as the foot progression angle were considered. All data were obtained during barefoot walking at self-selected speed, using a 10-camera motion capture system (Vicon, Oxford). For each subject, three trials were averaged and normalized to 100% gait cycle (GC). In order to track, in an objective way, significant differences between the kinematic profiles, one-dimensional statistical parametric mapping (SPMt) [4] was used.

RESULTS

Concerning the R3DFM, SPMt results indicated significant differences in several intersegmental angles in the 3 anatomical planes. In the sagittal plane, for Sha-Cal, the PTTD group exhibited an increased dorsiflexion between 0-7% GC and 48-73% GC (p=0.000). In Cal-Met we found increased dorsiflexion between 29-90% GC (p=0.000). In Mid-Met we found a decreased plantarflexion over the whole GC (p=0.000). F2Ps showed a decreased extension between 0-61%GC (p=0.000) and 84-100%GC (p=0.002).

In the frontal plane, we found decreased inversion within Cal- Mid angle (p=0.000), increased inversion of Cal-Met (p<0.000) as well as decreased inversion in Mid-Met (p=0.000) over almost full GC.
In the transversal plane, the PTTD group showed adduction in Cal-Mid (p=0.000) and decreased abduction in Cal-Met (p=0.000) over the whole GC. In Mid-Met we found slight abduction (p=0.000) between 0-48% and 59-100% GC.
Concerning the rigid foot model, in the sagittal plane we found increased dorsiflexion between 0-2%GC (p=0.015) and between 47-90%GC (p=0.000). In the frontal plane there was a decreased inversion between 0-3% GC (p=0.020), 45-50%GC (p=0.020) and 79-87%GC (p=0.015). In the transversal plane we recognized decreased external rotation over the whole GC (p=0.000).
Furthermore, we also observed a significant lower walking speed (p=0.000) in the PTTD group (0.9±0.15 m/s) compared to the control group (1.2±0.2 m/s).

DISCUSSION and CONCLUSIONS

This study demonstrates the benefits using a multisegmented foot model in the investigation of kinematic changes in subjects with stage II PTTD. As reported already by Tome et al. [1], dysfunction of the tibialis posterior muscle has not only implications at the rearfoot, but also at the midfoot and forefoot. Accordingly, this improves the insight in the function of the windlass mechanism. As proved by the current study, it is meaningful to consider the kinematics of both foot and shank, during both stance and swing phase. All these findings highlight the role of comprehensive 3D foot analysis to support decision making for conservative as well as surgical interventions.

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15:00-16:30 **UPPER LIMB ANALYSIS**
Aula Major ***Chairs: Andrea Cereatti, Stefano Rossi***

15:00-15:10 EFFECT OF SCAPULA LOCATOR DOUBLE CALIBRATION ON MEASUREMENT OF SCAPULAR KINEMATICS WITH INERTIAL AND MAGNETIC SENSORS IN SCAPULAR DYSKINESIS
J. van den Noort, S. Wiertsema, K. Hekman, C. Schönhuth, J. Dekker, J. Harlaar

15:10-15:20 SHRINERS HOSPITAL FOR CHILDREN UPPER EXTREMITY EVALUATION (SHUEE): A RELIABILTY STUDY
C. Heaver, S. Jarvis, J. Kuiper, B. Johnson, R. Freeman

15:20-15:30 UNI- AND BIMANUAL GOAL-DIRECTED ARM MOVEMENT ORGANIZATION IN CHILDREN AT 6-9 YEARS: EFFECTS OF A PRETERM BIRTH
C. Dahlström, M. Nygård, E. Domellöf, A. Johansson, L. Rönnqvist

15:30-15:40 GLOBAL ARM PROFILE SCORE ASSESSMENT IN CHILDREN WITH OBSTETRIC BRACHIAL PLEXUS INJURY
P. Salvia, C. Questienne, V. Sholukha, J. Sterckx, C. Mahieu, B. Bonnechère, B. Beyer, J. Bahm, F. Schuind, V. Feipel, S. Van Sint Jan, M. Rooze

15:40-15:50 EFFECTS OF THE UPPER LIMB ROBOT-ASSISTED THERAPY ON A DAILY TASK IN STROKE PATIENTS: PRELIMINARY RESULTS USING MOTION ANALYSIS
I. Aprile, E. Di Sipio, C. Simbolotti, M. Germanotta, L. Cortellini, M. Rabuffetti, L. Padua, M. Ferrarin

15:50-16:00 QUANTITATIVE EVALUATION OF THE UPPER LIMB KINEMATICS IN POST-STROKE PATIENTS UNDERGOING REHABILITATION: INTEGRATED VS. TRADITIONAL REHABILITATION TREATMENT
L. Pianta, E. Tacchini, M. Bigoni, V. Cimolin, M. Galli, C. Nicola, S. Baudo, P. Capodaglio, A. Mauro

16:00-16:10 INTRODUCING A STANDARDIZED NINE HOLE PEG TEST IN PERSONS WITH STROKE – KINEMATIC ANALYSIS
G.M. Johansson, H. Grip, C.K. Häger

16:10-16:20 CAN CAPSULAR STRETCHING CHANGE THE SCAPULO-HUMERAL COORDINATION IN BASEBALL PITCHERS?
I. Parel, A. Pellegrini, P. Tonino, P. Paladini, F. Campi, G. Porcellini, A.G. Cutti

16:20-16:30 BIOMECHANICS OF THE UPPER LIMBS: 3D ANGULAR VELOCITY, SEGMENT INTERACTION AND MOVEMENT UNITS IN ASYMPTOMATIC ADULTS
A. Assi, A. Massaad, Z. Bakouny, M. Karam, W. Skalli, I. Ghanem

EFFECT OF SCAPULA LOCATOR DOUBLE CALIBRATION ON MEASUREMENT OF SCAPULAR KINEMATICS WITH INERTIAL AND MAGNETIC SENSORS IN SCAPULAR DYSKINESIS

J.C. van den Noort (1,2), S.H. Wiertsema (1), K.M.C. Hekman (1), C.P. Schönhuth (3), J. Dekker (1), J. Harlaar (1,2)
(1) VU University Medical Center, Dept. of Rehabilitation Medicine, Amsterdam, the Netherlands (2) MOVE Research Institute Amsterdam, the Netherlands (3) VU University Medical Center, Dept. of Orthopaedics, Amsterdam, the Netherlands

Main topics: analysis of clinical movement data, rehabilitation

INTRODUCTION and AIM

3D scapular kinematics in patients with scapular dyskinesis [1] can be conveniently measured using an inertial and magnetic measurement system (IMMS). Anatomical calibration of the sensor with respect to the scapular bone can based on alignment of the IMMS sensor with the spina scapulae (ISEO protocol [2]). However, skin movement artefacts and a fixation offset might cause inaccuracies. To improve the anatomical calibration, a scapula locator (tripod) with adjustable bars can be used [3]. Moreover, a double calibration at two elevation angles might improve accuracy of the kinematics even further, by correcting for underestimation of motion at higher elevation angles [3]. The aim of this study is to evaluate the effect of double anatomical calibration (at 0 and 120deg anteflexion) with the locator on 3D scapular kinematics.

PATIENTS/MATERIALS and METHODS

3D scapular kinematics were measured during a humeral anteflexion movement in ten patients with scapular dyskinesis. IMMS sensors were placed on the thorax, spina scapulae and upper arm (ISEO protocol [2]). Additionally, the scapula locator (with IMMS) was positioned on the scapula, while holding the upper arm at 0deg and 120deg anteflexion. For double calibration, the orientation between 0 and 120deg was interpolated using quaternion interpolation [4]. Subsequently, the scapular kinematics during humeral anteflexion as measured with the skin sensor (Skin, from ISEO) were also anatomical calibrated using single (0deg) and double calibration (0-120deg). Statistical differences between the joint angles of the different methods (Skin, Single and Double at 0,30,60,90,120deg elevation) were tested using a Linear Mixed Model.

RESULTS

Both single and double calibration resulted in a significant increase of scapular anterior tilt (17-21deg, P<0.001) for all elevation angles (Figure 1). Protraction was not significantly different between methods. At 120deg elevation, double calibration did not show a significant higher increase in lateral rotation compared to single calibration (Single 3deg; Double 5deg, P>0.05).

DISCUSSION and CONCLUSIONS

In conclusion, calibration with a scapula locator yields higher measures of scapular anterior tilt compared to the ISEO protocol. For shoulder movements that do not exceed 120 deg elevation, there is no gain in using double calibration.

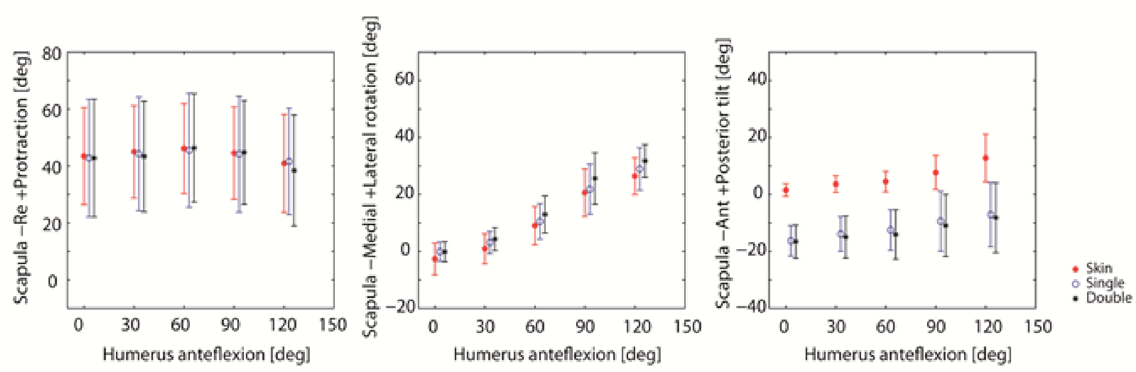

Figure 1: Scapular kinematics in patients with scapular dyskinesis measured with an inertial and magnetic measurement system with a sensor on the spina scapulae (Skin), and anatomically calibrated at 0deg (Single) and 0 and 120deg (Double) with a scapula locator

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SHRINERS HOSPITAL FOR CHILDREN UPPER EXTREMITY EVALUATION (SHUEE): A RELIABILITY STUDY

C Heaver, S Jarvis, B Johnson, J Kuiper, R Freeman
ORLAU, Robert Jones and Agnes Hunt Hospital, Oswestry.

Main topics: Analysis of clinical movement data, Reliability and service development, Outcomes after clinical intervention

INTRODUCTION

The SHUEE is a video based tool used to assess upper limb movement and function in children with hemiplegic cerebral palsy. It focuses on three domains; spontaneous function (SFA), dynamic position (DPA) and the ability to grasp/release (G/R). Function of the thumb, fingers, wrist, forearm and elbow are assessed. In ORLAU the SHUEE is used as an assessment tool to help plan interventions and then repeated as an outcome measure. The SHUEE is validated with excellent reliability[1] but there are no published studies outside the inventing centre to confirm this. We performed a reliability study to determine whether the inter and intra-observer correlation reported are reproducible in other centres and to ensure that repeatability within our unit when scored by different staff members. A power calculation based on the published results calculated that four observers needed to report 20 patients to achieve statistical significance.

METHOD

Twenty retrospective videos of SHUEE assessments carried out in 17 children were identified. All had hemiplegic cerebral palsy. Mean age of 8 (5-13yrs), 9 girls and 8 boys, 7 left and 10 right affected limbs. Before the study all 4 assessors met up and spent time training together to ensure a consistent interpretation of the SHUEE manual. The scores were completed in a single session with no discussion between observers. Ten videos were re-scored 4 weeks after the initial sitting. Inter-observer and intra-observer reliability was calculated using the interclass correlation co-efficient.

RESULTS

Table 1: Table to show results of Intra and inter-observer reliability of our study and the original by Davis et al.

	Intra-observer Reliability (ICC)		Inter-observer Reliability (ICC)	
	Our study	Davids et al 2006	Our study	Davids et al
SFA	0.84 (0.62-0.93)	0.90	0.86 (0.75-0.94)	0.90
DPA	0.83 (0.61-0.93)	0.89	0.77 (0.61-0.89)	0.89
G/R	1.0		0.98 (0.96-0.99)	

DISCUSSION

We have shown the SHUEE to be valid outside the inventing centre and have achieved excellent correlation scores in nearly all domains. Our results are not as good as the inventing centre but that is not unexpected. The weakest area of agreement was in the dynamic positioning domain particularly in assessing the finger position. This highlights an area for further training in the interpretation of the video, to improve consistency. The SHUEE is a very useful tool in the assessment of function and movement of the arm. We recommend that where more than one person scores the SHUEE in a centre, repeatability studies are carried out to ensure high standards are maintained.

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UNI- AND BIMANUAL GOAL-DIRECTED ARM MOVEMENT ORGANIZATION IN CHILDREN AT 6-9 YEARS: EFFECTS OF A PRETERM BIRTH

C. Dahlström (1), M. Nygård (2), E. Domellöf (3), A-M. Johansson (4), L. Rönnqvist (5)
(1), (2) MSc, Department of Psychology, Umeå University, Umeå, Sweden
(3), (4), (5) PhD, Department of Psychology, Umeå University, Umeå, Sweden

Main topics: Analysis of clinical movement data, motor control and motor learning

INTRODUCTION and AIM

Psychomotor deficits are more commonly reported among children born preterm (PT) than those born full-term (FT). Further, evidence exists for more covert motor problems in children born preterm at school age [1]. Such findings may be associated with a more immature spatio-temporal model of movements and lower cognitive functioning in children born PT than FT [2]. The main aim of this study was to investigate the effects of gestational age (GA) on uni- and bimanual goal-directed arm movement organization and on cognitive functioning in children at school age.

PATIENTS/MATERIALS and METHODS

Participants consisted of 88 children between 6-9 years of age (M = 7.7 years; 40 PT, 19 girls; 48 FT, 22 girls) without known developmental delays or deviations. Children born PT were divided into two subgroups: moderately PT (M-PT), 34-36 weeks' gestation (GW), and very PT (V-PT), < 34 GW. Movement kinematics were examined during performance of a goal-directed task, where the participants pushed three buttons in a sequential order in two different directions (vertical or horizontal) with either the right or left hand (unimanual) and with both hands simultaneously (bimanual). Movements were recorded by a 6-camera movement registration system (240Hz, ProReflex) and the number of movement units (MUs) was derived from head, shoulders, elbow, and wrist movement velocity profiles. Cognitive function in terms of verbal IQ (VIQ) and full scale IQ (FSIQ) was measured by the Wechsler Intelligence Scale for Children, 4th edition (WISC-IV).

RESULTS

Overall, a significant difference between the groups regarding number of MUs and FSIQ was found. In general, children born V-PT showed more MUs compared with the FT and M-PT group. Regardless of group, a significant higher amount of MUs was found in the bimanual condition than in the unimanual, and during horizontal movement performance in comparison with vertical. Furthermore, GA was significant negatively correlated with number of MUs for right and left wrist and right elbow, and also with FSIQ.

DISCUSSION and CONCLUSIONS

These findings suggest that lower GAs are associated with both more segmented goal-directed arm movements as well as with lower general cognitive ability. During the more demanding tasks, i.e. bimanual and horizontal movements, this association became particularly evident, where the children born V-PT exhibited the greatest difficulties. Thus, this indicate immature spatio-temporal movement organization as a long-lasting effect of risk factors associated with a preterm birth, specifically for children born V-PT, that may be related to lower cognitive function. Further, limitations in kinematic degrees of freedom, leading to restricted amounts of solutions when solving a motor task, may also partly explain these findings.

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GLOBAL ARM PROFILE SCORE ASSESSMENT IN CHILDREN WITH OBSTETRIC BRACHIAL PLEXUS INJURY

P. Salvia (1), C. Questienne (1), V. Sholukha (1), JL Sterckx (1,2), C. Mahieu (1), B. Bonnechère (1), B. Beyer (1), J. Bahm (3), F. Schuind (3), V. Feipel (2), S. Van Sint Jan (1), M. Rooze (1,2)
(1) Laboratory of Anatomy, Biomechanics and Organogenesis. (2) Laboratory of Functional anatomy (3) Laboratory of Research in Orthopaedics and Tromatology, Université Libre de Bruxelles, Belgium

Main topics: Movement deviation indexes, analysis of clinical movement data

INTRODUCTION and AIM

Developments of 3D upper limb (UL) motion analysis methodologies (3D_ULMA) [2,3] can provide added value to the analytical and functional assessments of patients suffering from upper limb injuries (e.g. obstetric brachial plexus injury (OBPI) or hemiplegia [1,2,3]). However, to meet the clinic expectation, 3D_ULMA must provide tools to reduce the amount of information computed from the multi functional tasks required by the child, such as put hand to mouth, hands to head or behind the back and abduction. Jaspers [1], using RMSe between motion curves similar to the "Gait Profile Score" approach [4], developed a scale for upper limbs in hemiplegic children. The purpose of this study was to develop a similar scale for OBPI children using the principal and associated components of 4 functional tasks to provide a Global Arm Profile score summarizing these 4 tasks.

PATIENTS/MATERIALS and METHODS

Ten OBPI children (C5-C6 or C5-C6-C7 lesion) were evaluated using motion analysis with a palpation procedure [2] to quantify the 39 degrees of freedom (DOF) of both UL and trunk, considered as multi segment chains including clavicles, scapula, humerus, forearms and wrists. The six functional tasks included in the Mallet score [5] were evaluated using Bone and Joint rotation representations [6]. Six of OBPI children were followed after a humeral derotational osteotomy. Range of Motion (ROM), angles of point task achievement (PTA) and variability of motion patterns were compared to a control group of 24 typically developing children (TDC) aged between 6 and 16 years. Using principal (DDL1) and associated (DDL2) DOF of the task previously estimated in the TDC group, we tested various combinations of Arm Profile Scores (APS).

RESULTS

ROM, PTA, Arm Variable score (AVS) and APS were computed for each task and each UL-DOF showing a markedly improved patterns for shoulder and elbow motion. Global APS (4 tasks) values decrease of 30% after surgery (6 pre-postop children). An example of AVS and APS of a 6 years-old patient (C5-C6) before and after surgery is shown on Figure 1.

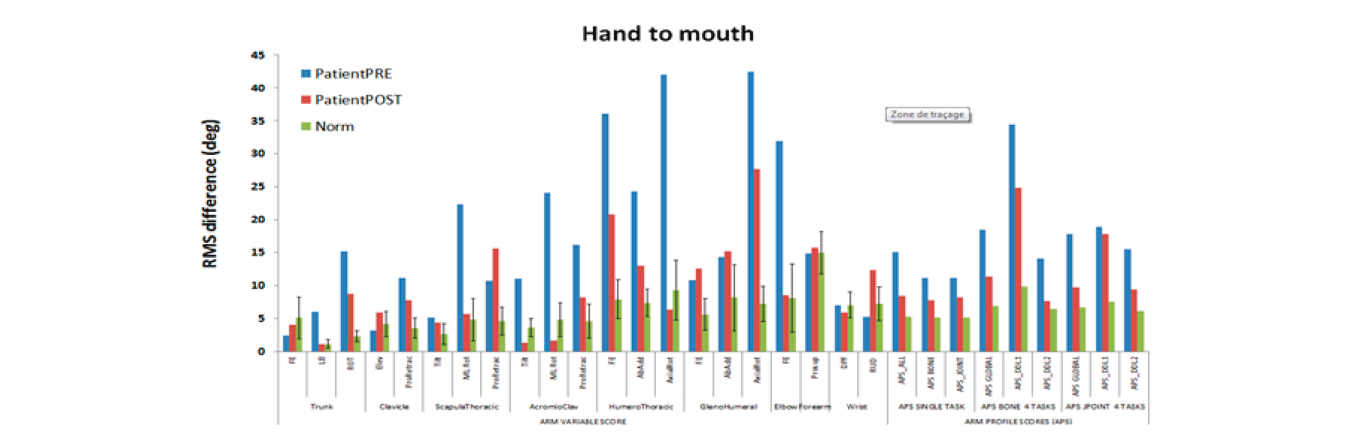

Figure 1: Arm Variable Score before and after surgery of a young OBPI patient for a hand to mouth task for all DOF of UL with scapulo- and humerothoracic joint (Bone rotation); different APS using only the principal DOF of the 4 tasks (DDL1) and including associated components (DDL2).

DISCUSSION and CONCLUSIONS

Based on the reference values of 3D_ULMA in TDC, APS seem relevant to help in clinical interpretation on OBPI results based on the main and associated DOF previously defined to refine the therapeutic decision with a more detailed description of coping strategies.

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EFFECTS OF THE UPPER LIMB ROBOT-ASSISTED THERAPY ON A DAILY TASK IN STROKE PATIENTS: PRELIMINARY RESULTS USING MOTION ANALYSIS

I. Aprile (1), E. Di Sipio (1), C. Simbolotti (1), M. Germanotta (2), L. Cortellini (1), M. Rabuffetti (3), L. Padua (1,4) and M. Ferrarin (3)
(1) Don Carlo Gnocchi Foundation, SM Provvidenza Movement Laboratory, Rome, Italy
(2) Department of Mechanical and Aerospace Engineering, "Sapienza" University of Rome, Italy
(3) Don Carlo Gnocchi Foundation IRCCS, Biomedical Technology Department, Milan, Italy
(4) Neuroscience Department of Catholic University, Rome, Italy
Main topics: Analysis of clinical movement data, Movement deviation indexes, Robotic devices in human movement science and rehabilitation

INTRODUCTION and AIM

In the past few years, there has been an increasing focus on Robot - Mediated Therapy (RMT) for the rehabilitation of patients after neurological disease. Robotic devices facilitate patient access to therapy, increase time on training of the impaired limb and decrease time consumption. Data recorded by robots are quantitative measures, highly repeatable, and more sensitive with respect to clinical scales. Despite the development of many rehabilitation approaches to recover the use of the upper limb after a stroke, the identification of effective treatments remains a matter of study. Six months after a stroke, about 65% of patients cannot use the affected hand in their usual activities [1]. Therefore, the aim of rehabilitation is to improve the daily activities shoulder performance in stroke patients. Reaching for a glass and bringing it to the mouth to drink is a very common and important daily life activity. This work presents the preliminary results of the effects of robot-assisted therapy of the upper limb in stroke patients, evaluating their performance in a daily task (drinking from a glass) using motion analysis.

PATIENTS/MATERIALS and METHODS

We enrolled 5 patients with sub-acute stroke. The patients performed an augmentative rehabilitation treatment (4 weeks, 3 sessions a week) using a robotic arm (MJS 403, Tecnobody) in addition to conventional physiotherapy. Clinical evaluation included Fugl-Meyer Motor Assessment (FMA) and the Wolf Motor Function Test (WMFT). The robotic evaluation included the following exercises: shoulder anterior flexion (SAF, ROM 60°) and shoulder abd-adduction (SAA, ROM 45°). Each exercise lasted 60 s and was evaluated by means of: (i) the number of repetition; (ii) the mean angular velocity of the shoulder; (iii) the normalized jerk (NJ) (a index inversely correlated to the smoothness of the movement [2]). The evaluation of the daily task (reaching and drinking from a glass) was performed using a motion analysis system (SMART D-500, BTS), adopting a specific protocol previously reported [3]. Motion analysis indices were (i) the ROM of the elbow, and (ii) the trunk inclination contribution to the reaching for the glass. Robotic and motion analysis evaluations were performed before (TO) and after treatment (T1). Statistical analysis was performed by a Wilcoxon signed-rank test to evaluate the difference of indices between T0 and T1.

RESULTS

After robot-assisted therapy, both robotic and motion analysis evaluation showed an increase of the subjects' motor performance. Reported data are medians unless otherwise stated. During SAA, we observed a statistically significant improvement in the number of repetitions (T0: 12, T1: 52, $p<0.05$), mean velocity (T0: 11.9 m/s, T1: 42.1 m/s, $p<0.05$), and smoothness of movement, as determined by a decrease in NJ (T0: 523.9, T1: 30.0, $p<0.05$). Also during SAF there was a statistically significant increase in the number of repetition (T0: 18, T1: 49, $p<0.05$), mean velocity (T0: 20.2 m/s, T1: 55.6 m/s, $p<0.05$), and smoothness of movement, as determined by a decrease in NJ (T0: 158.9, T1: 23.4, $p<0.05$). Referring to the daily task, motion analysis showed a significant increase of the ROM of the elbow (T0: 6.6°, T1: 16.7°, $p<0.05$) and a significant decrease of the trunk inclination contribution to reaching (T0: 96.7%, T1: 82.6%, $p<0.05$), indicative of an improved use of the upper limb with less employment of compensatory trunk strategy.

DISCUSSION and CONCLUSIONS

Our preliminary results show that a robot-assisted treatment could improve the performance of the upper limb in sub-acute stroke patients during daily activities. Therefore, they support the usefulness of this technological approach to the rehabilitation of the sub-acute stroke patients.

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QUANTITATIVE EVALUATION OF THE UPPER LIMB KINEMATICS IN POST-STROKE PATIENTS UNDERGOING REHABILITATION: INTEGRATED VS. TRADITIONAL REHABILITATION TREATMENT

L. Pianta (1), E. Tacchini (1), M. Bigoni (1), V. Cimolin (1, 2, 4), M. Galli (2, 3), N. Cau (1, 2, 4), S. Baudo (1), P. Capodaglio (4), A. Mauro (1, 5)

(1) Department of Neurology and NeuroRehabilitation, Ospedale San Giuseppe, Istituto Auxologico Italiano, IRCCS, Piancavallo (Verbania), Italy

(2) Department of Electronics, Information and Bioengineering, Politecnico di Milano, Milano, Italy

(3) IRCCS "San Raffaele Pisana", Tosinvest Sanità, Roma, Italy

(4) Orthopaedic Rehabilitation Unit and Clinical Lab for Gait Analysis and Posture, Ospedale San Giuseppe, Istituto Auxologico Italiano, IRCCS, Piancavallo (Verbania), Italy

(5) Department of Neuroscience "Rita Levi Montalcini", University of Torino, Torino, Italy

INTRODUCTION

The limitations of upper limb function in post-stroke patients , are, to date, a stumbling block to the achievement of autonomy during the Activities of Daily Living. In fact, while 75% of patients recover autonomy in standing and in walking, about 55-75% retain serious limitations of functionality of the upper limb.The functional recovery in neurological patients is based upon the nervous system plasticity, primarily due to a reorganisation of cerebral activity. Each motor task corresponds to the concept of motor image, which is the basis of the imitation and learning processes, that consequently found wide applications in several rehabilitative protocols. The role of mirror neurons, based upon the motor image processes, is of great importance. The proposed rehabilitative approach was based on mixed rehabilitative techniques. The intervention was based on task oriented approach, preceded by motor imagery techniques and integrated with some Brain Gym exercises (mirror drawing, eight of the alphabet and eight of the infinite). In particular, the program focused on exercises aimed to control the trunk and shoulder stabilisation, followed by functional activities for upper limb muscles coordination and for the hand functionality. In literature, no quantitative studies are present regarding this rehabilitative approach for the upper limb. The aim of the present study is to compare, in a group of post-stroke patients, the effects of a traditional physiotherapic treatment, which includes passive mobilization, muscle strengthening exercises and Activities of Daily Living, vs. an innovative integrated rehabilitative treatment in terms of upper limb kinematics changes, using instrumental evaluation.

METHODS

A total of 15 post-stroke hemiplegics were quantitatively assessed during pointing task. Among them, 10 patients were treated with the innovative rehabilitative program and 5 patients were treated with traditional physiotherapic program. Rehabilitation treatment for both groups includes ten session lasting an hour and a half.

Kinematic analysis was performed by an optoelectronic system (Vicon, UK). The subjects were asked to reach an object on a screen in front of her at a normalised distance (80% of subject's arm length); the subjects were seated with flexed arm flexed on the desk. The task was repeated 12 times (six movements, right and left). Kinematic analysis was conducted identifying and computing specific parameters of movement duration, velocity, smoothness and upper limbs angles [1, 2]. All patients were assessed in two sessions: PRE and POST treatment. The comparison between the two sessions of each rehabilitative program was done using non parametric tests ($p< 0.05$).

RESULTS

The upper limb kinematics evaluation showed that in PRE session the most of parameters of both groups were different from normality range, with no differences between the two evaluated groups. In particular, they executed the movement slower, with higher movement duration, and with lower precision. After the innovative treatment we found significant improvements in terms of movement duration, in particular during going phase (1.3 vs. 1.0 s; $p< 0.05$; controls: 0.8 s) and total duration (3.6 vs. 2.5 s; $p< 0.05$; controls: 1.9 s), and number of unit movements (15.2 vs. 7.5; $p< 0.05$; controls: 2.8); our data showed higher mean velocity (0.3 vs. 0.5 m/s; $p< 0.05$; controls: 0.6 m/s) and an increased ROM of shoulder flex-extension (32.9 vs. 36.9 degrees; $p< 0.05$; controls: 43.9 degrees). On the contrary, the group treated with traditional rehabilitative program showed no statistically changes.

DISCUSSION

Our preliminary data, even if a low number of subjects, showed quantitatively the effects of the proposed rehabilitative approach on the treated patients, which globally lead to an improvement of upper limb functionality during the requested pointing task in terms of speed, coordination and precision respect to the traditional rehabilitative treatment. Vicon resulted reliable for studying upper limbs patterns of movement.

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INTRODUCING A STANDARDIZED NINE HOLE PEG TEST IN PERSONS WITH STROKE – KINEMATIC ANALYSIS

G M Johansson[1], H Grip[1], and C K Häger[1]
[1]Umeå University, Dept of Community Medicine and Rehabilitation; Physiotherapy, Umeå, Sweden

INTRODUCTION and AIM

Almost half of the stroke survivors in Sweden report impairments in fine hand movements three months post stroke [1]. Such impairments may be assessed by the commonly used dexterity test; Nine Hole Peg Test (NHPT) [2]. Persons with stroke often take a longer time to accomplish the NHPT. Besides time to perform the NHPT, there is no other clinical outcome of this test. A kinematic analysis provides more detailed information than merely the time to perform the movement, data that is not possible to capture with the human eye alone. Such information may increase the knowledge of underlying constructs and properties of existing clinical tests [3]. We developed a new and more standardized version of the NHPT, involving moving nine pegs between two square boards with holes instead of between one square board and a box, thus increasing the precision demand in the task and making the movement trajectories more comparable. The aim was to compare the performance of the Standardized Nine Hole Peg Test (SNHPT) by persons with stroke to that of healthy persons based on kinematic analysis of the upper body and upper extremities.

PATIENTS and METHODS

Thirty persons with stroke (19 men, age 69 ± 9 yrs) and 41 controls (22 men, age 66 ± 12 yrs) were included. All were assessed using an 8-camera 3D motion capture system (240 Hz, Oqus®, Qualisys Gothenburg, Sweden). Reflective markers were placed either individually on anatomical landmarks or as part of rigid clusters placed on the upper arms. Segments included the thorax, upper arms, forearms, and the hands. All data was filtered at 15Hz with a critically damped digital filter and processed in the software Visual 3D (C-motion Inc.,). The participants were seated on a height-adjustable chair (Mercado Medic REAL® 9000 PLUS) with their back supported and the test board in front of them on a table. The seated position was not restrained and thus allowed compensatory movements. The pegs from the ipsilateral square board with respect to the hand used, were picked up one at a time, transported and inserted into the holes of the other square board (distance between boards 18 cm) and then returned one by one to the ipsilateral square board as quickly as possible. The SNHPT was repeated twice for both hands after a familiarization trial.

RESULTS

Comparable movement trajectories were achieved for all participants. Preliminary analysis showed significantly different kinematics for the paretic arm compared to the non-dominant arm of the controls, indicating alternative movement patterns to accomplish the test. The persons with stroke performed the task less smoothly (higher number of movement units), less effectively (prolonged time to pick up the pegs, fill the holes, and release the pegs), and used excessive shoulder and trunk movements (increased displacement of trunk and shoulder markers).

DISCUSSION & CONCLUSION

The SNHPT enables more reliable results of repeated measures and group comparisons compared to the original NHPT since it encompasses a standardized order of which peg to pick or which hole to fill. Therefore, we suggest that the SNHPT is a better way of assessing variability than the original NHPT. However, in either version, the current clinical outcome (time to perform the peg test) does not provide sufficient information about motor performance and possible use of compensatory movements. For that reason, complementary measures that consider quality of movement are recommended when interpreting a time reduction (improvement) of the NHPT.

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CAN CAPSULAR STRETCHING CHANGE THE SCAPULO-HUMERAL COORDINATION IN BASEBALL PITCHERS?

I Parel (1), A Pellegrini (2), P Tonino (3), P Paladini (1), F Campi (1), G Porcellini (1), AG Cutti (4)
(1) Laboratory of Biomechanics, Cervesi Hospital, Cattolica, Italy
(2) Orthopedic Clinic University of Parma, Parma, Italy
(3) Sport Medicine Unit, Loyola University Hospital, Chicago, US
(4) INAIL Prosthetic Center, Bologna, Italy

Main topics: Analysis of clinical movement data; outcome after clinical intervention.

INTRODUCTION

Injury in the throwing shoulder of baseball pitchers and overhead throwing athletes is common. Previous studies assessed scapular kinematics using electromagnetic tracking devices, demonstrating that patients with impingement have a reproducible pattern of shoulder dyskinesia [1]. In addition, they showed a correlation between posterior shoulder tightness and forward scapular posture and confirmed that baseball players have more forward scapular posture of the dominant arm [2]. Possibly, capsular stretching programs might help restoring a normal scapulo-humeral coordinate. The aim of this study was to test this hypothesis by studying the scapular kinematics before and after a four weeks posterior stretching protocol in asymptomatic baseball pitchers.

PATIENTS/MATERIALS and METHODS

Eleven asymptomatic collegiate baseball pitchers were involved in the study. Pitchers were randomly separated in two groups: group A (6 pitchers) underwent four weeks of a regimented therapy protocol; group B (5 pitchers) did not received any treatment. Each pitcher was tested on two separate days: at the first day of the study (S1) and after four weeks (S2). The ISEO protocol was used to collect the kinematics of trunk, scapula and humerus [3] of both the throwing side (TS) and the contralateral (CS). The Scapulo-Humeral Coordination (SHC) during humerus elevation in the sagittal (FlexExtension - FE) and scapular (AbAdduction - AA) plane was collected and then analyzed by means of coordination plots, considering a common humeral Range of Motion (ROM) from 10° to 110°, divided in steps of 5°. SHC's patterns of each subject were compared to age stratified reference bands (RB) computed from healthy subjects [4]. In order to verify if biological modifications occurred, for each subject, firstly, the SHC's pattern of TS and CS were compared to the age stratified reference bands (RB); secondly, the scapula ROM variations of TS between S1 and S2 were computed and compared to the Smallest Detectable Difference (SDD) of ISEO [5].

RESULTS

The comparison of the SHC patterns with RBs showed that both TS (in S1 and S2) and CS of all subjects are within the correspondent reference bands, except one subject from group B, that presented alterations at TS only in S1. From the comparison of scapula ROM variations (S1-S2) with SDD values, group B showed that significant variations occurred only for one subject in MELA ROM during FE and AA and PA during AA. On the contrary 4 out of 6 pitchers that received the therapy showed clear signed of SHC alterations. Specifically, 4 subjects (67%) had variations in MELA during FE and 3 (50%) in MELA during AA, and 1 subject in PA during both FE and AA. These changes were towards the RB mean patterns, proving an improvement of the SHCs of TSs after the physical therapy. It is important to notice that variations in the subjects of group A occurred for both movements (FE and AA), strengthening the conclusion that the variation was real.

DISCUSSION and CONCLUSIONS

This study highlights how posterior capsular stretching protocol can favour the maintenance of the SHC in asymptomatic baseball pitchers. Being a randomly and blinded study all pitchers of group A underwent the physical therapy protocol even if in S1 they had not presented an altered SHC compared to reference bands. The preliminary result of the study can indicate that, in order to prevent the pathologic cascade linked to these sports activities, this physical training protocol might become integral part of the normal daily exercises of baseball pitchers and over-head athletes.

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BIOMECHANICS OF THE UPPER LIMBS: 3D ANGULAR VELOCITY, SEGMENT INTERACTION AND MOVEMENT UNITS IN ASYMPTOMATIC ADULTS

A. Assi (1,2,3,4), A. Massaad (2), Z. Bakouny (1), M. Karam (3), W. Skalli (4), I. Ghanem (1,2,5)

School of Medicine, Saint-Joseph University, Beirut, Lebanon
Gait lab, SESOBEL, Beirut, Lebanon
Physical Therapy Institute, Saint-Joseph University, Beirut, Lebanon
Laboratoire de Biomécanique, Arts et Métiers ParisTech, Paris, France
Hôtel Dieu de France Hospital, Beirut, Lebanon

Main topics: Kinematics, Upper limbs, Adults, Angular Velocity, Anatomical movements, Activities of daily living, Movement units

INTRODUCTION and AIM

The velocity of upper limb movements has been widely studied as linear velocity of the distal segments [1]. In order to study segment interaction and movement smoothness, a database of the angular velocities during anatomical movements (AM) and activities of daily living movements (ADLM) of asymptomatic adults, aged 20 years or above, was constructed.

PATIENTS/MATERIALS and METHODS

Thirty asymptomatic adults (15M, 15F) with a mean age of 29 years (SD=7.6) formed our database. The placement of markers on the upper limbs and trunk was based on the ISB protocol [2]. Clusters were fixed on the humerus and forearm. Seven Vicon MX3 (200Hz) cameras were used for data acquisition. AM were performed with both upper limbs: shoulder circumduction, flexion/extension, abduction, internal/external rotation, horizontal abduction/adduction, elbow flexion/extension and wrist pronation/supination. The subjects were positioned opposite a table in order to perform the ADLM (inspired by the Melbourne test): hand to head, reach a target, bring a cup to one's mouth, move an object from the controlateral to the unilateral side and back. Each movement was repeated 3 times using each limb (dominant and non-dominant). The center of the glenohumeral joint was defined as the center of a sphere based on shoulder movements [3]. A repeatability study was conducted on 12 asymptomatic adults, who each repeated the procedure twice, with an interval of one week between sessions. The angular velocities were calculated using the homogeneous matrices method [4] and the norm of the joint angular velocity vector (NJAV) was evaluated [5]. The number of movement units (number of accelerations-decelerations in the velocity profile) was calculated, for each joint, during each movement, in order to assess the movement's smoothness [6]. The movements of the dominant and the non-dominant limbs were compared.

RESULTS

The joint velocity angles were calculated in 3D for the thorax, scapula (scapula-thoracic), shoulder (humero-thoracic), elbow and wrist, thus defining the corridors of normality (mean ± 1SD). The contribution of each joint and of each plane of movement, were evaluated for each AM and ADLM. The mean NJAVmax was calculated for each joint and for each movement and its repeatability was evaluated by calculating the 95% of Confidence Interval (CI). The number of movement units varied between 4 and 5 for AM and between 4 and 11 in ADLM. The comparison between the dominant and non dominant limbs showed a poor CMC (<0.6) between velocity curves in the elbow and wrist during wrist pronation/supination (AM) as well as during all ADLM.

DISCUSSION and CONCLUSIONS

The database of angular velocities and the number of movement units during AM and ADLM of the upper limbs, in asymptomatic adults, will be used in the evaluation of the motor deficiencies in patients with hemiplegia. The 95% CI will be taken into consideration when a patient's results will be compared to the asymptomatic database.

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15:00-16:30 **FUNCTIONAL TASKS**
Aula Minor ***Chairs: Eva Broström, Andreas Kranzl***

15:00-15:10 NEUROMUSCULAR CONTROL MECHANISMS DURING SINGLE-LEG JUMP LANDING IN ACUTE ANKLE SPRAIN PATIENTS
F. Zumstein, L. Allet, S. Armand, L. Radlinger, P. Eichelberger, I. Punt

15:10-15:20 THE EFFECTIVENESS OF VERTICAL JUMP ANALYSIS AS A STRENGTH SCREENING TOOL FOR OLDER ADULTS
S. Strike, H. Ritchie, A. Carlisle

15:20-15:30 INSTRUMENTED FINGER-TO-NOSE TEST FOR THE QUANTITATIVE ASSESSMENT OF INTENTION TREMOR IN MULTIPLE SCLEROSIS:A HILBERT-HUANG-BASED APPROACH
I. Carpinella, D. Cattaneo, G. Bonora, M. Ferrarin

15:30-15:40 AGE-RELATED DYNAMIC MOTION STRATEGIES IN CLUTCH PEDAL DEPRESSIONS
I. Pasciuto, S. Ausejo, J.T. Celigüeta, A. Suescun

15:40-15:50 LOWER LIMB MUSCLE STRENGTH DIFFERENCES IN SUBJECTS WITH DIABETIC NEUROPATHY COMPARED TO CONTROLS: A PILOT STUDY
Z. Sawacha, A. Scarton, A. Guiotto, F. Spolaor, G. Guarneri, A. Avogaro, C. Cobelli, I. Yonkers

15:50-16:00 LANDING AND INJURIES: THE INFLUENCE OF HIP ABDUCTOR FATIGUE
S. Gafner, I. Punt, S. Armand, N. Place, L. Allet

16:00-16:10 HOW IS PERIPHERAL VISUAL INFORMATION USED FOR STAIR CLIMBING?
V. Graci, M. Rabuffetti, M. Ferrarin

16:10-16:20 EVALUATION OF KNEE FLEXORS AND EXTENSORS ISOKINETIC TORQUE AND IGF-1 / IGFBP-3 CONCENTRATIONS AFTER ECCENTRIC TRAINING IN CHRONIC HEMIPARETIC SUBJECTS
C.C. Alcântara, M.A. Silva-Couto, C.L. Prado-Medeiros, T.F. Salvini, T.L. Russo

16:20-16:30 COMPUTERIZED FIDGETY MOVEMENT ASSESSMENT IN INFANTS WITH HIGH RISK OF NEUROLOGICAL IMPAIRMENTS
EAF. Ihlen, L. Adde, R. Støen

16:30-17:00 Coffee break

NEUROMUSCULAR CONTROL MECHANISMS DURING SINGLE-LEG JUMP LANDING IN ACUTE ANKLE SPRAIN PATIENTS

F. Zumstein (1), L. Allet (2,3), S. Armand (3), L. Radlinger (1), P. Eichelberger (1), I.M. Punt (2,3)
(1) Bern University of Applied Sciences, Bern, Switzerland
(2) University of Applied Sciences of Western Switzerland HES-SO, Geneva, Switzerland
(3) University Hospitals of Geneva, Geneva, Switzerland

Main topics: Analysis of clinical movement data, Motor control and motor learning, Orthopaedics

INTRODUCTION and AIM
Ankle sprain injury is the most common type of acute sports trauma worldwide [1]. Optimal neuromuscular control mechanisms (i.e. feedforward and feedback control) are essential for preparing, maintaining and restoring functional joint stability during jump landing and to prevent ankle injuries [2]. Feedforward control is mainly involved in the foot position at touchdown and the injury-prone phase [3]. In acute ankle sprain patients, neither muscle activity nor kinematics during jump landing has been assessed.
The aim of this study was to compare neuromuscular control mechanisms and kinematics between acute ankle sprain patients and healthy subjects of a 25 centimeter single-leg jump.

PATIENTS/MATERIALS and METHODS
Fifteen patients and 15 healthy persons performed three barefoot single-leg jumps. EMG activity (Aurion ZeroWire, Milan, Italy) of the *m. gastrocnemius lateralis*, *m. tibialis anterior*, and *m. peroneus longus* as well as kinematic data (Vicon Mx3+, Vicon Peak, Oxford, UK) for ankle, knee, and hip joint were recorded during the pre-initial contact phase (30ms before touchdown until impact), the post-initial contact phase (0 ms – 30 ms), and the reflex-induced phase (30 ms – 150 ms) of jump landing.

RESULTS
During performing a single-leg 25cm jump, EMG activity of the three muscles did not differ for any of the analyzed time intervals (all $P > 0.050$).
However, ankle sprain patients showed a more dorsiflexed position (mean 1.03° ± SD 5.20°) of the ankle joint during the post-initial contact phase compared to the healthy persons (-3.12° ± 5.19°) ($P = 0.046$, Figure 1). On the other hand, ankle inversion/eversion angles were comparable between the groups immediately after touchdown ($P > 0.050$). Furthermore, no between-group differences for the knee and hip angles ($P > 0.050$) during the different phases were observed.

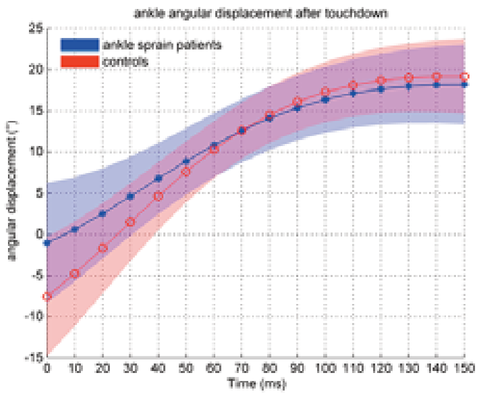

Figure 1: Angular displacements (dorsiflexion (+) and plantar flexion (-)) of the ankle joint during post-initial contact (0ms-30ms) and reflex-induced phase (30ms-150ms). Solid lines represent group mean and shaded areas the 95% confidence interval.

DISCUSSION and CONCLUSIONS
The increased dorsiflexed position of the ankle during the post-initial contact phase showed that ankle sprain patients have an altered jumping respectively landing pattern. It might be that the altered motor pattern of ankle sprain patients represents a security strategy to avoid recidivism. This dorsiflexed position of the ankle brings the joint in a more closed-packed position which offers greater protection to the lateral ligament complex. Alternatively, the dorsiflexion might be a precaution behavior of ankle sprain patients. It is possible that ankle sprain patients did not jump as high as healthy persons and therefore could not have the foot hanging, because of the toes touching the floor. Our findings are important for optimizing treatment strategies, because altered movement patterns at this early stage of rehabilitation can lead to faulty pre-programming of neuromuscular control mechanisms and consequently lead to an increased risk of recurrent ankle sprains

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THE EFFECTIVENESS OF VERTICAL JUMP ANALYSIS AS A STRENGTH SCREENING TOOL FOR OLDER ADULTS

SC Strike, H Ritchie, A Carlisle
Department of Life Sciences, University OF Roehampton, London SW15 4JD, UK

Main Topics: Experimental studies in human movement science; Natural history of movement and ability

INTRODUCTION and AIM

Early establishment of factors that contribute to maintaining walking and partaking in recommended levels of daily activity may be essential to delay frailty and prevent disability in older age (Boyer et al, 2012). Specific clinical tests designed to assess functional capacity for relatively young older adults do not exist. The purpose of the study was to utilise vertical jump height (VJH) analysis as a performance outcome measure to investigate age-related strength, balance and gait deficits in older adults.

PATIENTS/MATERIALS and METHODS

Fifteen older (O) and fifteen younger (Y) healthy adults participated in the study (Mean (SD) Age: O = 63(2); Y = 26(5)). Three-dimensional kinematic and kinetic data were collected using a VICON system integrated with 2 Kistler force plates. Each participant completed 5 habitual speed walks with force plate contact on each limb, followed by 3 countermovement jumps from which the highest was selected for further analysis. Positive and negative muscle powers at the ankle, knee and hip were calculated in the take-off and landing phase of the CMJ respectively. Four jump phases: countermovement, concentric, eccentric, time to stabilise (TTS) were defined, and time spent in each phase was calculated. In addition, temporal-spatial parameters and positive ankle power during terminal stance of habitual walking gait were quantified for both groups walking at a self-selected speed.

RESULTS

Between-group statistical analyses revealed significant *($p<0.05$)* differences in VJH, positive ankle, hip and knee powers during take-off, negative knee powers during landing, and time spent in concentric and TTS jump phases. No significant differences *($p >0.05$)* were found between groups for temporal spatial gait parameters and positive ankle power during the terminal stance phase of walking.

DISCUSSION and CONCLUSIONS

The VJH capacity and muscle power generation during jumping was reduced in older compared to younger adults, and the older adults spent a longer period of time preparing for, and stabilising after a CMJ. Temporal-spatial gait parameters and positive power generation at the ankle (A2S) were maintained in both groups. The CMJ is a useful movement to assess for strength deficits in the young old which are not apparent in walking.

Table 1. Mean (SD) and p values for jump variables.

	Younger	Older	p value
Jump height (mm)	313.74 (45.63)	212.46 (38.19)	<0.001
A1+ (W/Kg)	8.47 (1.23)	6.23(0.99)	<0.001
K1+ (W/Kg)	5.18 (1.89)	3.57 (1.26)	= 0.010
H1+ (W/Kg)	4.13 (1.28)	2.05 (1.10)	<0.001
A1- (W/Kg)	-7.01 (1.97)	-6.63 (1.64)	= 0.56
K1- (W/Kg)	-5.52 (2.27)	-3.70 (1.61)	= 0.017
H1- (W/Kg)	-3.43 (1.48)	-2.19 (2.34)	= 0.96
Countermovement phase (s)	0.54 (0.11)	0.62 (0.22)	= 0.21
Concentric phase (s)	0.28 (0.06)	0.34 (0.08)	= 0.03
Eccentric phase (s)	0.18 (0.08)	0.19 (0.06)	= 0.69
Time to stabilise (s)	0.77 (0.16)	1.02 (0.34)	= 0.014

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INSTRUMENTED FINGER-TO-NOSE TEST FOR THE QUANTITATIVE ASSESSMENT OF INTENTION TREMOR IN MULTIPLE SCLEROSIS:A HILBERT-HUANG-BASED APPROACH

I. Carpinella (1), D. Cattaneo (2), G. Bonora (1), M. Ferrarin (1),
(1) Biomedical Technology Department, Found. Don C. Gnocchi Onlus, IRCCS, Milan, Italy
(2) Department of Neurorehabilitation, Found. Don C. Gnocchi Onlus, IRCCS, Milan, Italy

Main topics: Analysis of clinical movement data, movement deviation indexes.

INTRODUCTION and AIM

Intention tremor, characterized by increasing amplitude toward the end of goal-directed movements, is a highly disabling symptom of Multiple Sclerosis (MS) [1]. It is usually assessed using clinical ordinal scales rating tremor amplitude during the finger-to-nose test. Although widely used, ordinal scales suffer from high examiner-dependency and poor sensitivity. In the present study, an instrumented finger-to-nose test (FTN) is proposed to overcome these limitations and provide an objective quantitative assessment of intention tremor in MS subjects.

PATIENTS/MATERIALS and METHODS

20 MS subjects and 13 healthy controls (CO) executed FTN (5 repetitions) with an inertial sensor (Xsens, The Netherlands) on the hand's dorsum (X-axis longitudinal, Y medio-lateral, Z normal to the dorsum). Gyroscope signals were processed using Hilbert-Huang transform (HHT) [2], a novel technique suitable for the analysis of non-linear and non-stationary processes. HHT consists of two steps: a) empirical mode decomposition, which decomposes the raw signal in a set of components called Intrinsic Mode Functions (IMF) and b) Hilbert spectral analysis which computes the time-course of instantaneous frequency and instantaneous amplitude of each IMF. After HHT, noise, tremor and voluntary movement were reconstructed, considering that voluntary movement is below 1Hz while tremor in mainly between 2Hz and 6Hz with a vision-dependent component around 1Hz [3]. The following mode selection criterion was proposed: 1) median frequency (MF), median amplitude (MA) and inter-quartile range of amplitude (IQRA) were computed for each IMF; 2) IMFs with MF > 7Hz were assigned to noise; 3) the IMF with the maximum MA and MF < 1Hz was assigned to movement together with the subsequent modes; 4) IMFs with MF between 2Hz and 7Hz were assigned to tremor; 5) remaining IMFs, with MF around 1Hz, were assigned to tremor if their MA was within the IQRA of the last mode assigned to tremor, else they were assigned to movement. A tremor index (TI: percentage ratio between root mean square of tremor and the norm of raw angular velocity) was proposed to quantify tremor during either the first and the final part of each FTN movement. Intention tremor was also clinically assessed through Fahn Tremor Rating Scale (FTRS).

RESULTS

FTRS showed intention tremor in 11 MS subjects (MS_T) and no tremor in 9 patients (MS_NT). According to the definition of intention tremor, TI of MS subjects was significantly higher in the final part of the movement (TI2) with respect to the first part (TI1). No such a difference was found in CO. As reported in Table 1, MS_T showed a TI2 significantly higher than CO (X,Y and Z components) and MS_NT (X and Y components). TI2 related to Z component was significantly altered also in MS_NT. Finally, a significant positive correlation was found between FTRS score and TI2 related to X (ρ=0.587, p=0.006) and Y components (ρ=0.682, p<0.001).

DISCUSSION and CONCLUSIONS

Present results suggest that HHT is a suitable technique to analyse intention tremor from gyroscope data in MS. With respect to common methods based on Fourier transform, the proposed procedure has two main advantages: i) it is able to automatically extract tremor components without any a priori knowledge of the tremor frequency specific of each subject, ii) it provides a finer separation between tremor and voluntary movement, that is essential to study the multiple components of MS tremor, which includes low-frequency components around 1Hz. Moreover, the proposed tremor index (TI): i) is able to discriminate between healthy controls and MS subjects with tremor, ii) is significantly correlated with the clinical tremor score, iii) detects subtle alterations in MS subjects with FTRS=0 that deserve further study. In conclusion, present results support the use of the proposed procedure as a quick and easy-to-use tool for the quantitative assessment of intention tremor in MS.

Table 1: TI2 (mean ± sd) for the 3 groups. Letters a,b,c indicate significant difference (p<0.05) with respect to the specific group (Kurskal-Wallis and Bonferroni-Holm tests).

	CO (a)	MS_NT (b)	MS_T (c)
TI2 X (%)	8.5±2.4 c	10.1±3.9 c	16.4±6.9 a,b
TI2 Y (%)	7.9±4.8 c	10.3±4.0 c	21.0±11.9 a,b
TI2 Z (%)	6.3±3.5 b,c	10.7±5.5 a	10.8±3.9 a

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AGE-RELATED DYNAMIC MOTION STRATEGIES IN CLUTCH PEDAL DEPRESSIONS

I. Pasciuto (1), S. Ausejo (2), J.T. Celigüeta (2), Á. Suescun (2)
(1) Univerisity Foro Italico, Rome, Italy; CEIT and Tecnun (University of Navarra), San Sebastian, Spain
(2) CEIT and Tecnun (University of Navarra), San Sebastian, Spain

Main topics: Experimental studies in human movement science, Motor control and motor learning.

INTRODUCTION and AIM
As the elderly population increases at a high rate, it is paramount for ergonomics to address the specific needs of older adults, in order to promote active and healthy ageing and encourage them to continue activities that extend their independent living, such as driving. It is important for ergonomic tools to adequately take age effects into account, as young and elderly people tend to employ different motion strategies. In fact, age-related differences in motor behaviour have often been observed [1], mostly by analysing the temporal and kinematic characteristics of motion. This study aims at identifying age-related behaviours in terms not only of the kinematics but also of the dynamics involved in a common task for drivers, as is the clutch pedal depression.

PATIENTS/MATERIALS and METHODS
Ten male volunteers, 5 young (age 26±5) and 5 elderly (age 72±5), were recruited to perform the task in an adjustable vehicle mock-up representing 6 vehicle configurations. One clutch pedal depression motion was performed in each configuration except for one in which two additional repetitions were carried out. A total of 80 motions were recorded using an optoelectronic motion capture system and a 3D force sensor placed on the clutch pedal. Kinematic and dynamic motion reconstruction was then performed, using a 13 degree of freedom model of the pelvis and left leg, as described in [2].

RESULTS
No significant differences were observed between the young and elderly subjects when comparing the kinematic profiles in the motion, as it is strongly constrained by the environment. However, significant differences appear during the pedal depression (Table 1, $p<0.01$) concerning: the flexion-extension torques at the joints; the moment acting on the pelvis in the sagittal plane, due to the subject's interaction with the seat backrest; and the pedal radial force coefficient, defined as the ratio between the radial force (which does not cause the pedal to move) and the tangential force exerted on the pedal (which determines its depression).

DISCUSSION and CONCLUSIONS
The differences in the motion of young and elderly subjects reveal two age-related dynamic motion strategies: young people tend to reduce the muscular effort required at the joints (smaller hip and knee joint torques), whereas the priority for the elderly is not to load their backs (smaller seat reaction moment). These different strategies are ultimately determined by the value of the pedal radial force coefficient during the pedal depression. In fact, its value controls the orientation of the pedal reaction force, as suggested by [3], and either tends to align it with the hip joint centre to reduce the load on the back (elderly strategy) or to increase its vertical component to minimise the joint torques (young strategy). Generally, motion strategies are identified when significant differences are encountered in the kinematic profiles [4]. Nevertheless, we found that, although motor behaviours may seem undistinguishable in terms of kinematics, the dynamics involved in the motion can both characterise different strategies and reveal information concerning the criteria which guide the motion.

Table 1: Values of dynamic variables at the end of the pedal depression (mean ± 95% confidence intervals of the mean). Joint torques are positive when representing the contribution of flexor muscles.

group	hip F/E torque (Nm)	knee F/E torque (Nm)	ankle F/E torque (Nm)	seat reaction moment (Nm)	pedal radial force coefficient (N/N)
young	1.5±10.6	-22.1±8.4	-13.6±3.2	73.4±10.7	0.63±0.07
elderly	50.0±13.0	-46.5±9.2	-6.9±3.7	20.9±16.7	0.29±0.07

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ACKNOWLEDGEMENTS
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LOWER LIMB MUSCLE STRENGTH DIFFERENCES IN SUBJECTS WITH DIABETIC NEUROPATHY COMPARED TO CONTROLS: A PILOT STUDY

Z. Sawacha (1), A. Scarton (1), A. Guiotto (1), F. Spolaor (1), G. Guarneri (2), A. Avogaro (2), C. Cobelli (1), I. Jonkers (3).
(1) Department of Information Engineering, University of Padova, Padova, Italy
(2) Department of Clinical Medicine and Metabolic Disease, University Polyclinic, Padova, Italy
(3) Department of Kinesiology, KU Leuven, Leuven
Main topics: Musculoskeletal modeling, Analysis of clinical movement data

INTRODUCTION and AIM

Gait characteristics and balance are altered in diabetic neuropathic patients (DNS) [1]. Muscle strength significantly contributes to lower limb joints loading during walking and recently attention has being focused on specific training in order to improve gait speed, balance, muscle strength and joint mobility in DNS [2]. Even though state of art of quantitative muscle strength evaluation relies on isokinetic dynamometry [2], a comprehensive biomechanics evaluation should integrate joints kinematics and muscle function during gait. The objective of this study was to evaluate whether DNS exhibit lower limb muscle strength deficits compared to controls(CS). With this purpose musculoskeletal modelling was applied to estimate DNS and CS' muscle forces.

PATIENTS/MATERIALS and METHODS

Seven CS (mean±SD age 62.8±7.1 and BMI 24.3±2.9) and 7 DNS (mean±SD age 57.2±4.1, BMI 24.16±1.8) have been enrolled at the University Clinics of Padova Hospital. The protocol has been approved by the local Ethic Committe. Subjects routine gait analysis was performed and lower limb joints kinematics, kinetics, time and space parameters estimated by means of a modified version of the IORgait protocol as [1]. Gait analysis data were processed either as in [1], or with Opensim (v3.2) and 3D lower limb joints kinematics and kinetics calculated. In Opensim data were processed as follows: scaling, inverse kinematics (IK), inverse dynamics (ID), static optimization, residual reduction algorithm [3]. Joint kinematics and kinetics derived from the modified IORgait were used as ground truth for evaluating the simulations results of ID and IK, and Person correlation coefficient between curves estimated. Afterword envelope shapes, peak values and position with respect to the gait cycle, estimated directly from the experimental data, were used as ground truth for static optimisation outcome measures.

RESULTS

In agreement with state of art[1], both methodologies were able to highlight differences in joint kinematics and kinetics between DNS and CS on all joints' angles and moments (see Figure 1) apart from pelvis-and hip adduction and lumbar angle (angles: $P<0.019$, moments: $P<0.039$). Furthermore musculoskeletal modelling showed significant differences between DNS and CS' gluteus medius, gastrocnemius lateralis and peroneus longus muscles forces and envelopes peaks position in % of stance phase of gait ($p<0.05$). Low to good agreement (Fig 1) was found between gait variables obtained with both techniques (angles: CS $0.2<R<0.7$ DNS $0.1<R<0.7$; moments: CS $0.2<R<0.9$, DNS $0.3<R<0.9$).

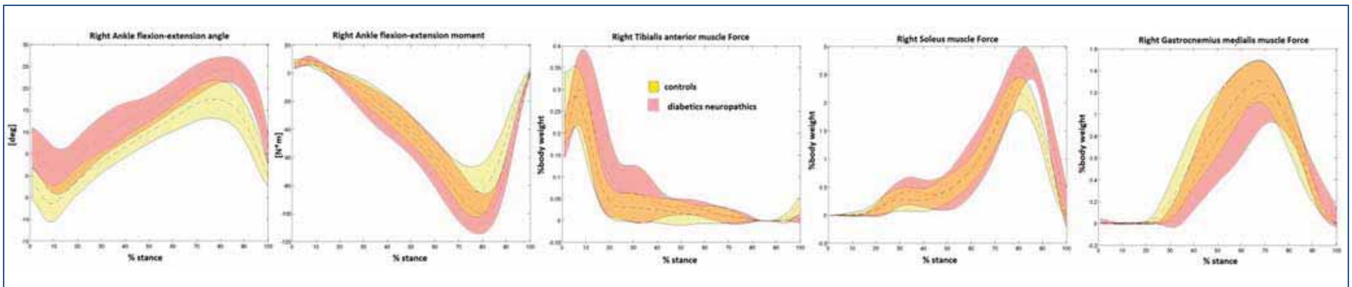

Figure 1: Mean/SD of ankle flex-extension rotation/moment, muscles forces related to ankle function. DNS (red), CS (yellow).

DISCUSSION and CONCLUSIONS

Besides different assumptions between models [1, 3] results showed good agreement between musculoskeletal simulation results and state of art gait analysis with respect to the trunk (internal-external) and ankle (flex-extension) rotations and of each joints moments in the sagittal plane ($0.6<R<09$). The methodology presented herein may strengthen DNS training programs' planning by providing opportunity towards a more targeted approach for identification and management of DNS which may benefit from these type of treatments.

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LANDING AND INJURIES: THE INFLUENCE OF HIP ABDUCTOR FATIGUE

S. Gafner (1,2), I.M. Punt (1,3), S. Armand (3), N. Place (4), L. Allet (1,3)
(1) University of Applied Sciences of Western Switzerland HES-SO, Geneva, Switzerland
(2) Zurich University of Applied Sciences, Winterthur, Switzerland
(3) University Hospitals and University of Geneva, Geneva, Switzerland
(4) University of Lausanne, Lausanne, Switzerland

Main topics: Analysis of clinical movement data, Orthopaedics

INTRODUCTION and AIM

Many popular sports like running, athletics, soccer or handball induce injuries to the lower extremity [1]. Knee injuries mostly happen during jumping, cutting or decelerating movements [2]. The influence of hip abductor fatigue or weakness on injuries appearing during such challenging tasks is not yet well understood [3].

The aim of the present study is to examine the influence of hip abductor fatigue of healthy volunteers on the performance of landing after a single leg jump and sidestep cutting maneuver. We hypothesize that knee valgus angles increase at landing after having fatigued the hip abductor muscles.

PATIENTS/MATERIALS and METHODS

Twenty physically active participants performed a single leg jump and sidestep cutting maneuver before (pre-fatigue) and after (post-fatigue) having realized a hip-abductor fatigue protocol. The protocol consisted of repetitive side-lying 30° hip abduction movements in a rhythm of 60 beats per minute, until participants were not able to touch the 30° abduction bar in 2 consecutive movements. Kinematic data of the knee and trunk (angle and timing, Vicon Mx3+, Vicon Peak, Oxford, UK) as well as EMG activity (onset, peak and mean activity during 500 ms after initial contact, Aurion ZeroWire, Milan, Italy) of the *m. gluteus medius* (GM), *m. tensor fasciae latae* (TFL), *m. vastus medialis* (VM) and *m. erector spinae* (ES) were recorded during the tests before and after the fatigue protocol.

RESULTS

Hip abductor fatigue increased the maximum knee angle into varus direction during the single leg jump (pre-fatigue: 6.2±6.6°, post-fatigue: 8.3±7.1°, $P<0.05$). For the side-step cutting maneuver, no differences in knee kinematics were observed due to fatigue. Trunk obliquity was not influenced by hip abductor fatigue during the single-leg jump. However, the occurrence time of the maximum angle was delayed after fatigue (pre-fatigue: 183±223ms, post-fatigue: 244±231ms, $P=0.01$) for the side-step cutting maneuver.

EMG onset of the GM, ES and VM was delayed during the single-leg jump test ($P<0.05$). In addition, VM peak (mV) and mean muscle activities of the TFL and VM (mV) were increased after the fatigue protocol ($P\leq0.04$, Table 1). Fatigue increased the ES peak and mean TFL EMG activity during side-step cutting ($P<0.03$, Table 1)

DISCUSSION and CONCLUSIONS

Contrary to our hypothesis, hip abductor fatigue does not seem to accentuate the knee valgus position at landing. Our results rather showed an increased varus direction and delayed maximum trunk obliquity. Furthermore muscle activity during both tests is affected by hip abductor fatigue.

Table 1: Muscle activity during single-leg jump and side-step cutting maneuver. Values are median ± interquartile range (IQR).

		Single-leg jump			Side-step cutting		
		Onset (ms)	Peak (mV)	Mean (mV)	Onset (ms)	Peak (mV)	Mean (mV)
GM	Pre-fatigue	-198 ± 37	0.08 ± 0.09	0.05 ± 0.05	-184 ± 40	0.08 ± 0.12	0.03 ± 0.05
	Post-fatigue	-174 ± 34	0.08 ± 0.13	0.03 ± 0.05	-174 ± 46	0.08 ± 0.11	0.03 ± 0.06
	P value	*0.01**	*0.40*	*0.66*	*0.15*	*0.63*	*0.57*
ES	Pre-fatigue	- 196 ± 48	0.04 ± 0.06	0.02 ± 0.03	-184 ± 43	0.04 ±0.04	0.02 ± 0.03
	Post-fatigue	-171 ± 36	0.06 ± 0.08	0.03 ±0.05	-185 ± 49	0.06 ± 0.11	0.02 ± 0.05
	P value	*<0.05**	*0.09*	*0.06*	*0.87*	*0.02**	*0.09*
TFL	Pre-fatigue	- 126 ± 92	0.04 ± 0.12	0.01 ± 0.03	- 96 ± 32	0.03 ± 0.16	0.01 ± 0.04
	Post-fatigue	- 113 ± 83	0.07 ± 0.12	0.02 ± 0.07	- 111 ± 90	0.08 ± 0.27	0.02 ± 0.06
	P value	*0.06*	*0.20*	*0.02**	*0.32*	*0.21*	*0.02**
VM	Pre-fatigue	-193 ± 53	0.09 ± 0.14	0.04 ± 0.05	-175 ± 102	0.10 ± 0.18	0.04 ± 0.06
	Post-fatigue	-171 ± 28	0.12 ± 0.23	0.06 ± 0.08	-174 ± 39	0.11 ± 0.19	0.06 ± 0.09
	P value	*0.03**	*0.03**	*0.04**	*0.78*	*0.97*	*0.05*

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HOW IS PERIPHERAL VISUAL INFORMATION USED FOR STAIR CLIMBING?

V. Graci (1), M. Rabuffetti (2), M. Ferrarin (2)
(1) Department of Neurology, University of Maryland, Baltimore, MD.USA
(2) Biomedical Technology Department, IRCCS Don Carlo Gnocchi Foundation, Milano, Italy

Main topics: Motor control and motor learning, Experimental studies in human movement science

INTRODUCTION and AIM

The importance of peripheral visual cues during stair climbing is unclear. Previous authors examining fixation behaviour on staircases found that gaze fixation during stair climbing was occurring 2-4 steps ahead and that, surprisingly, transition steps (e.g. last step) did not require more fixation than mid-steps [1]. It was postulated that the knowledge of predictable characteristics of the steps may decrease the reliance on foveal vision and transfer the visual guidance of stair climbing to peripheral vision [1]. Hence the aim of this study was to investigate if and how peripheral lower visual occlusion influenced stair climbing and if peripheral visual information was weighted differently between staircase steps.

PATIENTS/MATERIALS and METHODS

Ten male participants (age range: 24-37 years) ascended a 5-step staircase 3 times under 2 visual conditions: full vision (FV) and lower visual occlusion (LO) provided by glasses that prevented the participants from gathering peripheral visual information from the lower limbs. Kinematic data (100 Hz) were collected with an 8-camera 3D-motion capture system (ELITE, BTS Milan, Italy). The effect vision (FV and LO) and step (1st, 2nd, 3rd, 4th and 5th) on vertical forefoot clearance was examined with a Repeated Measures 2-way ANOVA ($p<=0.05$). Tukey's HSD test was used for post-hoc comparisons.

RESULTS

A significant main effect of step ($p<0.003$) and interaction vision x step ($p<0.012$) were found. Post-hoc tests showed that vertical forefoot clearance was greater for the 5th step compared to the other steps ($p<0.002$) and in LO compared to FV condition only for the 1st and the 2nd steps ($p<0.013$).

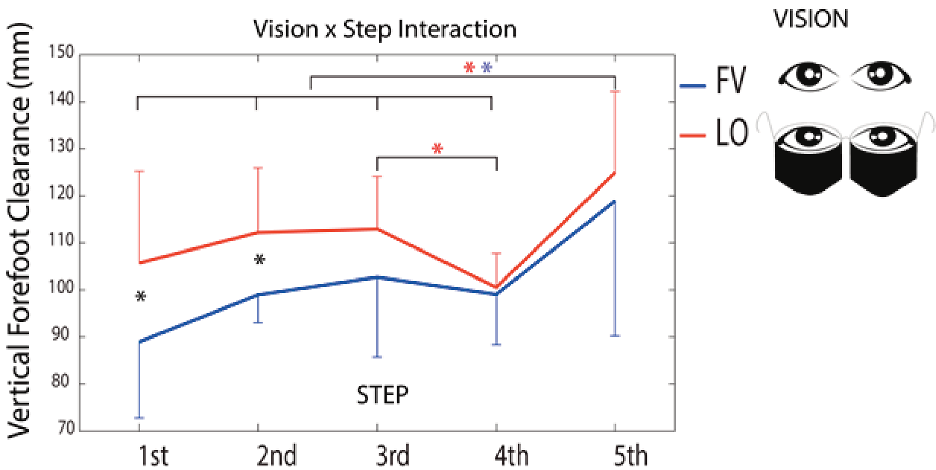

Fig1. Group of Means (SD) of the vertical forefoot clearance. Error bars represent the standard deviation. Black asterisks represent significant differences between visual conditions, blue asterisks represent significant differences between steps in FV and red asterisks represent significant differences between steps in LO.* P<0.05

DISCUSSION and CONCLUSIONS

The vertical forefoot clearance of the first two steps was greater in LO, suggesting that peripheral vision may be needed to provide online visual guidance for fine-tuning foot placement [2]. However the 3rd, 4th and 5th steps were not influenced by LO. These results may lead to different hypothetical interpretations. First, proprioceptive information about the limb position might compensate for the absence of peripheral visual cues after the second step because of the predictability of step height. Second, while climbing on the first step, the line of sight would be roughly aligned with the 4th/5th steps, enhancing visual working memory of the step height of the last 2 steps. Third, considering that the vertical forefoot clearance on the 5th step was greater compared to all the other steps in both visual conditions, the last step of the staircase may require a different motor planning that may not rely on peripheral visual guidance. In conclusion, these findings seem to suggest that peripheral visual information might be more relevant when approaching the first few steps, rather than the end of a staircase.

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EVALUATION OF KNEE FLEXORS AND EXTENSORS ISOKINETIC TORQUE AND IGF-1 / IGFBP-3 CONCENTRATIONS AFTER ECCENTRIC TRAINING IN CHRONIC HEMIPARETIC SUBJECTS

CC. Alcântara (1), MA. Silva-Couto (1), CL.Prado-Medeiros (1), TF. Salvini (1), TL. Russo (1)
(1) Federal University of Sao Carlos (UFSCar), Sao Carlos, Brazil

Main topics: Motor control and motor learning, Rehabilitation

INTRODUCTION and AIM

The effects of strengthening training on force generation and on molecular mechanisms of neuroplasticity and muscle trophism in chronic post-stroke subjects remain unclear. The aim of the present study was to evaluate the effect of knee flexors and extensors eccentric strength training on their concentric and eccentric peak torque and serum insulin-like growth-factor 1 (IGF-1) and insulin-like growth-factor binding protein 3 (IGFBP-3) concentrations in chronic post-stroke subjects compared to healthy ones.

PATIENTS/MATERIALS and METHODS

Eccentric training was performed three times a week, during 12 weeks, using an isokinetic dynamometer. Serum IGF-1 and IGFBP-3 concentrations were analyzed by ELISA. Concentric and eccentric peak torque were assessed by isokinetic dynamometer trials at 60°/s. Comparisons between groups were performed using independent-T-test or Mann-Whitney, in both pre- and post-training periods. Comparison between pre- and post-training in hemiparetic group was performed using a paired-samples T-test or Wilcoxon.

RESULTS

Eighteen subjects (hemiparetic: n=9; control: n=9, matched for age, gender and body mass) participated in this study. No differences were observed between pre- and post-training serum IGF-1 concentrations in hemiparetic group, as well as compared to control group (p>0,05). Serum IGFBP-3 concentrations also showed no differences between pre- and post-training in hemiparetic group, although a decrease was observed in its concentration compared to control group in pre- and post- training (p=0,01). Regarding peak torque, paretic limbs presented lower values for both concentric and eccentric peak torque compared to control ones during pre- and post-training analyses (p>0.05). Nevertheless, an increase in concentric peak torque was observed in both paretic knee extensors (p=0,04) and flexors (p=0,03) post-training comparing to pre-training.

DISCUSSION and CONCLUSIONS

Eccentric strengthening training was capable to induce gains in force generation, specifically in concentric torque of knee extensors and flexors of chronic hemiparetic subjects. These changes were not associated with serum IGF-1 and IGFBP-3 concentrations changes throughout the training, despite decreased IGFBP-3 concentrations compared to control in both pre- and post-training.

COMPUTERIZED FIDGETY MOVEMENT ASSESSMENT IN INFANTS WITH HIGH RISK OF NEUROLOGICAL IMPAIRMENTS

EAF. Ihlen (1), L. Adde (2, 3), R. Støen (2,4)
(1)Department of Neuroscience, Norwegian University of Science and Technology, Trondheim, Norway
(2)Department of Laboratory Medicine, Children's and Women's Health, Norwegian University of Science and Technology, Trondheim, Norway
(3) Clinics of Clinical Services, St. Olavs University hospital, Trondheim, Norway
(4) Department of Pediatrics, St. Olavs University hospital, Trondheim, Norway

Main topics: Methodology paper

INTRODUCTION and AIM

Abnormal movements in infants with high risk of neurological impairments are a strong marker for later cerebral palsy (CP). Today, the detection of abnormal movements is based on detection and classification of fidgety movements (FM) by general movement assessment (GMA) [1]. GMA classify fidgety movements into four categories; continuous (FM++), intermittent (FM+), sporadic (FM-/+), and absent (FM), where FM-/+ and FM- is defined as as abnormal infant movements indicating a high risk of later disability. Computerized detection of FMs may be a more objective way to identify abnormal movements in high risk infants [2]. Several computerized methods have been developed the last decade for infant movement assessment, but few of them detect clinically important movement patterns, like FMs, and few of them have been tested on a relevant populations of high risk infants. The aim of the present study was to evaluate a computerized detection of abnormal movement in a sample of high risk infants.

PATIENTS/MATERIALS and METHODS

GMA was performed on video recordings from the fidgety movement's period (10-15 weeks) in 146 infants with high risk of developing CP. The same videos were analyzed using computer vision software which derived outcome variables from the calculation of displacement of pixels from one video frame to the next [3]. The software derived five variables from computerized infant movement assessment, the standard deviation of the displacement of the centroid of motion (Csd), the mean and standard deviation of the quantity of motion (Qsd, Qmean) and two composite variables, CPP and FMD, of the former three. These variables have been shown in previous studies to be most sensitive detecting FM and predicting CP [2,4]. Sensitivity and specificity and area under ROC curve (AuC) were defined for several outcome variables.

RESULTS

Of the five quantitative variables derived, Csd, CPP and FMD had the highest sensitivity (80.0) and specificity (52.0 to 61.0) in classifying normal and abnormal GMs (see Table 1). The specificity (81.0 to 100) was improved in classifying complete absence (FM-) and continual presence (FM++) of FMs (see Table 2).

Table 1: Specificity and area under ROC curve (AuC) for distinguishing between normal and abnormal GM for variables derived from CIMA when sensitivity was set to 80%

Variables	Specificity	AuC
Qmean	27	0.56 (0.45, 0.66)
Qsd	28	0.56 (0.45, 0.67)
Csd	52	0.70 (0.61, 0.79)
CPP	57	0.75 (0.67, 0.83)
FMD	61	0.75 (0.67, 0.84)

CPP (Cerebral Palsy Predictor) = Qmean+Qsd+Csd;

Table 2: Specificity and area under ROC curve (AuC) for distinguishing between total presence (FM++) and total absence (FM-) of FMs for variables derived from CIMA when sensitivity was set to 80%

Variables	Specificity	AuC
Qmean	54	0.68 (0.52, 0.84)
Qsd	7	0.54 (0.36, 0.72)
Csd	81	0.90 (0.80, 0.99)
CPP	94	0.94 (0.86, 1.00)
FMD	100	0.94 (0.87, 1.00)

FMD (Fidgety Movements Detector) = Qsd+Csd

DISCUSSION and CONCLUSIONS

The performance in detecting abnormal General Movements was poorer compared to previous studies [2,4], but improved considerably when differencing between continual presence (FM++) and absence (FM-) of FMs. The present results suggest that the method is not precise enough in detecting the temporal organization of FMs in infants with intermittent (FM+) and sporadic (FM-/+) FMs. Furthermore, the distribution of the different categories of of FMs may be different between a group of infants with high risk of later neurological impairment and a group of a mix of high risk and normal infants included in a former study using the same method [2]. Nevertheless, the outcome variables evaluated in the present study is an important step in the development of more cost effective clinical detection of abnormal GMs.

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17:00-18:00 **Aula Major**	**ORTHOTICS / PROSTHETICS** ***Chairs: Han Houdijk, Vincent de Groot***
17:00-17:10	EFFECTS OF ANKLE-FOOT BRACES ON SPASTIC MEDIAL GASTROCNEMIUS MORPHOMETRICS IN CHILDREN WITH CEREBRAL PALSY *M. Hösl, H. Böhm, A. Arampatzis, L. Döderlein*
17:10-17:20	SUCCESSFULLY USING A PASSIVE APPROACH IN UPPER-LIMB ROBOTIC REHABILITATION OF CHRONIC STROKE PARTIENTS *M. Caimmi, A. Chiavenna, F. Digiacomo, G. Gasperini, C. Giovanzana, M. Malosio, N. Pedrocchi, A. Scano, F. Vicentini, F. Molteni, L. Molinari Tosatti*
17:20-17:30	ALTERED LOWER LIMB MOMENTS IN PATIENTS WITH KNEE OSTEOARTHRITIS DURING A CONTROLLED SIT-TO-STAND MOVEMENT *S.J. Preece, T. Cacciatore, R. Jones*
17:30-17:40	THE RESPONSE OF THE SHANK-TO-VERTICAL-ANGLE TO MANIPULATIONS OF THE ANKLE-FOOT ORTHOSIS FOOTWEAR COMBINATION *Y. Kerkum, H. Houdijk, M. Kessels, A. Sterk, F. Steenbrink, J. van den Noort, M. Brehm, A. Buizer, J. Becher, J. Harlaar*
17:40-17:50	EVOLUTION OF KNEE KINEMATIC THREE MONTHS AFTER TOTAL KNEE REPLACEMENT *A. Bonnefoy-Mazure, S. Armand, Y. Sagawa Jr, P. Hoffmeyer, H. Miozzari, D. Suvà, K. Turcot*
17:50-18:00	IMMEDIATE KINEMATIC AND MUSCLE ACTIVITY ADAPTATIONS IN HABITUALLY SHOD REARFOOT STRIKERS DURING BAREFOOT RUNNING *J. Strauts, N. Vanicek, M. Halaki*

EFFECTS OF ANKLE-FOOT BRACES ON SPASTIC MEDIAL GASTROCNEMIUS MORPHOMETRICS IN CHILDREN WITH CEREBRAL PALSY

M. Hösl(1), H. Böhm(1), A. Arampatzis (2), L.Döderlein (1),
(1) Orthopaedic Hospital for Children, Aschau i. Chiemgau, Germany
(2) Humboldt University of Berlin, Department of Training and Movement Sciences, Berlin, Germany

Main topics: Musculoskeletal imaging, Orthotics, Analysis of clinical movement data

INTRODUCTION and AIM

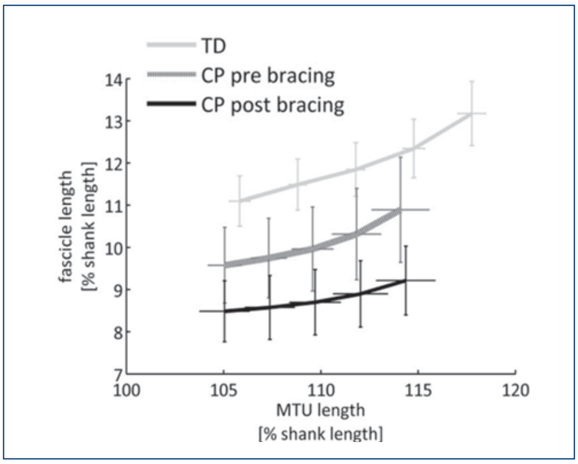
In Cerebral Palsy (CP) bracing of the ankle is a common treatment for spastic, non-rigid equinus. Reviews indicate increased joint excursion and positive effects on gait [1]. Yet, effects on plantarflexor morphometrics are unclear. While muscle stretch by bracing is a potential stimulus for tissue growth, immobilization could also promote atrophy. We examine the effects of ankle-foot braces on spastic medial gastrocnemius (MG) morphometrics while referencing to controls. We hypothesized that morphometrics in CP would develop towards reference values.

PATIENTS/MATERIALS and METHODS

17 children with spastic CP (9/8 uni- and bilaterally involved, 7/10 GMFCS I and II, aged 10±2 years) and non-rigid equinus were analyzed before and after 4.2±1.8 months of ankle-foot bracing. 15 typically developing (TD) (aged 9±3 years) served as reference. MG muscle belly (L_{MB}), fascicle (L_{FAS}) and tendon lengths (L_T) were captured by 2D ultrasound imaging and tracking of the muscle-tendon junction and mid-belly fascicles during passive, manually applied stretches [2,3]. The ultrasound videos, probe position and leg movement were simultaneous captured with a Vicon System. L_{MTU} was geometrically derived [4]. For L_{MTU}, L_{MB}, L_{FAS} and L_T, peak values and extensibility [%] were calculated. To analyze L_{MB}, L_{FAS} and L_T at similar states, the L_{MTU} at 50% stretch was used. To standardize comparison between CP and TD, the average midrange L_{MTU} from CP was used to extract parameters for TD. To compare morphometrics before and after bracing, L_{MB}, L_{FAS} and L_T were extracted at individually matched midrange L_{MTU}.

RESULTS

Prior to bracing, the entire MTU extensibility was on average 22% less in children with CP and ultimate L_{MTU} was 3% shorter (both *P*<0.01). At midrange MTU stretch, the L_{MB} and L_{FAS} were 10% and 14% shorter while L_T was 11% longer (all *P*<0.03). Overall, spastic fascicles only displayed 57% of the elongation seen in TD (*P*=0.023). After bracing, the MTU, L_{MB} and L_T did not significantly lengthen but at matched degrees of muscle-tendon unit stretch further 12% of L_{FAS} were lost (*P*=0.047). The diminished contribution of the fascicles to MTU extensibility was seemingly compensated for by more compliant tendons.



DISCUSSION and CONCLUSIONS

Before the treatment, children with CP had shorter MG muscle bellies but longer tendons than TD [5,6]. Also the finding of shorter and less extensible fascicles agrees with recent reports [7,8]. Fewer sarcomeres or the accumulation of connective tissue could be responsible.

Strikingly, below knee braces failed to improve MG morphometrics. Further shortened fascicles after ankle-foot bracing are concerning and likely display longitudinal atrophy caused by a loss of sarcomeres typical for immobilization at short muscle length [9]. Thus bracing might have kept the bi-articular MG generally off-tension or potentially decreased the MG use. We assume that the positive treatment outcomes seen during gait are induced by uni-articular structures (eg. soleus), could be only habitual or primarily rely and altered neural activation. In summary, construction of below knee braces for spastic equinus needs to be reconsidered and complementary treatments are needed to promote MG muscle growth.

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SUCCESSFULLY USING A PASSIVE APPROACH IN UPPER-LIMB ROBOTIC REHABILITATION OF CHRONIC STROKE PARTIENTS

M. Caimmi (1), A. Chiavenna (1), F. Digiacomo (2), G. Gasperini(2), C. Giovanzana (2), M. Malosio (1), N. Pedrocchi (1), A. Scano (1), F. Vicentini (1), F. Molteni (2), L. Molinari Tosatti (1).
(1) Institute of Industrial Technologies and Automation, Council of National Research of Italy, Milan, Italy
(2) Villa Beretta Rehabilitation Center –Valduce Hospital, Costa Masnaga (LC), Italy.

Main topics: Assistive devices; Rehabilitation; Motor control and motor learning.

INTRODUCTION and AIM

The importance of using the *Assist As Needed* Training Paradigm (AasNTP) [1] to permit the exploration of the effort-error relationship to stimulate motor re-learning [2] is well known in upper-limb robotic rehabilitation. Concurrently, there are evidences in the literature that robotic interventions based on movements against gravity successfully reduce shoulder-elbow impairment in stroke [3]. Unfortunately the AasNTP is often of little applicability in training against gravity, especially in the case of low functioning patients. When an active control of the robot is not possible, "*passive mobilization*", based on super imposed trajectories, is the only remaining option. In the present work we present an upper-limb robotic rehabilitation protocol based on *"passive mobilization"* and the first extremely positive results obtained in chronic stroke patients.

MATERIALS and METHODS

Participants. Eight chronic stroke patients (5 males, 63±8 years old, 5 right hemiparesis, 32±25 months from the stroke). Patients were recruited during routine clinical examinations at Villa Beretta Rehabilitation Center. They were not submitted to any other kind of treatment of the upper- as well the lower limb.
Equipment. Robot platform Mitsubishi Pa10, 6 dof Force Sensor, IMU, 6 TVC optoelectronic 3D system (Elite, BTS, Italy), wireless electromyography (FreeEMG, BTS, Italia) installed at the ITIA-CNR Robotic Rehabilitation and Research Lab.
Intervention. The treatment consisted of 12 sessions (3 per week) of Super Imposed Trajectories (SIT) [4] robotic treatment. Every session consisted of 20 minutes of execution of reaching movements against gravity and 20 minutes of hand to mouth, both with a bell-shaped velocity profile. Every minute the velocity profile was scaled with peak velocities comprised between 0.30 and 0.80 m/s (slow movements were alternated to physiological ones, customizing the parameters on the patient's capability). During the mobilization, the patient was alternately asked to relax or to try to actively follow the rigidly imposed movement.
*Measures. F*ugl-Meyer (FM), Motricity Index (MI), Medical Research Council (MRC), Modified Ashworth Scale (MAS). Interaction Forces/torques and EMG activation pattern

RESULTS

All patients, but one, improve in the performance of active movements (FM section D, mean increment 5(±5) points, $p < 0.01$) see Fig.1. This patient, an high functioning one (FM=48/61), improved in shoulder abduction and elbow extension force (4 to 5 in MCR). Also MAS at the elbow decreased from 2 to 1.
Further, 4 patients referred reduced pain (increase 3.5±2.5), 5 patients improved in MAS (at least 1 point). Interestingly, almost all patients referred improvements at wrist and hand although the intervention was intended for shoulder and elbow functional recovery only. More interestingly, general improvements were not correlated to time distance from the stroke event.

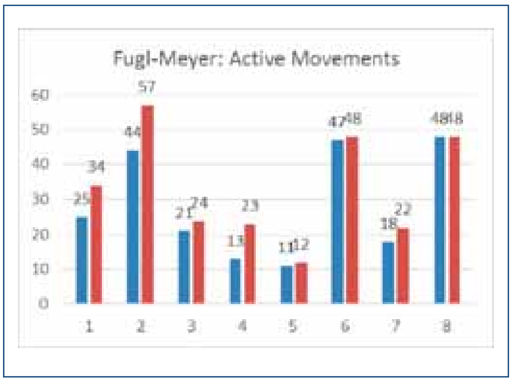

Fig.1 FM of each patient pre-intervention (blue) and post-intervention (red).

DISCUSSION and CONCLUSIONS

First results demonstrate the validity of a robotic training based on functional movements against gravity even if based on "*passive mobilization*". Results are extremely positive considering the short time of intervention (1 month) and the time of distance from the event. Further studies will be performed in the next months to verify whether patients can benefit from a longer intervention. Further investigations based on EEG acquisitions will be performed for verifying and trying to demonstrate the presence of neuroplasticity effects.

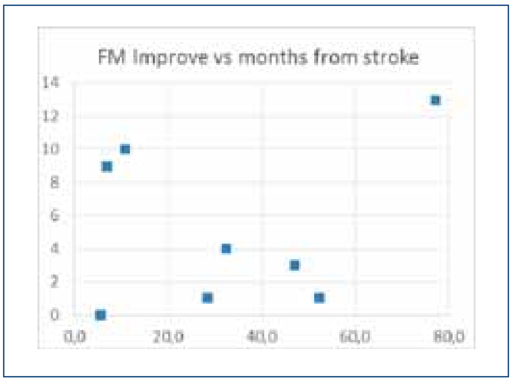

Fig.2 FM score of each patient vs months from stroke event.

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ALTERED LOWER LIMB MOMENTS IN PATIENTS WITH KNEE OSTEOARTHRITIS DURING A CONTROLLED SIT-TO-STAND MOVEMENT

S.J. Preece[1], T. Cacciatore[2], R. Jones[1]
[1]School of Health Sciences, University of Salford, UK & [2]Institute of Neurology, UCL, UK

INTRODUCTION and AIM

Numerous studies have demonstrated that individuals with knee osteoarthritis (OA) exhibit alterations in sagittal joint moments during the sit-to-stand movement [1,2]. However, previous experimental protocols have failed to standardised movement speed [1,2]. It is therefore unclear whether the reported differences are a consequence of altered motor control strategies or simply result from differences in the demands of the task. The aim of the study was to compare lower limb moments between patients with knee OA and healthy controls during a tightly constrained sit-to-stand movement.

PATIENTS/MATERIALS and METHODS

Twenty participants with OA were matched with 20 healthy participants for age, weight and height. Each participant performed five repetitions of a controlled sit-to-stand movement whilst kinematic data was collected from the lower limbs and pelvis and force data collected under each foot. The starting position for the movement was constrained such that seat height was 1.05% of fibula head height, greater trochanter position was 5cm back from the edge of the seat and the shank aligned to be 10° to the vertical. Participants were then instructed to stand up smoothly over a two-second period. Time to perform the movement was calculated using the change in orientation of a set of kinematic markers positioned on the upper back. Following each trial, subjects were given feedback on movement speed until they were able to perform the movement over 2±0.2 seconds. Trials were then aligned so that t=0 corresponded to 50% weight transfer.

RESULTS

There were no differences in peak hip or knee extensor moment between the groups on either the affected or non-affected side. However, patients with knee OA had a lower peak dorsiflexor moment ($p<0.05$) on both sides and a reduced knee extensor moment during the extension phase ($p<0.01$) on the affected side.

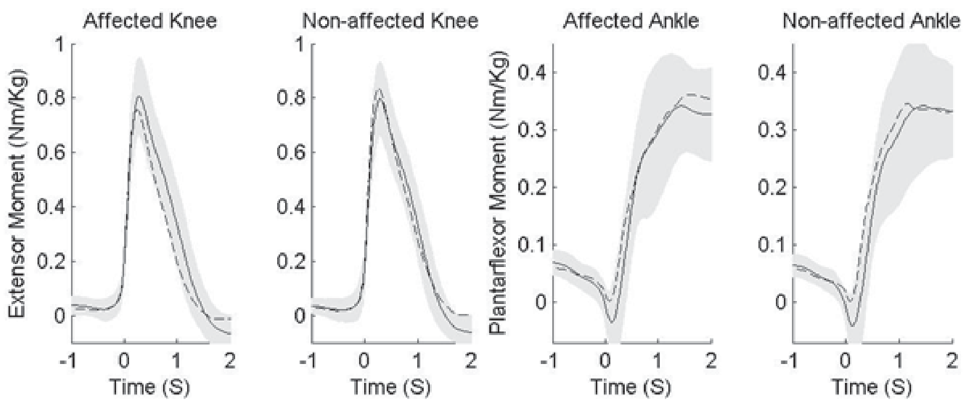

Figure 1: Ankle and knee moments, normalised to body mass, for healthy (solid) and knee OA (dashed) subjects with envelopes illustrating the standard deviation of the healthy group.

DISCUSSION and CONCLUSIONS

Patients with knee OA appear to adopt a strategy characterised by a reduced ankle dorsiflexor moment during the momentum transfer phase and a reduced knee extensor moment during the extension phase of a constrained and challenging sit-to-stand movement. A lower peak dorsiflexion moment requires the body to travel further forward to rise successfully and therefore could affect performance ability.

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THE RESPONSE OF THE SHANK-TO-VERTICAL-ANGLE TO MANIPULATIONS OF THE ANKLE-FOOT ORTHOSIS FOOTWEAR COMBINATION

YL. Kerkum (1,2), H. Houdijk (2,3), MLC. Kessels (2), A. Sterk (2), F. Steenbrink (4), JC. van den Noort (1,2), MA. Brehm (1,2), AI. Buizer (1), JG. Becher (1,2), J. Harlaar (1,2)
(1) Department of Rehabilitation Medicine, VU University Medical Center, Amsterdam, The Netherlands
(2) MOVE Research Institute Amsterdam, Faculty of Human Movement Sciences, VU University, Amsterdam, The Netherlands
(3) Heliomare Rehabilitation, Research and Development, Wijk aan Zee, The Netherlands
(4) Motek Medical BV, Department of New Product Development, Amsterdam, The Netherlands

Main topics: Analysis of clinical movement data, rehabilitation, orthotics

INTRODUCTION and AIM

Ankle-Foot Orthoses (AFOs) aim to intervene in gait deviations of children with Cerebral Palsy by normalizing joint kine(ma)tics[1]. Tuning of the AFO Footwear Combination (AFO-FC) to align the Ground Reaction Force with respect to the joints may optimize the effectiveness[3]. The Shank-to-Vertical-Angle (SVA) in midstance has been proposed as an effective indicator[4]. However, quantitative data on the effects of tuning on joint kine(ma)tics based on the SVA are lacking[5]. This study aims to investigate how manipulations of the AFO-FC affect the SVA and how this reflects changes in joint angles and net moments during walking.

PATIENTS/MATERIALS and METHODS

Nine healthy subjects walked at comfortable speed on a split-belt instrumented treadmill (GRAIL, Motek Medical BV, the Netherlands), while 3D kinematic and kinetic data were processed in real-time. Subjects were provided with bilateral rigid dorsal shelf AFOs and shoes. AFO-FC manipulations included changing the heel height using wedges (i.e. low, medium and high), each combined with a flexible or stiff footplate. The SVA and sagittal hip, knee and ankle angles and net joint moments of the right leg (25 strides) during midstance were determined.

RESULTS

The SVA significantly increased with increasing heel height ($p<.001$). No effect of footplate stiffness was found on the SVA, nor an interaction effect of heel height with footplate stiffness. In concert with the change in SVA, knee flexion angle and internal knee extensor moment increased with increasing heel height ($p<.001$). The stiff footplate inhibited this effect, as shown by a significant interaction effect of heel height and footplate stiffness ($p=.02$) on knee angle (knee moment ($p=0.051$)) (Figure 1). Effects of the manipulations on the hip and ankle kine(ma)tics were marginal.

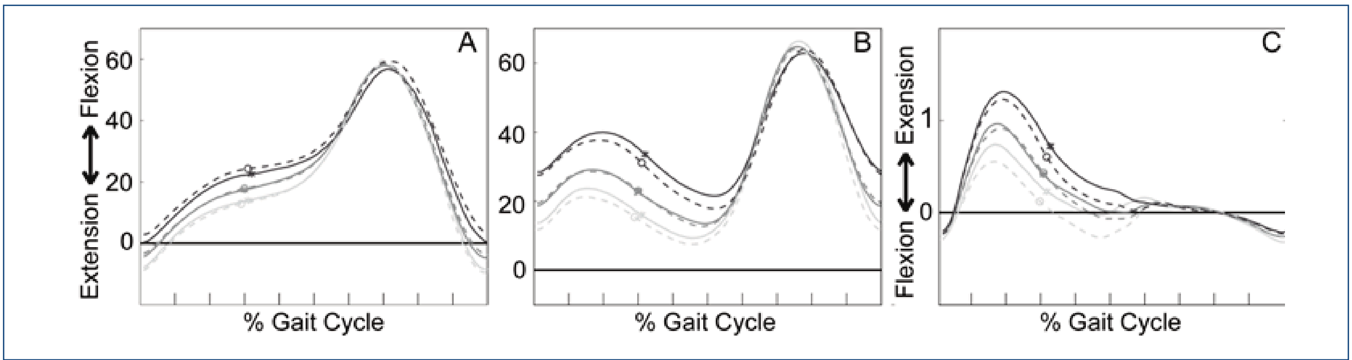

Figure 1. Mean (N=9) SVA [degrees] (A), sagittal knee angle [degrees] (B) and internal knee moment [Nm·kg-1] (C) for each trial averaged over the last 25 strides and normalized to percentage gait cycle. Light grey, low heel height; dark grey, medium heel height; black, high heel height; solid, flexible footplate; dotted, stiff footplate; *, midstance of flexible footplate trials; o, midstance of stiff footplate trials.

DISCUSSION and CONCLUSIONS

In healthy subjects walking with bilateral rigid AFOs, the SVA seems responsive to changes in heel height, and reflects concomitant changes in sagittal knee kine(ma)tics in midstance. The SVA seems less responsive to changes in footplate stiffness.

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EVOLUTION OF KNEE KINEMATIC DURING GAIT THREE MONTHS AFTER TOTAL KNEE REPLACEMENT

A. Bonnefoy-Mazue (1), S. Armand (1),Y. Sagawa Jr (2), P. Hoffmeyer (1), H. Mozziari (1), D.Suvà (1), K. Turcot (3)
(1) Geneva University Hospitals and Geneva University, Geneva, Switzerland.
(2) Laboratoire d'Exploration Fonctionnelle Clinique du Mouvement, CHRU de Besançon, France.
(3) Department of Kinesiology, Laval University, Quebec, Canada.

INTRODUCTION and AIM

In patients with debilitating knee osteoarthritis (OA), total knee replacement (TKR) is the most common surgical procedure [1]. Numerous studies have demonstrated that knee kinematics one year after total knee replacement are still altered compared to the healthy joint [2,3]. However, little is known regarding impairments and functional limitations of patients several months after total knee replacement [4,5]. The aim of this study was to investigate the evolution of the knee kinematic during gait in patients with knee OA before and three months after a TKR.

PATIENTS/MATERIALS and METHODS

Ninety patients who were to undergo total knee replacement were included in this study (54 females and 36 males). Twenty-three subjects (10 females and 13 males) were recruited as the control group. Sixty-eight patients received a PFC Sigma® TKR (Depuy Orthopaedics, Inc., Warsaw, IN, USA) and 22 patients received a GMK System® TKR (Medacta, Inc, Castel San Pietro, Switzerland). All patients went through a standard rehabilitation program. Three-dimensional gait analysis was performed before (V1) and three months after surgery (V2). The spatio-temporal parameters and three-dimensional knee kinematics for the operated limb were evaluated during a comfortable gait and compared before and after surgery and with the control group. The control group walked at their comfortable speed and at a matched speed with patients. Statistical analyses were performed to compare V1 and V2 using paired Student t-test. Then to compare the two sessions (V1 and V2) with the control group, a unpaired Student t-test was used

RESULTS

Three months after surgery, patients walked with a slower gait velocity compared to control group at comfortable speed (Figure 1) and walked with lower knee flexion-extension movements compared to the control group at matched speed (Table 1). However, some progression was observed in term of the stride and step length, gait velocity and knee alignment in the coronal plane.
Thus, 30 % of the patients showed an increase in their gait velocity, 48 % of them were stable and in 22 %, there was degradation.

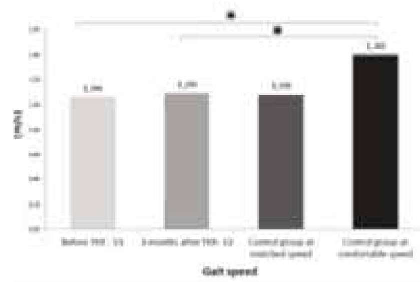

Figure 1: Gait speed (m/s) comparisons between patient groups before (V1) and after TKR (V2) and control group at matched and comfortable speed.

Table 1: Kinematic comparisons between patient and control groups: before TKR (V1), three months after TKR (V2) and control group at matched walking speed (C1). Significant differences (p<0.05) are marked in bold.

Knee Kinematics - Operated limb	Patients Before TKR (V1) (n=90) mean (SD)	Patients After TKR (V2) (n=90) mean (SD)	Control Group Matched speed (C) (n=46) mean (SD)	P value V1 / V2	P value V1 / C	P value V2 / C
Flexion range - loading response (°)	4.67 (2.02)	4.00 (1.83)	6.13 (2.52)	< 0.05	< 0.05	< 0.05
Range of Motion (ROM) - gait cycle (°)	43.49 (10.09)	41.93 (9.57)	54.89 (5.16)	0.103	< 0.05	< 0.05
Adduction/Abduction mean absolute value - stance (°)	7.28 (5.44)	3.73 (3.05)	2.16 (1.74)	< 0.05	< 0.05	< 0.05

DISCUSSION and CONCLUSIONS

Our results suggest that the disability is still significant for most patients three months after total knee replacement. A better understanding of the impairments and functional limitations following surgery would help clinicians design rehabilitation programs.

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IMMEDIATE KINEMATIC AND MUSCLE ACTIVITY ADAPTATIONS IN HABITUALLY SHOD REARFOOT STRIKERS DURING BAREFOOT RUNNING

J. Strauts (1), N. Vanicek (1,2), M. Halaki (1)
(1) Discipline of Exercise and Sports Science, Faculty of Health Sciences, University of Sydney, Australia
(2) Department of Sport, Health & Exercise Science, University of Hull, United Kingdom

Main topics: Experimental studies in human movement science, biofeedback

INTRODUCTION and AIM

The design of the modern running shoe, with an elevated heel, facilitates a rearfoot strike pattern [1]. Repeatedly striking the ground with the rearfoot causes continuous exposure to high collision forces approximating 1.5-3 times body weight during the first 50 ms following contact [1]. Conversely, habitually barefoot runners exhibit mid- or forefoot strike patterns that lack a distinct impact transient and experience peak vertical forces that are 3 times lower than in shod or barefoot rearfoot strike runners [1]. The debate surrounding barefoot and minimal footwear running is ongoing with one study suggesting barefoot running will prompt mechanical changes even in highly trained shod runners [2], although this is as yet unsubstantiated. The aim of this study was to quantify the immediate kinematic and electromyographic (EMG) changes as a result of barefoot running in habitually shod, recreational, rearfoot striking runners and to follow these changes over 30 minutes.

PATIENTS/MATERIALS and METHODS

Six recreational shod runners (4 male and 2 female; mean (SD): age 31.5 (9.9) years; height 181.1 (11.1) cm; mass 74.5 (8.6) kg) with a naturally occurring rearfoot strike and with no barefoot running experience participated in this study. 3D running kinematics (MAC, USA) and EMG data (Noraxon, USA) from 8 lower limb muscles were recorded unilaterally from the dominant leg during 1) shod conditions before and after a 30-minute bout of barefoot running and 2) at 5-minute intervals during the 30 minutes. Sagittal plane kinematics were calculated for the trunk, pelvis, hip, knee, ankle and midfoot with Visual 3D (C-Motion, USA) during the middle 20 seconds of each interval captured. Joint kinematic and EMG data were exported into MATLAB where all EMG signals were filtered and rectified. The envelopes of EMG activity were normalised to the maximum value during MVC tests. Repeated measures ANOVAs were performed to compare each of the EMG activation levels and kinematic variables across the different conditions; Fisher's LSD post-hoc tests were used with significant results ($\alpha = 0.05$).

RESULTS

Participants ran significantly faster in the shod condition compared to only the first 2 minutes of barefoot running ($p<0.01$) but this was not different after 3 minutes of barefoot running ($p=0.12$), ($F(5,25)=5.45$, $p<0.01$) with a mean speed (SD) of 9.8 (1.9) km/hr. Only anterior pelvic tilt and hip flexion joint kinematics decreased significantly by ~3° and ~4°, respectively, at initial contact during the first minute of barefoot running ($p<0.05$), and continued through all barefoot conditions ($p<0.05$). These adaptations were retained in the Shod_post condition ($p<0.05$) compared to the Shod_pre condition (Figure 1). Mean EMG levels across the running cycle significantly decreased for soleus, tibialis anterior, gastrocnemius lateralis, vastus medialis and biceps femoris muscles in barefoot running compared to the Shod_pre condition ($F(8,40)\leq 2.19$, $p<0.05$).

DISCUSSION and CONCLUSIONS

Contrary to our hypothesis, barefoot running did not evoke any significant immediate kinematic changes at the ankle or midfoot joints. The midfoot joint profiles indicated a trend ($p=0.06$) that participants transitioned to a less dorsiflexed position (i.e., more flat foot) upon initial contact. Our result of significantly less hip flexion and anterior pelvic tilt was consistent with Shih et al. (2013) who reported similar findings with a forefoot running pattern, either in barefoot or shod conditions. Thus subtle adaptations distally may have translated to significant differences proximally at the hip. The biceps femoris showed the most consistent and significant results with decreased average EMG activity throughout all the barefoot trials, and was retained in the Shod_post condition compared to Shod_pre. This matched closely with the kinematic changes at the hip and pelvis.

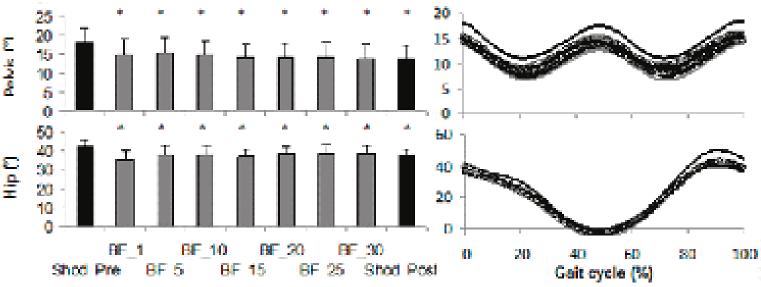

Figure 1. Anterior pelvic tilt and hip flexion angles at initial contact and across the cycle. *indicates significant difference when compared to Shod_pre, p<0.05.

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17:00-18:00 — *Aula Minor*

PLANTAR PRESSURE

Chairs: Tim Theologis, Sebastian Wolf

17:00-17:10

CLINICAL RELEVANCE OF FOOTPRINT ANATOMICAL MASKING IN CLUBFOOT
C. Giacomozzi, J. Stebbins, L. Way

17:10-17:20

DYNAMIC ANGLES AND FOOTPRINT INDEXES FOR CLASSIFYING FLATFOOT SEVERITY
C. Giacomozzi, P. Caravaggi, L. Berti, S. Giannini, A. Leardini

17:20-17:30

INTEGRATING PRESSURE AND MOTION CAPTURE TO ASSESS DEVIATIONS FROM NORMAL IN THE CLUBFOOT POPULATION
J. Stebbins, L. Way, C. Giacomozzi

17:30-17:40

THE COMPARISON OF PLANTAR PRESSURE DISTRIBUTION OF IDIOPATHIC SCOLIOSIS WITH HEALTHY ADOLESCENTS
E. Timurtaş, B. Özgül, M.G. Polat

17:40-17:50

CENTRE OF PRESSURE PROGRESSION AND GAIT PARAMETER DEVIATIONS MAY BE RELATED TO SECOND ROCKER DYSFUNCTION IN CHILDREN WITH FLAT FEET
A. Kothari, C. Kerr, J. Stebbins, A. Zavatsky, T. Theologis

17:50-18:00

PLANTAR PRESSURE SIMULATION TO SUPPLEMENT 3D GAIT ANALYSIS: APPLICATION IN CONTROL SUBJECTS AND DIABETIC PATIENTS
W. Aerts, A. Scarton, A. Guiotto, Z. Sawacha, J. Vander Sloten, C. Cobelli, I. Jonkers

CLINICAL RELEVANCE OF FOOTPRINT ANATOMICAL MASKING IN CLUBFOOT

C. Giacomozzi (1), J A. Stebbins (2), L. Way (2)
(1) Istituto Superiore di Sanità, Rome, Italy
(2) Oxford Gait Laboratory, Oxford, UK

Main topics: Reliability and service development, Technical developments in movement science, Orthopaedics.

INTRODUCTION and AIM

Anatomy-based regionalization of dynamic pressure footprints has been proved to be feasible when accurate kinematic and baropodometric measurements are integrated [1], and are especially valuable when footprints are incomplete or severely altered.. This study focusses on anatomy-based masking in paediatric clubfoot using the Oxford Foot Model (OFM, [2]), which identifies 5 plantar regions of clinical relevance in this population. Validation is performed by comparing to optimized geometrical masking and differences among age groups investigated.

PATIENTS/MATERIALS and METHODS

19 healthy volunteers (H: mean age 11.5 years, mean BMI 18.1) and 10 patients with clubfoot (P: mean age 10.8 years, mean BMI 19.9) were examined at the Oxford Gait Lab by using the OFM and an integrated setup based on a VICON motion system and an EMED-m baropodometer. 3-5 footprints per foot were acquired for each individual while walking barefoot at self-selected speed. The anatomical masking (AM) allowed identification of medial hindfoot, lateral hindfoot, midfoot, medial forefoot, and lateral forefoot. The geometrical masking (GM) which best corresponded to the AM definition was used for comparison. Relevant baropodometric parameters were calculated for each footprint using AM and GM. Non-parametric statistics were applied to all comparisons.

RESULTS

143 H and 84 P footprints were analysed. No differences were found between the two groups as for age, BMI and stance duration (H: 689±37ms; P: 675±49ms).

Results from AM and GM were very similar for the H group, for all parameters and regions (median difference 0.9% [0.4-2.7]). The biggest difference was associated with % length of contact at the midfoot region (17%), but this only corresponded to a difference of 1-5% in the other parameters and resulted in negligible differences in the other regions. Subjects in the age range 10-16 showed the lowest differences between AM and GM. The pathologic group showed higher differences between AM and GM methods (3.4% [2.0-6.8]), despite the fact that most feet demonstrated near complete footprints. In particular, it is worth noting that the GM line which separates the hindfoot from the midfoot was significantly further back than the corresponding AM line.

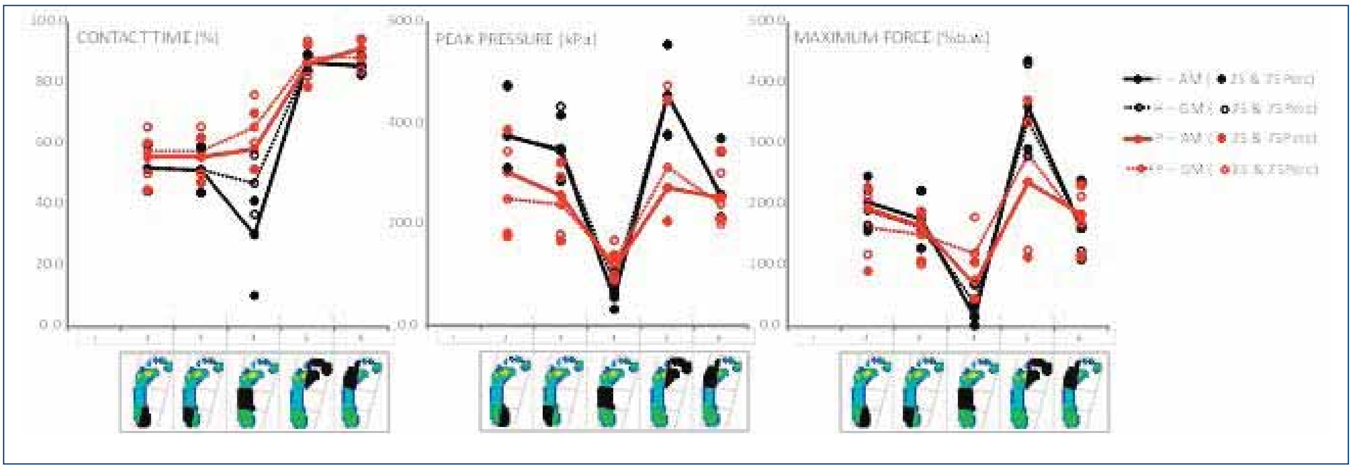

Figure 1: Regional distribution (median value, 25° and 75° percentile) of three relevant parameters. Black lines represent the healthy group (H), red lines the pathological group (P). Solid lines connect the outcomes of anatomical masking (AM), dotted line those of geometrical masking (GM).

DISCUSSION and CONCLUSIONS

The proposed AM proved to be equally valid compared to the GM on a selection of healthy footprints, and more effective in magnifying differences between the healthy and clubfoot regional parameters. The AM is appropriate in the presence of foot deformity where the footprint shape and GM cannot be relied upon.

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Stebbins et al, Gait Posture, 2006, 23:401-411

DYNAMIC ANGLES AND FOOTPRINT INDEXES FOR CLASSIFYING FLATFOOT SEVERITY

C. Giacomozzi(1), P. Caravaggi (2), L. Berti (2), S. Giannini (2-3), A. Leardini (2)
(1) Department of Technology and Health, Istituto Superiore di Sanità, Rome, Italy
(2) Movement Analysis Laboratory, Istituto Ortopedico Rizzoli, Bologna, Italy
(3) 1st Orthopaedic Clinic, Istituto Ortopedico Rizzoli, Bologna, Italy

Main topics: Functional outcome measures

INTRODUCTION and AIM

Static radiographic angles and dynamic footprint angles, as well as the arch index, are commonly used in the clinics to classify flatfeet. Also, correlation of foot shape measurements with radiographic angles was preliminarily investigated in young flatfeet [1]. We hypothesized that thorough dynamic measures can better account for structural and functional changes in the flatfoot. This study aims at identifying the most appropriate - existing or purposely defined - angles and indicators obtained from baropodometry and stereophotogrammetry during the stance phase of gait. Sensitivity and specificity of each index was also assessed in the study.

PATIENTS/MATERIALS and METHODS

Sixty among healthy volunteers and patients were clinically screened and enrolled in the study. Three consistent trials of level barefoot walking were acquired for each subject/foot by using an integrated pressure-kinematics technique based on a VICON motion system, an EMED baropodometer, and the IORfoot model ([2]) for spatial matching. 45 feet were clinically classified as Control (C, normally-arched, 15 feet), Level 1 Flatfoot (F1, 15 feet), or Level 2 Flatfoot (F2, more severe than F1, 15 feet). The following variables were calculated (Fig. 1): Subarch Angle (SA); Arch Index (AI); Modified Subarch Angle (SAM) originated at point M rather than L; midfoot width w; Midfoot/Forefoot Ratio (RMFW), i.e. the ratio between w and A'B'; ROM of sagittal- and frontal-plane angles at the main foot joints and of medial longitudinal arch (MLA), and MLA angle at midstance. Two footprints for each selected foot were randomly included in the reference dataset, and one was used for assessing sensitivity and specificity.

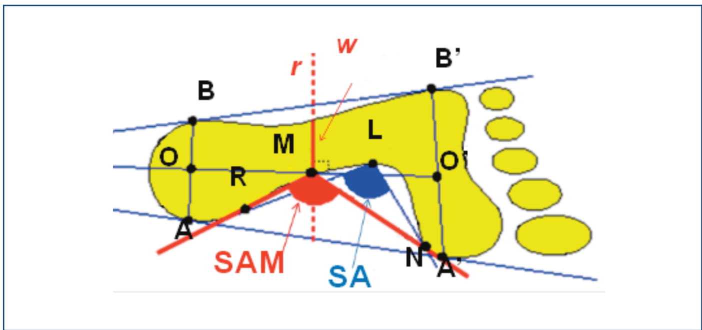

Figure 1: dynamic footprint measurements as calculated by the Novel software. In addition: M represents the intersection between medial midfoot and the line r perpendicular to OO' and passing through its midpoint; w is the midfoot width over line r. In case of w=0, M is taken at the intersection between r and the external tangent through BB'.

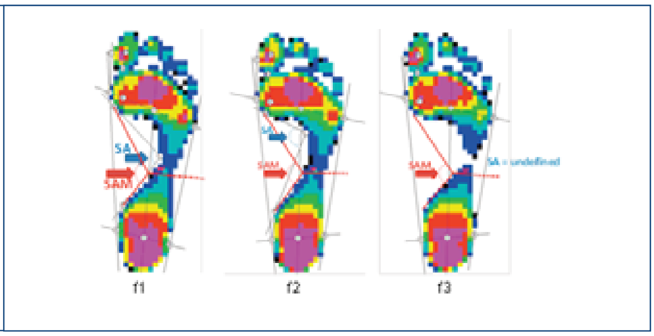

Figure 2: Identification of SAM and SA angles over 3 footprints associated with the same healthy foot.

RESULTS

The three groups were homogeneous with respect to age. BMI of F1 and F2 was comparable, and significantly greater than BMI in C. Stance duration was comparable in C and F1, and statistically shorter than in F2. SAM (C:107±6°; F1:126±6°; F2:158±19°) and RMFW (C:0.19±0.10; F1:0.41±0.04; F2:0.61±0.13) best identified the three groups. C was not different from F1 according to SA, MLA and MLA at midstance. The remaining kinematic angles did not statistically discriminate the groups. Sensitivity and specificity calculated with respect to C, F1 and F2 separately, showed that: sensitivity ranged 73-100% for SAM and RMFW, (mean 89%), 73-87% for AI (mean 80%), 60-71% for SA (mean 64%), 53-67% for MLA at midstance (mean 60%), and 20-80% for MLA (mean 53%). Specificity ranged 83-100% for SAM and RMFW, 77-100% for AI, 69-97% for SA, 70-90% for MLA at midstance, and 70-80% for MLA. Figure 2 shows the greater variability of SA with respect to SAM in three footprints from one volunteer.

DISCUSSION and CONCLUSIONS

SAM and RMFW seem to be the most appropriate dynamic footprint indexes for classifying flatfeet. SAM appears to be an improvement with respect to SA, which seems less discriminant and robust with respect to footprint alterations. MLA seems to be specific for F2 only, accounting for significant structural changes with respect to C and F1.

REFERENCES

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INTEGRATING PRESSURE AND MOTION CAPTURE TO ASSESS DEVIATIONS FROM NORMAL IN THE CLUBFOOT POPULATION

J A. Stebbins (1), L. Way (1), C. Giacomozzi (2)
(1) Oxford Gait Laboratory, Oxford, UK
(2) Istituto Superiore di Sanita, Rome, Italy

Main topics: Reliability and service development, Technical developments in movement science, Orthopaedics.

INTRODUCTION and AIM

It is becoming increasingly common for pedobarography to be used to aid treatment planning. While there is some consensus on the use of this data in specific populations (for example diabetes in adults) there is little information on how it should be interpreted in those with paediatric orthopaedic conditions, such as clubfoot. This is due in part to a scarcity in the literature of "normal" reference data for children. The other challenge is creating a pressure mask where the foot shape is abnormal. The aim of this study was to determine if the plantar pressure distribution in children with clubfeet can reliably be distinguished from an age-matched, typically developing population, by integrating the pressure data with data obtained from a motion-capture system.

PATIENTS/MATERIALS and METHODS

73 typically developing (TD) children (age 6-16 years) with no known pathology and 25 children with treated clubfoot (CF) (age 5-16 years) participated. Plantar pressure data (emed-m, novel, Germany) were obtained while walking at self-selected speed. Synchronous trajectory data were collected from reflective markers placed on the feet according to the Oxford Foot Model [1] using a 16 camera system (Vicon, Oxford, UK). Pressure images were masked into 5 areas using projected marker co-ordinates (Figure 1) [2]. The TD children were grouped into 6 age bands. Data from each CF subject was compared to age-matched data from the TD population.

RESULTS

Differences were found across the age groups in the TD population (Figure 2) with a progressive increase in peak pressure with age in most areas. Significant differences were found compared to the TD population in 40 out of 46 feet in at least one sub-area. The most frequent differences in the CF population were found in the mid-foot region, with 57% of feet having increased pressure in this region. There was generally a reduction in pressure in the hindfoot region, and a mixed response at the forefoot.

DISCUSSION and CONCLUSIONS

Markers placed on the foot were used to automatically mask the footprint for this study, allowing accuracy of masking to be maintained, even in the presence of abnormal foot shapes. This allowed direct comparison of sub-areas between the TD and CF populations. Substantial variation in pressure distribution was found in the TD population. Despite this, almost all CF subjects demonstrated significant differences compared to age-matched TD data. This suggests that pedobarography provides adequate sensitivity for assessing this population. "Normal" reference data may be used as a comparison (similar to other gait data) but care should be taken that this is appropriately age-matched. Future work will assess variables other than peak pressure.

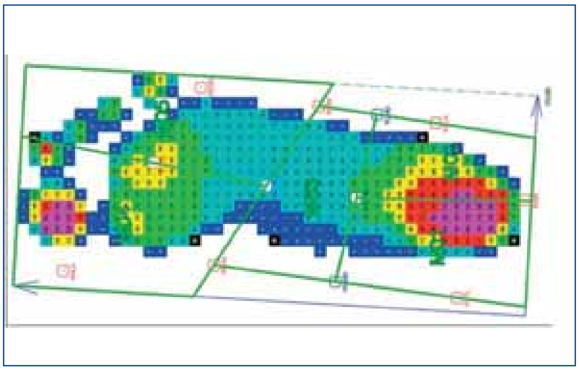

Figure 1:
CF footprint mask based on marker co-ordinates

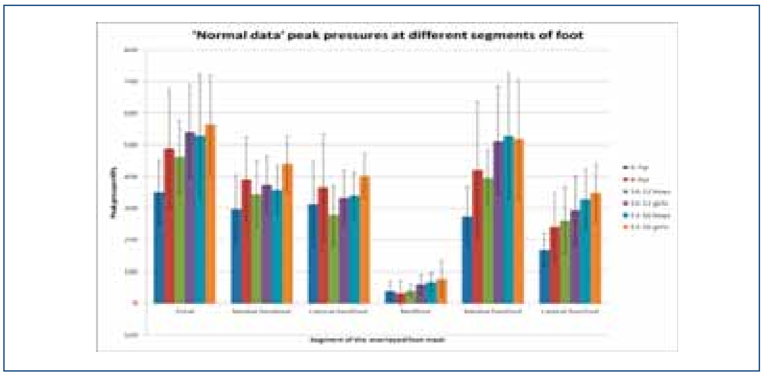

Figure 2: Peak pressure in each sub-area across different ages

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THE COMPARISON OF PLANTAR PRESSURE DISTRIBUTION OF IDIOPATHIC SCOLIOSIS WITH HEALTHY ADOLESCENTS

Eren Timurtaş (1), Mine Gülden Polat (1), Bahar Özgül (1)
(1) Marmara University Health Sciences Faculty, Department of Physiotherapy and Rehabilitation, İstanbul, Turkey

INTRODUCTION and AIM

Scoliosis is one of the most frequent reasons of applicaiton to physical therapy clinics in adolescent age group (1). Variations in the gait parameters and foot structure of adolescents with scoliosis compared to healthy adolescents have been investigated for a long time (2, 3). It was demostrated that there was diffierences at kinetic and kinematic parameters of lower limb adolescents with idiopathic scoliosis during walking (4, 5). However, the studies which investigated distribution of plantar pressure at idiopathic scoliosis are limited. The investigation of plantar pressure distribution according to the direction of single major scoliosis curvature compare to healthy adolescents is aimed in this study.

PATIENTS/MATERIALS and METHODS

32 adolescents (27 female and 5 male, with mean age of 15,37) with idiopathic scoliosis and 33 healthy adolescents (28 female and 6 male, with mean age of 14,03) were included in the study. Scoliosis degree of children with adolescent idiopathic scoliosis were examined by using Cobb method and vertebral rotation rates recorded by scoliometer after recording physical characteristics (gender, body weight, height) of subjects. Peak pressure (kPa), maximum force (N), contact duration (sec) and plantar pressure rate of the contact area (%) were evaluated by using dynamic pedobarography system (EMED-M, 38 × 42 cm, four sensors per square centimeter, 50 Hz; Novel GmbH., Munich, Germany) at self-selected speed. Independent T test was used to compare pedobarographic data of healthy adolescents and concave and convex side of single major scoliosis. The level of significance was determined as $p<0,05$.

RESULTS

Mean cobb angle of subjects with scoliosis was 28,09°(between 15°-60°) and mean vertebral rotation angle was 10,54°(between 6°-22°). Types of scoliosis of subjects according to King Classification were determined respectively; 6 subjects King1, 11 subjects King2, 12 subjects King3, 2 subjects King4, 1 subject King5. Maximum pressure rates in convex and concave side of scoliosis were determined significantly higher than maximum pressure rates of healthy adolescents ($p=0,012$ $p=0,017$). In addition, contact duration in the concave side of scoliosis was detected significantly lower than the contact duration of healthy adolescents ($p=0,031$). Any difference was detected in the other pedobarographic parameters between healthy adolescents and adolescents with scoliosis ($p>0,05$).

DISCUSSION and CONCLUSIONS

The spine asymmetry that occurred in adolescent idiopathic scoliosis affects oscillations of shoulder, pelvis and hip in the frontal plane motion (6). The results of our study demonstrated the effect of the curvature of the spine on foot plantar structure in addition to the studies that showed the effect of the curvature of the spine on the lower extremity movements (7). Pressure difference that was obtained in the both concave and convex side of scoliosis was demonstrated affected the plantar structure of the foot together with spine column in idiopathic scoliosis. Examination of foot region with spine deformity is required in the clinics because of the long term probable effects of plantar pressure differences on seconder pathologies. We suggest the considering these factors in the clinical examination and treatment of patients suffering from scoliosis. In addition, the further researches that investigate the effect of direction of the curvature on plantar pressure distribution considering the scoliosis type and the degree of curvature, is necessary.

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CENTRE OF PRESSURE PROGRESSION AND GAIT PARAMETER DEVIATIONS MAY BE RELATED TO SECOND ROCKER DYSFUNCTION IN CHILDREN WITH FLAT FEET.

A Kothari(1), C Kerr(2), J Stebbins(3), A B Zavatsky(2), T Theologis(1)
(1)Nuffield Department of Orthopaedics Rheumatology and Musculoskeletal Sciences, Nuffield Orthopaedic Centre, Windmill Road, Oxford, OX3 7LD, UK
(2)Department of Engineering Science, University of Oxford, Oxford, OX1 3PJ, UK
(3)Oxford Gait Laboratory, Nuffield Orthopaedic Centre, Oxford OX3 7LD, UK

Main topics: Analysis of clinical movement data, orthopaedics

INTRODUCTION and AIM

The Centre of Pressure Progression (COPP) is thought to be a useful measure of dynamic function of the foot [1]. The COPP has been used as an outcome measure in flat foot surgery, with an improvement of COPP to resemble a 'normal' foot defining a successful surgical result [2]. It is, however, unclear how the COPP varies in children with flat feet (FF) compared to those with normal arches (NA) and how this relates to dynamic function of the foot. The aim of this study was to quantify the differences in COPP between flat and normal arched children and also to assess how any differences relate to temporal-spatial gait parameters.

PATIENTS/MATERIALS and METHODS

Forty children with NA and twenty-one with FF (age 8-15) underwent dynamic pedobarography with the Novel Emed-M pressure plate system. A representative pressure trial at a self-selected walking speed was masked into three foot regions (heel, midfoot and forefoot). The position of the COPP line with respect to the long axis of the foot was calculated and interpolated to sixty points and normalised to foot size. Mean differences between COPP position for FF and NA were calculated with 95% confidence intervals (CI) for each interpolated point. The percentage of roll over process (ROP) (defined as heel strike to toe off) in each foot region was calculated and differences between groups were assessed using a t-test. Walking speed normalised (NWS) to leg length was obtained from three dimensional motion analysis (Vicon, Oxford Metrics, Oxford, UK).

RESULTS

There were no significant age or gender differences between the FF and NA group. The COP was more laterally placed in the FF group at initial contact, but diverged medially as it progressed to the forefoot (figure 1). The timings of the ROP demonstrated a significantly decreased percentage of the ROP in the forefoot region of the FF group compared to the NA group; 50% vs 55% (p=0.03). NWS was significantly slower in the FF group compared to the NA group (p=<0.001).

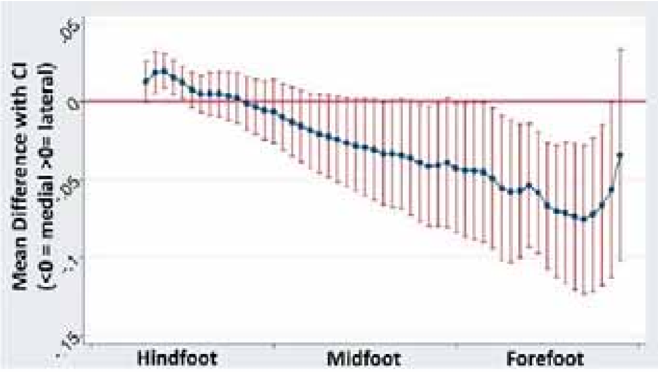

Figure1. Mean differences (FF minus NA) and 95% confidence intervals (CIs) of COPP, as a proportion of foot width, between FF and NA groups. Significant differences occur where confidence intervals do not cross zero.

DISCUSSION and CONCLUSIONS

This study has demonstrated that FF children have altered COPP compared to NA. The most significant difference is a more medial position of COP in the forefoot. This observation is most likely related to the hindfoot eversion and forefoot relative pronation seen in flat footed individuals. This result combined with the reduction in percentage of ROP in the forefoot region and reduced walking speed would suggest a dysfunction in progression of the second rocker.

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PLANTAR PRESSURE SIMULATION TO SUPPLEMENT 3D GAIT ANALYSIS: APPLICATION IN CONTROL SUBJECTS AND DIABETIC PATIENTS

W. Aerts(1), A. Scarton(2), A. Guiotto(2), Z. Sawacha(2), J. Vander Sloten(1), C. Cobelli(2), I. Jonkers(3).
(1) Department of Mechanical Engineering, KU Leuven, Leuven
(2) Department of Information Engineering, University of Padova, Padova, Italy
(3) Department of Kinesiology, KU Leuven, Leuven

Main topics: musculoskeletal modeling, mathematical simulation in human movement science.

INTRODUCTION and AIM

Plantar pressure (PP) measurements are widely used in clinical context as an aid in detecting diabetic neuropathic subjects at risk for foot ulcerations [1]. However, PP measurement systems are not often available within gait lab facilities. Musculoskeletal gait simulation offers at least the theoretical possibility to calculate the plantar pressure distribution based on experimental ground reaction forces ((GRFs) measured by force plates) and kinematics (measured using stereophotogrammetric system). The aim of this study is to compare two different techniques for calculating plantar pressure: one based on a discrete element model (DEM) and one based on a finite element model (FEM). The performance is tested for a cohort of healthy subjects (HS) and a cohort of diabetic neuropathic subjects (DNS). These approaches could be used in order to provide supplementary information to routine gait analysis.

PATIENTS/MATERIALS and METHODS

Standard gait analysis was performed on 5 DNS (mean age 62.8 ± 7.1 years, mean BMI 24.3 ± 2.9 kg/m^2) and 5 HS (mean age 57.2 ± 4.1 years, mean BMI 24.16 ± 1.8 kg/m^2). The experimental setup included a 6 cameras BTS stereophotogrammetric system, synchronized with 2 Bertec force plates and 2 PP systems (Imagortesi). The DEM contact simulation s performed during a moment-driven forward analysis using the experimental 3D kinematics and GRFs in combination with a scaled generic musculoskeletal model (23 DOF) as input in OpenSim. A scattered bed of spring-damper systems [2] was used as contact surface attached to the calcaneus of the model, which was obtained from an MRI scan of a HS. An optimization procedure optimized the contact parameters and the contact geometry position based on the experimental ground reaction force. For the FEM, two condition-specific models were developed by segmenting bones, cartilage and skin from MRI scans (Philips Achieva)[3]. FE simulations were run (ABAQUS) for 4 phases of the stance phase of gait: initial contact (IC), loading response (LR), mid stance (MS) and terminal stance (TS). The kinematic boundary conditions were defined based on the experimental marker data, whereas the kinetic ones were derived from an inverse analysis in OpenSim, more specific the joint reaction force and moment at the ankle joint. In order to compare the different approaches root mean square differences (RMSD) were estimated between DEM and Fem and experimental PP (Fig 1).

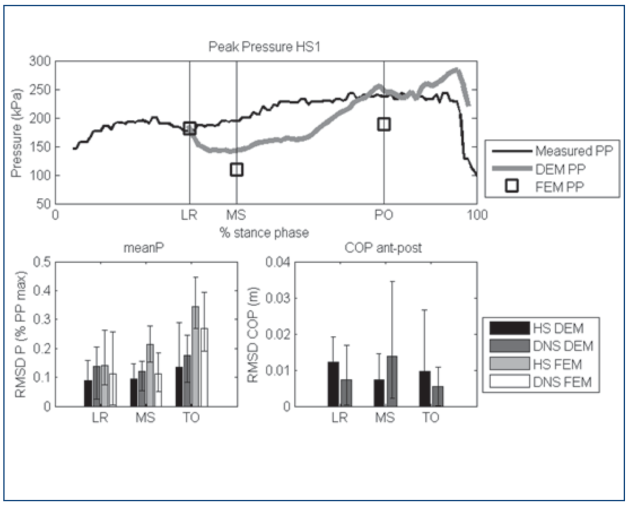

Figure 1: Upper plot shows an example of the simulate peak PP for a HS. Lower plots shows the RMSD between the measured and simulated mean PP (as % of max PP) and COP for both the FEM and DEM and HS/DNS.

RESULTS

A good agreement was found for both methods (see Fig. 1). Besides the peak and mean PP, also the center of pressure (COP) in anterior-posterior and in medial-lateral directions agreed with the experimental PP.

DISCUSSION and CONCLUSIONS

Both methods showed a good performance in predicting the PP distribution. With respect to FEM, the use of DEM allows continuous contact simulation of PP and COP displacement at a limited time cost based on measured GRFs and kinematics. Discrepancies in predicted DNS' peak PP may relate to the gross oversimplification of the currently implemented foot model in OpenSim, that do not allow to accurately represent reported alterations in hind – and forefoot kinematics in diabetic subjects. Secondly, improvements will be obtained by including patient-specific geometries into the musculoskeletal model.

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18:00-20:00 ***Aula 2***	**Cometa User Meeting**
	Sales Manager introduction
	What is new (technical)
	EMG Easy Report software presentation (Andrea Merlo)
	Q&A
	The meeting will be held in English.
20:30	**Gala Dinner**
	Terrazza Radisson Blu

8:30-9:00 **CMAster Stakeholder breakfast**
Aula 10

9:00-9:10 **CMAster launch**
Aula Major

9:10-9:50 **CMAster keynote:**
Aula Major

THE NEUROMUSCULAR PREREQUISITES OF NORMAL WALKING AND THE EARLY LOSS OF AMBULATION IN CEREBRAL PALSY

Adam P Shortland
Gait Lab, Basement, Southwark Wing, Guy's Hospital, Great Maze Pond, London, SE1 9RT

e-mail: Adam.shortland@gstt.nhs.uk

ABSTRACT. The neuromuscular prerequisites of normal walking and the early loss of ambulation in cerebral palsy. Normal walking requires the development of a strong, sustained and organised efferent output from the spinal cord, and a parallel progression in the strength and structural organisation of the skeletal muscles of the lower limbs. When an injury to the motor centres of the brain occurs during early life, the maturation of the spinal circuits can be affected and the trajectory of muscle growth can be blunted. In this presentation, we will explore the intimate relationship between neural and muscular development during the lifespan, and propose a pathophysiological basis for the early loss of mobility of people with cerebral palsy. Question 1: Briefly describe 3 principal roles of the corticospinal tract in the development of motor control. Question 2: What is the relationship between body mass and lower limb muscle volume in the typically developing child? How is this trajectory altered in children with CP?

9:50-10:10 Coffee break

10:10-11:40 **Gait Classification / Patterns**
Aula Major
Chairs: Michael Schwartz, Pietro Caliandro

10:10-10:20 AGE-BASED BIOMECHANICS OF RUNNING GAIT: A LONGITUDINAL STUDY
C. Diss, G. Weeks, M. Gittoes, R. Tong, D. Kerwin

10:20-10:30 A RELIABLE CLASSIFICATION SYSTEM FOR NEUROMUSCULOSKELETAL GAIT DISORDERS
R. Matias, R. Martins, J. Magarreiro, A. Gomes, C. Cavaco, H. Gamboa

10:30-10:40 ASSOCIATION BETWEEN INSTRUMENTAL STABILITY MEASURES OF GAIT AND CLINICAL RATING SCALES IN STROKE PATIENTS
F. Riva, P. Tamburini, D. Mazzoli, R. Stagni

10:40-10:50 FUNCTIONAL AND GAIT ASSESSMENT IN CHILDREN WITH FRIEDREICH ATAXIA: COMPARISON OF QUANTITATIVE AND FUNCTIONAL EVALUATION
G. Vasco, M. Petrarca, S. Gazzellini, M.L.. Lispi, G. Della Bella, S. Carniel, M. Zazza, E. Castelli, E. Bertini

10:50-11:00 THE EFFECT OF WALKING PATH CONFIGURATION ON SIX-MINUTE WALK TEST PERFORMANCE AND GAIT VARIABILITY: A PILOT STUDY
C.T. Barnett, J.S. Jackman, N.C. Moore, T. Rayne , R.D. Heald, C.M. Pope

11:00-11:10 PATTERN RECOGNITION METHODS IN CLINICAL GAIT ANALYSIS – WHAT DO WE GAIN?
M. Bruderer-Hofstetter, F. Rast, C. Bauer, E. Graf, A. Meichtry

11:10-11:20 CLASSIFICATION OF GAIT PATTERNS THROUGH AN ULTRASOUND-DOPPLER MOTION ANALYSIS SYSTEM
R. Ricci, A. Sona, Z. Sawacha, A. Guiotto, C. Cobelli

11:20-11:30 KNEE ADDUCTION AND FLEXION MOMENTS DO NOT REFLECT KNEE LOADING DURING STANCE PHASE OF GAIT
S. Meireles, F. De Groote, S. Verschueren, C. Maganaris, I. Jonkers

11:30-11:40 FEMORAL ANTEVERSION RELATED GAIT ABNORMALITIES IN NEUROLOGICALLY INTACT INDIVIDUALS
N.E. Akalan, A. Adnan, S.. Kuchimov, Y. Temelli, F. Bilgili

AGE-BASED BIOMECHANICS OF RUNNING GAIT: A LONGITUDINAL STUDY

CE.Diss (1), G. Weeks (1), MJR. Gittoes (2), RJ. Tong (2), DG. Kerwin (2)
(1) University of Roehampton, London, UK
(2) Cardiff Metropolitan University, Cardiff, UK

Main topics: Experimental studies in human movement science, Analysis of gait and motor disorders

INTRODUCTION and AIM

Biomechanical research exploring the age-based mechanics of running gait can provide valuable insight into the reported decline in master endurance running performance (Tarpenning et al., 2004). Exposure to regular athletic training may minimise the loss of the number of motor units associated with ageing, and contribute to a maintained or marginally adapted endurance running performance in competitive master athletes (Power et al., 2012). The aim of the study was to develop an understanding of the age-based biomechanics of running performance of male endurance athletes through a longitudinal experimental approach.

PATIENTS/MATERIALS and METHODS

Six running trials were performed at a self-selected running velocity by 10 male endurance athletes (mean±SD: velocity = 3.83±0.40m·s^{-1}, age = 53.54±2.56 years). A nine camera infra-red system (Vicon™, 120 Hz) synchronized with a force plate (Kistler™, 1080 Hz) were used to collect lower limb joint coordinate and ground reaction force data. The protocol and data collection was replicated seven years later for each participant. The stance phase was sub-divided into two sub-phases defined as negative and positive, which were distinguished by the time of amortization (the time when the resultant horizontal and vertical displacement of the whole body centre of mass was minimal). Ground reaction forces, lower limb kinetics and kinematics including joint stiffness measures and step characteristics were determined and statistically compared between each year.

RESULTS

Table 1 illustrates a significant increase in step length (p=0.02) and decrease in step frequency (p=0.01) after a seven-year period. The ankle joint demonstrated a 75% significant (p=0.00) increase in plantar flexion at toe off whilst the hip joint's range of motion in the negative phase significantly (p=0.04) decreased by 27%. No significant differences (p>0.05) were found for all discrete vertical and horizontal forces examined except for the rate of vertical force during in the negative phase (p=0.04) and the maximum negative braking force (p=0.03). Joint moments and stiffness were examined at the hip, knee and ankle and there was a significant increase (p=0.01) in normalised knee moment and stiffness at amortization of 0.19 and 0.89 x 10^{-2} ($^{o-1}$), respectively.

DISCUSSION and CONCLUSIONS

After a seven-year period the master athletes demonstrated a longer step length, which has potentially caused an increase in vertical and braking force attenuation. The hip joint decreased absorption capabilities and stiffer knee suggests hip and knee joint inhibition with age. In order to minimise such changes associated with age competitive older athletes may be encouraged to exploit training protocols that enhance hip and knee joint dynamics e.g. plyometric centred activities.

Table 1: Group mean (±SD) for significantly different step characteristics from both data collection sessions.

Data collection	Step length (m)	Step frequency (Hz)
A	1.35 (±0.21)	2.81(±0.27)
A + 7 years	1.48 (±0.17)	2.61 (±0.28)

Table 2: Group mean (±SD) for significantly different kinematic/kinetic discrete measures from both data collection sessions.

Data collection	Ankle Plantar Flexion at toe off (o)	Hip Range of Motion (o)	Rate of Vertical Force in the negative phase (BW/s)	Maximum Braking Force (BW)	Normalised Knee Moment	Normalised Knee Stiffness (o-1)
A	3.93 (±5.78)	10.01 (±3.42)	23.92 (±4.28)	-0.47 (±0.11)	0.12 (±0.06)	0.37 (±0.25)
A + 7 years	15.97 (±4.66)	7.27 (±2.78)	31.43 (±11.28)	-0.59 (±0.18)	0.31 (±0.07)	1.26 (±0.43)

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A RELIABLE CLASSIFICATION SYSTEM FOR NEUROMUSCULOSKELETAL GAIT DISORDERS

R, Matias (1,2), R, Martins (2), J, Magarreiro (1), A.L, Gomes (3), C, Cavaco (3), H, Gamboa (3)

(1) School of Health Care of the Polytechnic Institute of Setúbal, Setúbal, Portugal
(2) Neuromechanics of Human Movement Research Group, University of Lisbon, Lisbon, Portugal
(3) Faculty of Science and Technology, New University of Lisbon, Lisbon, Portugal

Main topics: Analysis of clinical movement data, Analysis of gait and motor disorders.

INTRODUCTION and AIM
An impairment-based classification system is necessary to guide rehabilitation and clinical best practice [1]. The integration of 3D human movement information with automatic machine learning and statistical pattern recognition solutions that can accurately quantify and classify gait, can be the foundation for such a system to be applied. In this work we assess if a biomechanical-based approach is able to accurately classify neurological impaired and unimpaired individuals based on biomechanical gait information.

PATIENTS/MATERIALS and METHODS
3D Kinematics of 23 segments was collected from a sample of 20 subjects (10 neurological patients with different functioning status and levels of gait disorders, and 10 unimpaired individuals) using Xsens 17 MTx inertial sensors with a sample rate of 120Hz. A full-body calibration procedure was conducted to align the MTx sensors with body segments while subjects stood in an anatomical neutral position. Segments kinematics was obtained by using a biomechanical model that allowed sensor kinematics to be translated into segment kinematics [2]. 3D orientation accuracy and resolution have been reported by the manufacture at < 0.5º and 0.05º, respectively. Multiple classification models (Nearest Neighbors, Decision Tree, Random Forest, Adaptive Boosting, Naive Bayes) [3], received as attributes the sagittal plane joint angles, angular velocities and angular accelerations histories of the right and left hips, knees and ankles during 10 gait cycles/subject. A percentage of matches between model predicted and actual class (impaired and unimpaired individuals) was used to assess classification accuracy, with bootstrap cross-validation approach [4]. Attributes were added to the models in a stepwise manner, resulting in 50 possible combinations, in such a way that allowed to measure the influence of attributes combinations on models classification accuracy results. Classification performance was also obtained by measuring the computational time required to run the classifiers.

RESULTS
Classification accuracy ranged from good to excellent [5] with results from 0,82 to 0,97. Not surprisingly, the best classification accuracy result was achieved when having as attributes information from all joints involved. More interesting was the result obtained when considering single joint information (e.g. left knee flexion angle, angular velocity and angular acceleration) as attributes (0,92). Adaptive Boosting classifier provided the best accuracy value (0,97), while the Linear Discriminant Analysis method presented the highest computational speed values (0,05s).

DISCUSSION and CONCLUSIONS
This study results demonstrated that by merging a biomechanical-based approach with automatic machine learning and statistical pattern recognition solutions it is possible to fast and accurately classify gait disorders, such as those of neurological patients, with just one joint kinematics information easily acquired using wearable sensors. Such integrated solution can supply valuable information for (i) the diagnosis formulation, (ii) to support clinical decision making, or (iii) to document and monitor patient condition, that are the three main reasons why gait analysis is clinically performed [6]. Further work will be conducted to estimate classifiers accuracy to distinguish different gait neuromusculoskeletal disorders, to assess the contribution of patient clinical data to this accuracy and the value of integrating gait indices (e.g. Movement Deviation Profile and Gait Deviation Index).

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ASSOCIATION BETWEEN INSTRUMENTAL STABILITY MEASURES OF GAIT AND CLINICAL RATING SCALES IN STROKE PATIENTS

F. Riva (1), P.Tamburini (1), D. Mazzoli (2), R. Stagni (1, 3)
(1) DEI - Department of Electrical, Electronic, and Information Engineering 'Guglielmo Marconi', University of Bologna, Italy
(2) Gait & Motion Analysis Laboratory, Sol et Salus Hospital, Rimini, Italy
(3) Health Sciences and Technologies – Interdepartmental Center for Industrial Research (HST – ICIR), University of Bologna, Italy

Main topics: Analysis of gait and motor disorders, Movement deviation indexes.

INTRODUCTION and AIM

Subjects who suffered a stroke often experience alterations in the normal pattern of walking and a higher fall risk [1]. Clinical rating scales represent the standard approach used by clinicians for motor function assessment of post-stroke patients; this approach is however highly dependent on the clinician's subjective judgement [2]. Instrumental measurements of trunk accelerations during gait resulted promising in the assessment of gait stability and fall risk in healthy elderly subjects [3]. A more reliable and objective quantification of motor function could be obtained from the integration of stability measures and clinical rating scales. In order to evaluate the potential clinical benefits derivable from this approach, the association between stability measures and clinical scales has to be assessed. The aim of the present study is the assessment of the relationship between instrumental gait stability measures of trunk accelerations and some of the most used clinical rating scales in a sample of post-acute stroke patients.

PATIENTS/MATERIALS and METHODS

Thirty-three subjects post-acute stroke patients with hemiparesis (56 ± 14 years, 71 ± 14 kg) participated in the study. Seventeen subjects were not able to walk without a cane. Data were collected at Sol et Salus Hospital (Rimini, Italy). Motricity Index (MI), Trunk Control Test (TCT), Functional Ambulation Category (FAC), Walking Handicap Scale (WHS), Rivermead Mobility Index (RMI), Cumulative Illness Rating Scale (SI and CI), Timed-Up and Go Test (TUG) and Two Minute Walk Test (2MWT) were administered to subjects by the same operators. The 2MWT was administered with the addition of an IMU located on the trunk, at the height of the fifth lumbar vertebra. Four gait stability measures, namely Harmonic Ratio (HR), Index of Harmonicity (IH), Multiscale Entropy (MSE), and Recurrence Quantification Analysis (RQA), were calculated on trunk acceleration signal during gait obtained from 2MWT. Each measure was calculated for anterior-posterior (AP), medio-lateral (ML) and vertical (V) acceleration directions. Log transformed measures were then used as inputs for linear regression models.

RESULTS

Subjects who used a cane showed a high correlation between MSE, RQA and TCT, RMI. More sparse but significant correlation has been found between MSE and WHS, CIRS. IH showed no correlation with clinical parameters. Subjects who were able to walk without a cane showed high correlation values between MSE, RQA and TUG, 2MWT and WHS. TUG, 2MWT and SI correlated in a lesser extent with HR. IH showed high correlation values with TUG and RMI; RMI correlated with MSE and RQA also.

DISCUSSION and CONCLUSIONS

In subjects who walked with a cane, correlations between TCT and MSE were particularly consistent, highlighting an affinity between the instrumental measure of complexity of trunk acceleration and the clinical assessment of trunk control. For subjects who were able to walk without a cane TUG, 2MWT showed high correlations with stability measures, in particular with MSE and RQA (mainly in the ML direction), highlighting the importance of the medio-lateral control of the trunk during gait.

In conclusion, gait stability measures based on trunk accelerations (in particular MSE and RQA) showed promising correlation with clinical scales in stroke patients, and could complement the standard clinical scores in the assessment of locomotor performance of subjects with stroke, helping clinicians and physical therapists in the patient's rehabilitation process. Moreover, the use of instrumental measurements could lead, in the future, to a more reliable quantification of locomotor features, allowing avoiding inter-operator differences.

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FUNCTIONAL AND GAIT ASSESSMENT IN CHILDREN WITH FRIEDREICH ATAXIA: COMPARISON OF QUANTITATIVE AND FUNCTIONAL EVALUATION

G Vasco (1,2), M Petrarca (1), S Gazzellini (1), ML Lispi (1), G Della Bella (1), S Carniel (1), M Zazza (2), E Castelli (1), E Bertini (2)
(1) MARlab (Movement Analysis and Robotics Laboratory), Department of Neuroscience and Neurorehabilitation, Bambino Gesù Children's Research Hospital - Rome, Italy
(2) Unit of Neuromuscular Disorders, Laboratory of Molecular Medicine, Bambino Gesù Children's Research Hospital - Rome, Italy
Main topics: Analysis of gait and motor disorders, Analysis of clinical movement data, Functional outcome measures in mobility.

INTRODUCTION and AIM

Friedreich's ataxia (FRDA) is the commonest hereditary form of ataxia related to autosomal recessive GAA trinucleotide expansion in the first intron of the FXN gene[1]. Here we describe the gait pattern of a cohort of children and adolescents with FRDA using three-dimensional Gait Analysis and a functional rating scale considered so far the best choice for the disease (Scale for the Assessment and Rating of Ataxia – SARA)[2]. The purpose of this study was to describe the gait pattern of FRDA and to assess and correlate changes of several outcome measures over the period of 12 months..

PATIENTS/MATERIALS and METHODS

Eleven genetically confirmed FRDA patients (age range 7–18y, mean13y 8m ±3; 3:8 M:F) were involved in this study matched with 15 typically developing children and adolescents (age range 5y5m–23y, mean10y4m ±3; 5:9 M:F). All participants were able to walk independently and to complete the entire protocol in an outpatient settings. The whole assessment consisted in a complete history and neurological examination, SARA rating scale and Gait Analysis performed with an optoelectronic system (Vicon MX, UK, with 8 cameras operating at 200Hz) and two force platform (AMTI, US, or6-6), hidden in the floor at the centre of the walkway. So far, seven patient underwent to a 12 month follow up visit with the same assessment. Only one patient lost the ambulation during the period between the two visit. Kinematics, kinetic and spatio-temporal parameters were considered during gait analysis and compared with a control group. The Pearson test was conducted in order to verify the statistical significant correlation between SARA and quantitative indexes and T-test was conducted with controls and follow up.

RESULTS

Spatio-temporal parameters were significantly abnormal in our FRDA cohort compared to a control group. Gait analysis assessment showed a slight reduction of walking velocity respect to the control group (0.9±0.33 m/s vs 1.17±0.12m/s, <p0.01) mainly due to the increase of stride lenght (0.5±0.07m vs 0.59±0.06m, p=0.01). Stride time was increased respect to the control group but was not statistically significant. SARA inversely correlated with walking velocity and directly correlated with stride duration (<p0.01). We also analyzed the correlation with spatio-temporal parameters and SARA subscales. Gait and stance subscales, like total score, was highly inversely correlated with walking velocity and directly correlated with stride duration (<p0.01). The other parameters showed low correlation rates with no statistical significance. The evaluation of the follow up measures is ongoing. Preliminary data showed significant changes in both SARA scores and Kinematics, kinetic and spatio-temporal parameters. In particular, we observed decreased walking velocities, increased knee extension and decreased ankle dorsiflexion. Follow up is ongoing and conclusive analysis is needed to verify whether the differences detected in score measures over time are significant in our cohort.

DISCUSSION and CONCLUSIONS

The spatial and temporal parameters revealed to be the most sensitive quantitative indicators and have a good correlation with SARA. Walking velocity directly correlated with locomotor status as defined by SARA scale. We confirm that SARA is very useful for its compact nature and high construct validity and is a reliable assessment tool to define the severity of disabilities in patients affected by Friedreich ataxia. At the same time, gait analysis provides objective and quantitative information which are useful in characterizing the gait pattern for clinical decision-making on a single subject. The spatial and temporal parameters are the most sensitive quantitative indicators. Further analysis are ongoing to characterize changes over 12 month time. These functional assessment measures administered before and after treatment, as well as during the follow up appear to be very useful to monitor the efficacy of rehabilitation and of pharmacological therapies.

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THE EFFECT OF WALKING PATH CONFIGURATION ON SIX-MINUTE WALK TEST PERFORMANCE AND GAIT VARIABILITY: A PILOT STUDY

Barnett CT, Jackman JS, Moore NC, Rayne T, Heald RD and Pope CM.
SHAPE Research Group, Nottingham Trent University, Nottingham, United Kingdom.

INTRODUCTION and AIM

Gait variability reflects the inherent stability of gait resulting from pathology or ageing [1], while assessments such as the six-minute walk test (6MWT) provide an overall indicator of functional capacity [2]. Accurate measurement of these gait characteristics is important for clinical decision making and the reporting of valid research data. However, variation in the configuration of gait trials, such as walkway lengths, number of trials/strides recorded and familiarisation protocols, are proposed to impact upon the key outcome measures associated with these gait characteristics [3,4]. Therefore, the current study investigated the effect of walkway configuration on 6MWT performance and the variability of temporal-spatial gait measures.

PATIENTS, MATERIALS and METHODS

Sixteen healthy participants (age 22.1±1.0years, height 1.78±0.07m, mass 76.8±9.4kg), completed two familiarisation 6MWT trials according to the American Thoracic Society guidelines [2]. Participants then completed five randomly ordered experimental 6MWT trials over two days with walkway configurations of 5m (5M), 10m (10M) and 15m (15M) straight sections, a rectangular box (6x3m) (BOX) and figure of eight incorporating two 10m straight sections (FIG8). During these trials, reflective markers were attached to the sacrum and the posterior and anterior aspects of the feet with kinematic data being recorded at 100Hz by a nine-camera motion capture system (Qualisys, Gothenburg, SE). Data were processed in Visual 3D (C-Motion, Inc, Germantown, US) with the variability of temporal-spatial measures calculated.

RESULTS

Preliminary analysis of the data indicated that a decreasing need to turn and change direction, increased the 6MWT distance achieved ($F(4,60) = 101.97$, $p<0.001$, $\eta_p^2 = 0.87$) (Table 1). Post-hoc tests revealed that the greatest 6MWT distance was achieved during 15M and FIG8 trials ($p=0.01$), with the 5M trial resulting in a lower 6MWT distance when compared to all other trials ($p<0.01$). Walking speed was also increased, with the decreased need to change direction ($F(4,60) = 102.89$, $p<0.001$, $\eta_p^2 = 0.87$) (Table 1). Similarly, post-hoc tests revealed that the greatest walking speed was observed during the 15M and FIG8 trials ($p=0.01$) and the lowest during the 5M trial ($p\leq 0.02$). Although the number of strides participants took also increased with a reduced need to change direction ($F(4,60) = 7.93$, $p<0.001$, $\eta_p^2 = 0.35$) (Table 1), this effect was reduced across trials, with a maximum difference of 10.5 strides between 15M and 5M trials.

DISCUSSION and CONCLUSIONS

Results indicated that walkway configuration had a significant effect on 6MWT performance. Increased uninterrupted gait i.e. reduced turning, resulted in improved 6MWT performance. In addition, decreased performance in the BOX trial when compared to 10M, 15M and FIG8 trials, suggested that the length of uninterrupted gait also influenced 6MWT performance. Between trial variation in the number of strides taken was reduced vs. 6MWT distance variation, suggesting that stride length was also modified between trials. These findings support previous research [3], indicating that walkway configuration should be considered when designing protocols for and interpreting data from 6MWT trials. Kinematic gait data are currently being analysed and are expected to elucidate how the effects observed in 6MWT performance, interact with measures of temporal-spatial variability. In conclusion, walkway configuration significantly effects 6MWT performance and gait trials should reduce turning requirements and increase walkway length when conducting the 6MWT.

Table 1: Group mean and standard deviation 6MWT performance outcome variables from the five trials.

		5M	10M	15M	BOX	FIG8
Total Distance (m)	Mean SD	435.0	517.7	538.2	494.4	537.3
		38.7	45.4	48.4	46.5	53.9
Walking Speed (m/s)	Mean SD	1.21	1.44	1.50	1.37	1.49
		0.11	0.13	0.13	0.13	0.15
Number of Strides	Mean SD	345.3	354.2	355.8	346.4	354.9
		16.6	18.9	18.4	15.0	17.1

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PATTERN RECOGNITION METHODS IN CLINICAL GAIT ANALYSIS – WHAT DO WE GAIN?

M. Bruderer-Hofstetter[1], F. Rast[2], C. Bauer[2], E. Graf[2], A. Meichtry[1]
[1]Institute of Physiotherapy, University of Applied Sciences Zurich, Winterthur, Switzerland
[2]Laboratory for Motion Analysis, University of Applied Sciences Zurich, Winterthur, Switzerland

INTRODUCTION and AIM

Pattern recognition methods have been widely-used in clinical gait analysis[1]. Although a combination of principal component analysis (PCA) and support vector machines (SVM) demonstrated a high sensitivity to visualize subtle differences in movement patterns[2,3] the benefit of pattern recognition methods in clinical application remains uncertain. Therefore, the aim of our study was to compare the results of a discrete parameter analysis with a pattern recognition approach in order to detect differences in kinematics and kinetics between two different shod conditions.

PATIENTS/ MATERIALS and METHODS

Five walking trials for each of the two conditions of 20 healthy subjects were captured using a 7-camera-motion-analysis-system (Vicon, 200Hz) and two force-plates (AMTI, 1000Hz). Discrete parameter analysis calculated a priori chosen kinematic and kinetic parameters. Pattern recognition approach (PCA) extracted gait features (PC) from an input matrix containing kinematic and kinetic waveforms. Subsequently, a SVM classifier with linear kernel function was applied to determine the optimal PC-subspace. Within the remaining PCs and all parameters paired sample *t*-tests were applied and Cohens'*d* effect sizes were calculated.

RESULTS

Discrete parameter analysis revealed significant differences ($p<0.01$) for the second peak ankle flexion angle ($d=0.60$), the peak accelerating ground reaction force (GRF) ($d=0.86$) and the second peak vertical GRF ($d=-0.47$). Pattern recognition approach detected four condition dependent PCs. Significant differences ($p<0.01$) were found in PC2 and PC3 (effect sizes $d=-1.21$ and $d=2.75$, respectively). PC2 corresponded to angle differences at mid-stance at hip, knee and ankle joints and to anterior-posterior and vertical GRF differences at terminal-stance. PC3 represented knee angle difference at mid-stance, anterior-posterior GRF difference at terminal-stance and angle differences at hip and ankle joints and vertical GRF difference at pre-swing.

DISCUSSION and CONCLUSIONS

With the pattern recognition approach a deeper insight into the data was achieved. Differences between the two shod conditions were detected in other sections of the gait cycle than a priori supposed. Although the pattern recognition approach detected condition dependent differences independently of prior knowledge the benefit for clinical gait analysis application hinges on the ability to interpret the extracted gait features.

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CLASSIFICATION OF GAIT PATTERNS THROUGH AN ULTRASOUND-DOPPLER MOTION ANALYSIS SYSTEM

R. Ricci (1), A. Sona (1), Z. Sawacha (2), A. Guiotto (2), C. Cobelli (2).
(1) Department of Management and Engineering, University of Padova, Vicenza, Italy.
(2) Department of Information Engineering, University of Padova, Padova, Italy

Main topics: Experimental studies in human movement science, Technical developments in movement science

INTRODUCTION and AIM

Progress in new technologies has led the development of a series of devices and techniques which allow for objective evaluation of gait parameters [1], making measurements more efficient and effective and providing specialists with valuable information also outside of the gait laboratory settings. The state of art methods used in recognition and analysis of the human gait goes from image processing techniques to inertial sensor placed on the body. The aim of this contribution was to verify the applicability of an ultrasound technique [2] to recognize gait patterns. Some specific trajectories were acquired by using the ultrasound proposed system and a comparison was performed with the corresponding markers' trajectories acquired with a motion capture system.

PATIENTS/MATERIALS and METHODS

One healthy subject (age 26, BMI 20,47 Kg/m^2) was acquired during gait and while performing a set of specific movements with a 6 cameras BTS stereophotogrammetric system (60-120 Hz), synchronized with 2 Bertec force plates. The ultrasound system comprised an ultrasound transmitter-receiver (Tx-Rx) couple (working frequency 40 kHz). While Tx illuminates the target with a constant pressure sine wave, Rx collects a part of the energy backscattering from the human target. The received signal is processed and displayed in the frequency-time domain (spectrogram) in order to highlight the Doppler (or velocity) component due to the subject motion. The device was placed in front of the test subject and the following movements were acquired with both techniques simultaneously: (i) gait; (ii) forearm extension; (iii) punching; (iv) knee raise. A modified version of the IORgait protocol was adopted as in [1] for collecting motion capture data, and the following markers and joints' trajectory were extracted and used for comparison: RLE/RME, RLM/RRM, RVMH/RIMH, LLE/LME, LLM/LMM, LVMH/LIMH, RGT, LGT, IJ/PX, HD.

RESULTS

In figure 1, a comparison is show between some velocity trajectories acquired both with the stereophotogram-metric and the ultrasound systems, relatively to the gait movement. A good agreement can be noticed between the two set of trajectories. In table 1 the results of the HD velocity estimation are reported, in the case of the punching movement. The error expectation and the mean square error, MSE(v_{HD}) are reported E($e_{v,HD}$).

Table 1: Expectation (E) and mean square errors (MSE) of the HD velocity estimation by using the ultrasound-Doppler motion analysis system, in the case of the punching movement.

measure #	E(ev,HD) [m/s]	MSE(v_{HD})[(m/s)^2]
01	0.00	0.0081
02	-0.02	0.0053
03	-0.01	0.0037
04	-0.02	0.0229
05	-0.02	0.0068
06	-0.03	0.0073
07	0.00	0.0064
08	-0.01	0.0050
09	-0.01	0.0145
TOT	-0.01	0.0082

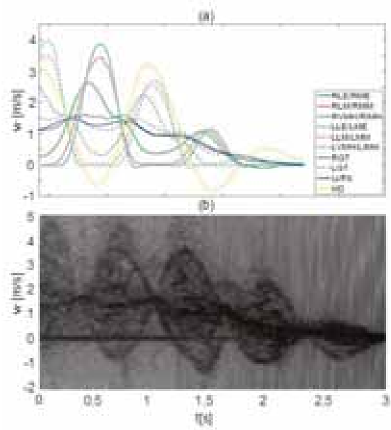

Figure 1: Upper plot shows an example of the simulate peak PP for a HS. Lower plots shows the RMSD between the measured and simulated mean PP (as % of max PP) and COP for both the FEM and DEM and HS/DNS.

DISCUSSION and CONCLUSIONS

Beside several limitations on the type of human movements that can be measured, results of the first measurement investigation show that ultrasound-Doppler system can profitably be applied for human motion analysis tasks. Furthermore, ultrasound systems can be applied in some environments and situations where camera-based systems show intrinsic limitations, e.g. underwater environment.

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KNEE ADDUCTION AND FLEXION MOMENTS DO NOT REFLECT KNEE LOADING DURING STANCE PHASE OF GAIT

S. Meireles (1), F. De Groote (2), S. Verschueren (1), C. Maganaris (3), I. Jonkers (1)
(1) Department of Kinesiology, Katholieke Universiteit Leuven, Leuven, Belgium
(2) Department of Mechanical Engineering, Katholieke Universiteit Leuven, Leuven, Belgium
(3) School of Sport and Exercise Sciences, Liverpool John Moores University, Liverpool, United Kingdom

Main topics: Musculoskeletal modelling, analysis of gait and motor disorders.

INTRODUCTION and AIM

Aberrant knee joint loading has been identified as a potential factor affecting onset and progression of knee osteoarthritis (OA) based on the external knee adduction moment (KAM). This study examines how strong KAM is as predictor for knee contact forces (KCF) calculated during gait in healthy adults and subjects with increasing severity of knee OA. Furthermore, the additional predictive value of the knee flexion moment (KFM) in combination to KAM was evaluated.

PATIENTS and METHODS

Fifty-nine female patients (mean age of 65.0) were recruited and separated into three groups: control subjects (n=20); early medial knee OA (n=16); established medial knee OA (n=23) based on MRI[1] and ACR classification [2]. Gait analysis consisted of level walking along a 10 m walkway at self selected speed. An active motion analysis system (Krypton, Metris) recorded the 3D positions of reflective markers. A force plate (Bertec Corporation), embedded in the middle of the walkway, measured ground reaction forces. OpenSim software was used to generate 3D, subject-specific simulations. The knee in the model consisted of a 2 DoF joint (flexion/extension and adduction/abduction). KAM, KFM and KCF were normalized to body weight (BW). Peaks values of all quantities were compared using ANCOVA with Sidak post hoc ($p \leq 0.05$) speed as a covariate. Multiple regressions were then performed to assess whether KAM, or a combination of KAM and KFM better predicts KCF during early and late stance phase of gait.

RESULTS

No significant differences were found between peaks in KAM and KFM (Figure 1). A significant difference was found between early and established groups in the first peak (p=0.047). For all KCF calculated, including the KFM as a second independent variable increased R^2 compared to the results for the KAM alone in particular during late stance (Table 1). However, correlations remain low.

DISCUSSION and CONCLUSIONS

Our findings suggest that reducing the peak KAM even in combination with KFM does not necessarily guarantee a corresponding decrease in peak KCF, especially during late stance. The use of resulting joint moments in the knee should therefore be treated with caution as biomarker for OA progression.

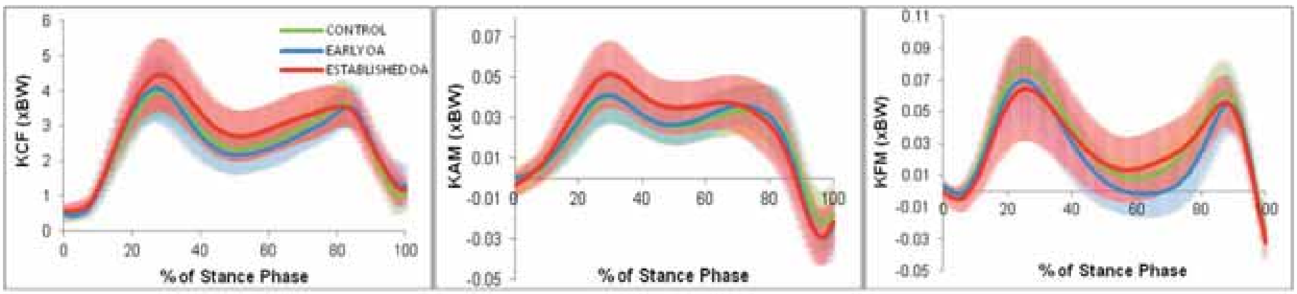

Figure 1: Average KCF, KAM and KFM during stance phase across varying OA severities (respectively, 1st, 2nd and 3rd).

Table 1: Correlations (R²) between moments and KCF during early and late stance phase and at the 1st and 2nd

GROUPS	PREDICTOR	Early Stance	Late Stance	Peak 1	Peak 2
Control	KAM/KAM&KFM	0.850/0.953	0.434/0.752	0.656/0.845	0.194/0.668
Early OA	KAM/KAM&KFM	0.816/0.954	0.247/0.639	0.653/0.922	0.000/0.634
Established OA	KAM/KAM&KFM	0.848/0.941	0.389/0.592	0.684/0.873	0.048/0.179

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FEMORAL ANTEVERSION RELATED GAIT ABNORMALITIES IN NEUROLOGICALLY INTACT INDIVIDUALS

N Ekin AKALAN (1), Adnan APTI(2), Shavkat KUCHIMOV(3), Yener TEMELLI(4), Fuat BILGILI (4)
(1) Istanbul University, Faculty of Health Sciences, Physiotherapy and Rehabilitation Division Istanbul, Turkey
(2) Istanbul University, Institute of Medical Science, Istanbul, Turkey
(3) Bogazici University, Institute of Biomedical Engineering, Istanbul, Turkey
(4) Istanbul Medical Faculty, Orthopaedics and Traumatology, Gait Analysis Laboratory, Istanbul, Turkey

Main topics: Analysis of clinical movement data, Orthopaedics, Analysis of gait and motor disorders

INTRODUCTION and AIM

Increased femoral anteversion (IFA) is a transverse plane problem, and causes sagittal and coronal plane gait abnormalities [1]. The aim of this study was to describe effects of increased femoral anteversion on gait kinematics for neurologically intact children.

PATIENTS/MATERIALS and METHODS

Forty participants, fiveteen typically developed children (TDC) (mean-age: 9.7 ± 0.49) with no IFA and twenty five TDC with IFA (9.5±1.5) were participated in this study. Femoral anteversion (FA) angle was examined by measuring internal and external rotation angle of each child on lying prone position [2-3]. For all children with IFA internal rotation angle were ≥70° and external rotation was ≤ 20° and for TDC group, hip internal rotation was ≤50°. Gait parameters were assessed by 3D gait analysis system (ELITE2002; BTS, Milan, Italy) at a self-selected speed. Normality test (Shapiro-Wilk test) and student-t test were used for statistical analysis ($p<0.05$).

RESULTS

For children with IFA, peak knee extension increased (9.49°) relative to TDC (2.71°), whereas knee range dropped from 56.01° to 50.87° in sagittal plane (Table-1, Figure 1). Unsurprisingly, hip internal rotation and internal foot progression angles increased in IFA group (Table 1). Reduced hip extension and increased anterior pelvic tilt were not statistically significant (Table 1). Stance time, stride time and double support time decreased and swing time, cadence increased significantly.

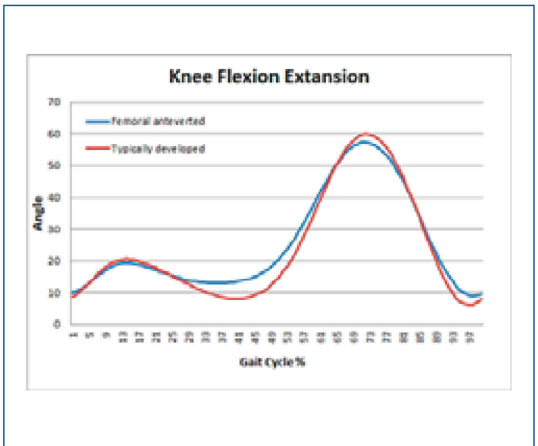

Figure 1: Knee flexion extension angle versus gait cycle

Table 1: Temporal, spatial and kinematics parameters

Parameters	Typically developed	Femoral anteverted	p-value
Stance time [% stride]	59.68±1.21	58.05±2.39	0.020
Swing time [% stride]	40.33±1.19	41.92±2.39	0.023
Stride time [msec]	1109.50±99.77	974.55±92.54	0.000
Cadence [step/min]	108.41±9.60	124.73±12.54	0.000
Doub.supp.time [msec]	106.57±22.04	86.27±17.32	0.002
Foot progression angle	-12.45±4.28	-3.93±6.10	0.000
Peak knee extension °	2.71±6.37	9.49±5.88	0.002
Knee flexion ext. ROM°	56.01±4.55	50.87±3.74	0.002
Hip rotation°	-0.21±10.21	8.42±5.97	0.003
Hip extansion°	-5.20±10.21	-1.42±8.66	0.229
Anterior pelvic tilt°	9.38±5.18	10.74±4.57	0.393

DISCUSSION and CONCLUSIONS

Increased femoral anteversion not only augments internal hip rotation and foot progression but also reduces the peak knee flexion and total range in sagittal plane for neurologically intact participators. It may cause different compensations for children with cerebral palsy because of spasticity and other problems such as sensory motor integration and motor control then it is seen in TDC[3]. Flexed knee posture with decreased knee flexion range make these children great candidate for stiff knee gait pattern. This study demonstrated that IFA itself may cause increased knee flexion in stance and stiff knee gait as well as internal hip rotation and foot-progression angle for neurologically intact individuals. Relation between stiff knee and IFA should be investigated in detail.

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10:10-11:40 **GAIT MODELS / DEVELOPMENTS**
Aula Minor *Chairs: Harald Böhm, Carlo Frigo*

10:10-10:20 ABERRANT FEMORAL GEOMETRY AND ABERRANT GAIT KINEMATICS BOTH IMPAIR HIP LOADING DURING GAIT
L. Bosmans, M. Wesseling, K. Desloovere, G. Molenaers, L. Scheys, I. Jonkers

10:20-10:30 EFFECT OF A REALTIME PROCESS FOR POSITIONING THE PLUG-IN GAIT WAND MARKERS
F. Leboeuf, A. Decatoire, R. Gross, L. Fradet

10:30-10:40 COMPARISON OF SUBJECT-SPECIFIC 3D MUSCULOSKELETAL PARAMETERS BETWEEN CHILDREN WITH SPASTIC CEREBRAL PALSY AND TYPICALLY DEVELOPING CHILDREN
A. Massaad, A. Assi, C. Sauret, W. Skalli, Z. Bakouny, I. Ghanem

10:40-10:50 PELVIS SOFT TISSUE ARTEFACT ASSESSMENT DURING 3-D HIP MOVEMENTS
V. Camomilla, T. Bonci, A. Cappozzo

10:50-11:00 COMPARATIVE ASSESSMENT OF THE EFFECTS OF DIFFERENT ERROR SOURCES ON THE ESTIMATE OF 3D ORIENTATION USING MAGNETIC-INERTIAL MEASUREMENT UNITS
G. Ligorio, E. Bergamini, A. Cappozzo, A.M. Sabatini

11:00-11:10 THE EFFECT OF HIP AND KNEE JOINT CENTER CALIBRATION METHOD ON MUSCULOSKELETAL MODELING OUTCOMES
E. Pietersma, M. van der Krogt, F. Steenbrink, J. Harlaar, D. Veeger

11:10-11:20 INFLUENCE OF DIFFERENT HIP JOINT CALCULATION METHODS ON HIP AND KNEE KINEMATICS AND KINETICS.
A. Kranzl, B. Attwenger, D. North

11:20-11:30 DESIGN OF A MODULAR SMALL DIMENSION FORCE PLATFORM FOR GAIT ANALYSIS OF CHILDREN AND NEUROLOGIC PATIENTS
P. Tamburini, R. Stagni, A. Cappello

11:30-11:40 HOW COMPLEX SHOULD LOWER-LIMB JOINT MODELS BE FOR SUBJECT-SPECIFIC MUSCULOSKELETAL MODELING APPLICATIONS?
L. Pitto, G. Valente, R. Stagni, F. Taddei

12:00-13:00 Prizes, communications and wrap up

ABERRANT FEMORAL GEOMETRY AND ABERRANT GAIT KINEMATICS BOTH IMPAIR HIP LOADING DURING GAIT

L Bosmans (1), M Wesseling (1), K Desloovere (2), G Molenaers (3), L Scheys (3), I Jonkers (1)
(1) KU Leuven, Department of Kinesiology, Leuven, Belgium
(2) KU Leuven, Department of Rehabilitation Sciences, Leuven, Belgium
(3) KU Leuven, Department of Development and Regeneration, Leuven, Belgium

Main topics: musculoskeletal modelling, musculoskeletal imaging, orthopaedics

INTRODUCTION and AIM

Children with cerebral palsy (CP) often present aberrant hip geometry, more specific increased femoral anteversion and neck-shaft angle. Furthermore, altered gait patterns are present within this population, which impose abnormal stresses and strains on the developing bones [1]. As bone naturally adapts to the applied loading conditions, the excessive physiological load imposed by the pathological gait characteristics may, at least partially, contribute to lower limb bone deformities [2]. This study analyzed the effect of aberrant femoral geometry on hip contact force (HCF) during typically developing (TD) and pathological gait.

PATIENTS/MATERIALS and METHODS

Eight subjects with diplegic CP (8-12 yrs) and one control subject were included in this study. For each subject, a clinical gait analysis was performed and magnetic resonance images of the lower extremities were captured. For each subject, a generic (with normal bone/muscle geometry) [3] and personalized (with personalized bone/muscle geometry) [4] musculoskeletal model was created. For each subject with CP, three combinations were created to perform dynamic simulations of gait: (i) TD-GEN: TD gait characteristics using a generic model, (ii) TD-MRI: TD gait characteristics using a personalized model and (iii) CP-MRI: CP-specific, pathological gait characteristics using a personalized model. For TD-GEN and TD-MRI, TD gait characteristics were extracted from the one control subject and applied to both model types. For all conditions, the magnitude and inclination angles of the two peaks of the HCF during the gait cycles were calculated and averaged for all subjects. Comparison between TD-GEN and TD-MRI reflects the effect of aberrant bone/muscle geometry on the calculated HCF during normal gait. Comparison between TD-MRI and CP-MRI reflects the additional effect of CP-specific gait characteristics on the calculated HCF in the presence of aberrant femoral geometry.

RESULTS

The comparison of TD-GEN and TD-MRI, confirms the effect of aberrant bone geometry on the magnitude of the HCF even during TD gait (Fig. 1), inducing an increase and decrease of the first and second peak respectively. The magnitude of the HCF is positively correlated with the degree of bony deformity and the inclination angle of the HCF is orientated more vertically (data not shown). When comparing TD-MRI and CP-MRI, a decrease of the first peak of the HCF is observed (Fig 1.), but induces an even more vertically and anteriorly inclined HCF (data not shown).

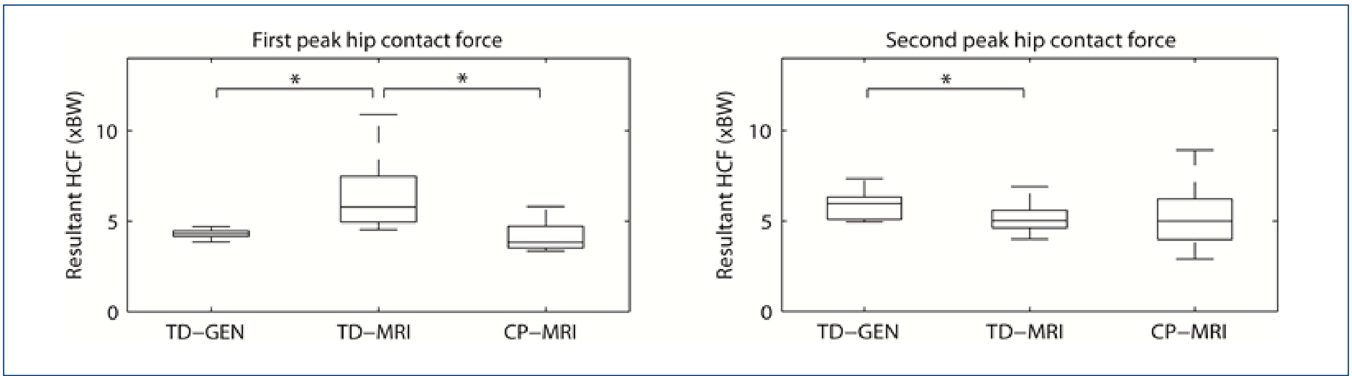

Figure 1: Magnitude of the first and second peak of the resultant HCF (in times bodyweight (xBW)) of TD-GEN, TD-MRI and CP-MRI.

DISCUSSION and CONCLUSIONS

This study showed that the presence of aberrant bone geometry affects hip joint loading, even during normal (TD) gait. The presence of aberrant femoral geometry and CP-specific gait characteristics optimized the magnitude of the hip joint loading, but changed the orientation of the vector. The analysis of the hip contact force during gait in children with CP may prove highly relevant as it is indicative for bone loading and consequently bone growth.

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EFFECT OF A REALTIME PROCESS FOR POSITIONING THE PLUG-IN GAIT WAND MARKERS

F. Leboeuf (1), A. Decatoire (2), R. Gross (1), L. Fradet (2),
(1) CHU de Nantes, Nantes, France
(2) CNRS - Université de Poitiers – ISAE-ENSMA - UPR 3346, Poitiers, France

Main topics: Technical developments in movement science, Experimental studies in human movement science.

INTRODUCTION and AIM

Quality of the popular Plug-in Gait (PiG) model [1] outputs depends primarily on marker positioning. Among them, the wand markers placed on the thighs and shanks are especially difficult to position because they involve non-palpable anatomical points: the hip and the knee joint centers, respectively.

This communication presents an optimal method for positioning wand markers using a real-time process. We examine the effect of this method on two operators (expert and non-expert). This process is expected to reduce the inter-session variability [2] and the maximum of the varus-valgus knee angle during swing phase.

PATIENTS/MATERIALS and METHODS

Gait data were collected on ten healthy subjects (62±10Kg, 1.69±0.09m) with an optoelectronic motion capture system (Vicon, Oxford Metrics). Except the wand markers, all the PiG markers, plus medial markers were placed by an expert operator (5-year experience in gait analysis). A custom program using the Vicon RealTime SDK was implemented in Matlab. It indicated when the thigh wand marker, for example, belonged to the plan formed by the hip joint center, the lateral and medial condyles, with a tolerance of ±1mm.

Firstly, each subject participated in four gait sessions, two with and two without real-time positioning by the expert. Between each session, the wand markers were fully removed. Four other gait sessions were then carried out with non-experts as operator (physiotherapist students without experience in gait laboratory).

Kinematics PiG data were calculated by the use of the Biomechanical toolkit [3]. A two-way mixed-anova examined the effect of the realtime process and operators.

RESULTS

Real-time positioning significantly reduced the inter-session variability of knee angles for the non-expert (fig1). For the expert, only the flexion-extension was different. Similarly, a significant difference of 6 degrees (tab 1) was observed for the maximal knee var/valgus angle provided from the non-expert positioning. Thanks to the real-time process, the maximal var/valgus of the non-expert did not differ from the expert one.

DISCUSSION and CONCLUSIONS

A real-time positioning of the wand markers proves to be essential especially for non-expert operators. This process limits the cross-talk effect characterized by a prominent knee var/valgus, which reinforces the use of knee var/valgus as an adhoc quality assurance tool [2]. Moreover, the real-time process reduces the intrinsic variability caused by marker mislocation. By this way, it would benefit to longitudinal gait studies by discerning consequence of therapeutic decisions.

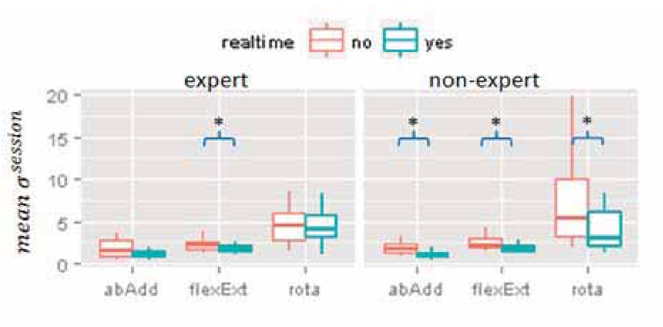

Table 1: maximum of the knee varus-valgus angle in swing phase.
(*) indicates a significant difference between conditions.

condition	Real-time (deg)	No real-time(deg)
Expert	13.8±1.4	14.9±1.4
Non-expert	14.3±1.8	20.3±1.4*

Figure 1: mean inter-session variability of the knee angles.
(*) indicates a significant difference

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COMPARISON OF SUBJECT-SPECIFIC 3D MUSCULOSKELETAL PARAMETERS BETWEEN CHILDREN WITH SPASTIC CEREBRAL PALSY AND TYPICALLY DEVELOPING CHILDREN

A. Massaad (1,2), A. Assi (1,2,3), C. Sauret (3), W. Skalli (3), Z. Bakouny (1), I. Ghanem (1,2,4)
School of Medicine, Saint-Joseph University, Beirut, Lebanon
Gait lab, SESOBEL, Beirut, Lebanon
Laboratoire de Biomécanique, Arts et Métiers ParisTech, Paris, France
Hôtel Dieu de France Hospital, Beirut, Lebanon

Main topics: cerebral palsy, 3D musculoskeletal parameters, MRI, EOS® biplanar Xrays, typically developing children

INTRODUCTION and AIM

Spasticity in children with cerebral palsy (CP) affects muscle function and geometry and is related to the development of skeletal malalignments [1,2] which can cause gait alterations. The aim of this study is to compare muscular and skeletal 3D parameters between CP children with neither medical nor surgical history and typically developing (TD) children.

PATIENTS/MATERIALS and METHODS

Fifteen CP children with a mean age of 11±3 (spastic diplegia N=13, spastic hemiplegia N=2) with neither medical nor surgical history had undergone 3D gait analysis (3DGA) where the gait deviation index (GDI) was assessed, among other kinematic and kinetic parameters. An EOS® biplanar Xrays exam was performed in order to calculate the 3D skeletal parameters of the lower limbs: femoral anteversion, tibial torsion, neck shaft angle as well as the pelvic parameters. This was performed on 30 lower limbs of CP children, which were age-matched to an equal number of lower limbs of TD children. Axial MRI acquisitions were performed on 22 of the lower limbs of the CP group, which were age-matched to 14 lower limbs of TD children, in order to obtain 3D subject-specific reconstructions of 18 muscles in each limb. Based on these reconstructions, each muscle's length, volume and cross sectional area (CSA) were calculated and then normalized to lower limb length or body mass (Figure 1).

RESULTS

The GDI of the CP population ranged between 41 and 90. The lengths of the lower limb muscles of the CP children were comparable to the TD children's muscle lengths, except for the adductor brevis, longus and magnus and the fascia lata which were significantly smaller ($p<0.05$). The normalized muscle volumes of the CP children were smaller for the gastrocnemius medius, adductor longus and anterior tibialis ($p<0.05$). The mean values of the femoral anteversion, tibial torsion and the neck shaft angle for the CP group were similar to those of age-matched TD children.

DISCUSSION and CONCLUSIONS

For the first time, both musculoskeletal 3D subject-specific parameters and 3DGA in CP could be compared, in parallel, to those of TD children. Even for children with high functional level (GMFCS level I, N=10), statistically significant differences could be found in some muscles' lengths and volumes. Larger groups of subjects will allow us to better understand the evolution of the musculoskeletal deformities that occur during the growth of spastic CP children, when compared to the growth of TD children.

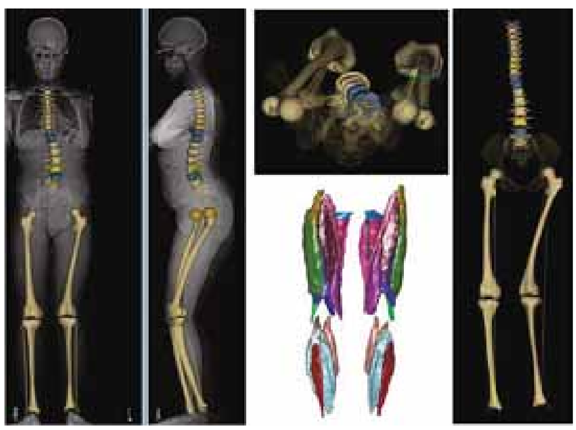

Figure 1: Musculoskeletal 3D reconstructions using EOS® biplanar Xrays and a MRI for an 11 year-old spastic diplegic female patient

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PELVIS SOFT TISSUE ARTEFACT ASSESSMENT DURING 3-D HIP MOVEMENTS

V. Camomilla (1,2), T. Bonci (1,2,3), A. Cappozzo (1.2)
(1) Department of Movement, Human and Health Sciences, Università “Foro Italico”, Rome, Italy
(2) Interuniversity Centre of Bioengineering of the Human Neuromusculoskeletal System
(3) Université de Lyon, F69622; Université Claude Bernard Lyon 1; IFSTTAR, UMR_T9406, LBMC, France.

Main topics: Experimental studies and technical developments in movement science.

INTRODUCTION and AIM

The soft tissue artefact (STA), as occurring during human movement analysis using non-invasive stereophotogrammetry, has been investigated with reference to skin markers located on various body segments. However, to date only one study assessed it with reference to markers located on the pelvis. This was done by determining how varied the local position of anatomical landmarks (ALs), as determined on the skin through manual palpation, while the hip assumed different flexion/extension angles (multiple anatomical calibration) [1]. In the present study the same approach was used but through a different anatomical calibration method which allowed for a better reliability (UP-CAST [2]) and for different hip flexion/extension and ad-abduction angles.

PATIENTS/MATERIALS and METHODS

One healthy subject (age, stature and mass: 40y, 1.64m, 60kg) volunteered to undergo an MRI scan of the pelvis. The bone digital model was reconstructed (AMIRA®). Seven anatomical landmarks (right and left anterior superior, RASI, LASI, and posterior superior iliac spines, RPSI, LPSI, and sacrum, SACR) were virtually palpated on the digital bone and manually palpated and marked with a felt pen on the volunteer. An anatomical frame (AF) was then associated with the bone model. Seven markers were attached close to the prominent portion of the pelvic bones (superior iliac spines and iliac crests). The subject stood in five static postures with the hip angles depicted in Fig.1. For each posture, the marker instantaneous positions were captured (VICON MX, 100 frames/s) and used to construct a technical frame (TF) and the TF and the AF were registered using the UP-CAST method by, first, identifying unlabelled bone points in the TF rolling the tip of a wand that carried four makers over the prominent bony parts and, second, registering the bone model with these points. The position of the marked ALs in the TF was acquired for each hip position using the wand, and then represented in the AF. To describe the STA range, for each AL mark, the maximal displacement of the AL mark positions in the AF obtained in the different hip positions, was determined.

RESULTS

The STA range of the different ALs between the five postures of the left hip was: LASI–13.6 mm, RASI–26.0 mm, LPSI–8.2 mm; RPSI–9.3 mm and SACR–11.1 mm.

DISCUSSION and CONCLUSIONS

The STA resulting from multiple static calibrations performed with the UP-CAST method was in the same range as assessed in [1], except for the RASI. To stabilize posture, the right leg on which the subject stood presented hip abductions wider than in gait, possibly causing a STA displacement larger than observed in [1]. The ASIS confirmed to have greater displacement than the PSIS, and the superior-inferior displacement to be wider than along the other directions. This proof of concept seems promising to enlarge current knowledge on pelvis STA, by performing further investigation on cohorts of subjects, possibly with different body mass indices.

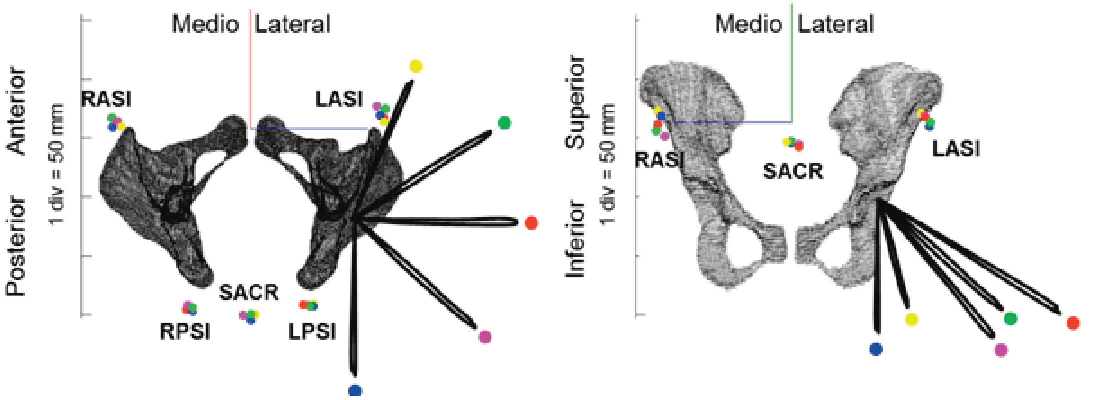

Figure 1: Skin ALs calibrated in five different hip positions are shown (blue, pink, red, green, yellow for the five positions, with the thigh represented as a black line) in the (a) transverse and (b) frontal plane.

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COMPARATIVE ASSESSMENT OF THE EFFECTS OF DIFFERENT ERROR SOURCES ON THE ESTIMATE OF 3D ORIENTATION USING MAGNETIC-INERTIAL MEASUREMENT UNITS

G. Ligorio (1), E. Bergamini (2), A. Cappozzo (2), A.M. Sabatini (1)
(1) Scuola Superiore Sant'Anna, Pisa, Italy
(2) Università degli Studi di Roma "Foro Italico", Rome, Italy
Main topics: Technical developments in movement science; Mathematical simulation in human mov. science

INTRODUCTION and AIM

The determination of the accurate 3D orientation of a body segment is a crucial aspect in clinical movement analysis [1]. Among motion capture technologies, wearable sensors, such as magnetic-inertial measurement units (MIMUs), are gaining popularity. Several methods were developed to estimate 3D orientation from MIMU data, in order to effectively exploit the complementary properties of inertial (gyroscopes and accelerometers) and magnetic sensors embedded in the MIMUs [2]. It is well known that these sensors are affected by several error sources, including measurement noise, bias instability, calibration errors, ferromagnetic disturbances, external accelerations [3]. The purpose of the present study is to assess the contribution of the sources of error associated to each sensor to the uncertainty affecting the 3D orientation estimation, during a consolidated clinical test.

PATIENTS/MATERIALS and METHODS

A Timed Up and Go test (TUG) was performed by ten healthy subjects (5 M, 5 F, 28 ± 5 y). One MIMU (Opal, APDM Inc.) was secured to the lower back of each subject and angular velocity, acceleration and local magnetic field vector data were collected. The trajectories of four markers attached to the MIMU were tracked by a stereophotogrammetric system (Vicon MX3), and the orientation of a marker-based frame was obtained and considered as reference. These marker trajectories were used to calculate the same variables measured by the MIMU. Measured and simulated MIMU data were then combined, as detailed in Table 1, obtaining five different scenarios. Each signal combination was fed as an input of an Extended Kalman Filter (EKF) [2] to estimate the 3D MIMU orientation. The rationale was to assess, both individually and jointly, the effect of the errors associated to the EKF model, as well as to each MIMU sensor. The accuracy of the obtained orientations was then evaluated in terms of orientation error [2]. A Kruskal-Wallis test with post-hoc Dunn comparisons ($\alpha=0.05$) was performed to investigate whether significance differences existed among the obtained orientation errors.

RESULTS

Results (mean ± one standard deviation) about the error contribution associated to the EKF model and to the MIMU sensors are reported in Fig.1. Significant differences with respect to SIM are indicated with an asterisk.

DISCUSSION and CONCLUSIONS

The results show that, during the TUG test, the EKF model (SIM) can be considered as appropriate (error = 0.4 ± 0.2 deg). The largest error contribution is caused by the gyroscope (GYRO) and magnetometer (MAG) signals ($p<0.01$). This can be due to (1) the unusually low short-time bias stability of the gyroscopes embedded in the MIMUs tested in the present study, and (2) the relatively large working space (4.0×0.2×0.5 m), which may affect the reliability of magnetic sensor signals. Conversely, no statistical differences were found between ACC and SIM ($p>0.05$). A plausible explanation is that external accelerations had a little effect on the EKF performance during relatively slow motions such as those involved in a TUG test.

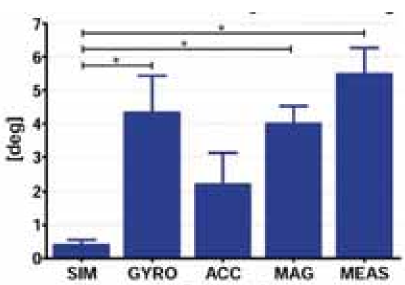

Figure 1: Orientation error

Table 1: Characteristics of the error contribution assessment

error effect	measured data	simulated data	Acronym
EKF model	–	ang vel – acc – mag	SIM
gyroscope	ang vel	acc – mag	GYRO
accelerometer	acc	ang vel – mag	ACC
magnetometer	mag	ang vel – acc	MAG
all three sensors	ang vel – acc – mag	–	MEAS

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ACKNOWLEDGEMENTS

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THE EFFECT OF HIP AND KNEE JOINT CENTER CALIBRATION METHOD ON MUSCULO-SKELETAL MODELING OUTCOMES

E. Pietersma (1), M.M. van der Krogt (2), F. Steenbrink (3), J. Harlaar (2), H.E. Veeger (1,4)
(1) Delft University of Technology, Delft, The Netherlands
(2) VU University Medical Center, Amsterdam, The Netherlands
(3) Motek Medical BV, Amsterdam, The Netherlands
(4) VU University, Amsterdam, The Netherlands

Main topics: Analysis of clinical movement data; Musculoskeletal modelling.

INTRODUCTION and AIM

In clinical gait analysis, hip and knee joint centres can be determined based on anatomical markers combined with regression equations, or using different functional calibration methods. The method of choice is known to strongly influence joint centre locations [1]. Much less is known about the functional relevance of this difference. In this study we investigated to what extent anatomical versus functional calibration methods of hip and knee joint centres affect kinematic, kinetic and musculoskeletal modelling outcomes.

PATIENTS/MATERIALS and METHODS

Three healthy adult subjects (1 male, 1.95 m, 96 kg, 2 female, 1.68 and 1.66 m, 65 and 69 kg, all between 20 and 25 years) underwent gait analysis including functional calibration trials on an instrumented treadmill. Marker trajectories (HBM model [2] extended with medial knee and ankle markers) and ground reaction forces were fed into OpenSim modelling software [3]. The generic Gait2392 model was scaled to the subjects in four ways; 1/MB: anatomical marker-based only; 2/HFC: functional hip joint centres (sphere fit method); 3/KFC: functional knee joint axes (instantaneous helical axis method); 4/HKFC: functional hip joint centres and knee joint axes. Furthermore, for KFC the effect of adding a sliding rather than a fixed hinge knee joint was evaluated. Resulting joint locations, joint angles, joint moments, muscle-tendon lengths and muscle forces were calculated using OpenSim and compared between the different models.

RESULTS

Functional calibration altered the hip joint centre location by 50.6±17.4 mm, the knee centre location by 38.7±21.7 mm and the knee axis orientation by 14.0±8.5°. The effect on kinematics was largest in the two female subjects (up to 28°, 20°, and 8° change for hip, knee and ankle angles respectively) (Fig. 1A). Also the effect on joint moments and powers was found to be significant (up to 29%, 31%, and 13% for hip, knee, and ankle moments, and 31%, 25%, and 32% for joint powers). Muscle-tendon length was affected strongly (up to 30%), but changes in length over the gait cycle were almost equal (Fig 1B). The use of a sliding versus fixed hinge for the knee had only little effect on all of the outcome measures.

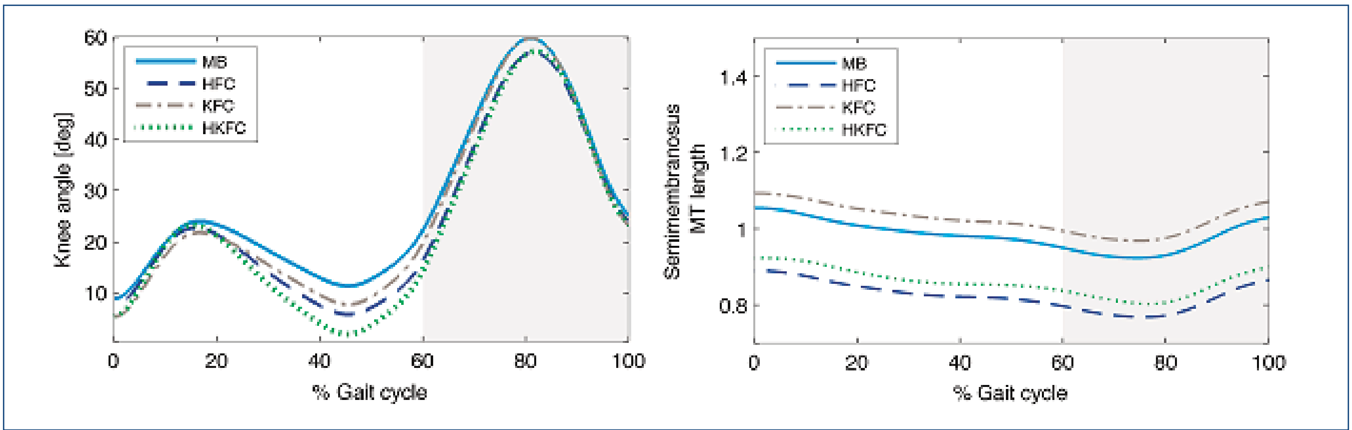

Fig 1. Knee angle and semimembranosus muscle-tendon length (normalized to rest length in MB) for one female subject

DISCUSSION and CONCLUSIONS

We conclude that joint calibration methods have a large and possibly clinically relevant effect on gait analysis and modelling outcomes and should be chosen with care. Our results cannot give a decisive answer on which method is best; for this validation against for instance imaging data is needed and a next step in our study.

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INFLUENCE OF DIFFERENT HIP JOINT CALCULATION METHODS ON HIP AND KNEE KINEMATICS AND KINETICS

Kranzl A.*, **Attwenger B*., North D.***
*Laboratory for Gait and Movement Analysis - Orthopaedic Hospital Speising, Vienna

Main topics: Orthopaedics, Analysis of clinical movement data, Analysis of gait and motor disorders.

INTRODUCTION and AIM

Determination of the proper position of the hip joint is still a challenge in gait analysis. On one hand there is the determination of the hip centre on regression formulas (Davis, Harrington) on the other hand, the functional determination methods (sphere fitting, transformational and global calibration technique). For the daily work it is difficult to decide whether the chosen calculation algorithm fit now and what impact would have a different calculation algorithm on the results. Especially in overweight or not normally proportioned patients the use of regression equation should be critically examined. Aim of the study was to compare different hip joint algorithm and the influence on joint kinematic and kinetic parameters and the clinical relevance of this differences.

PATIENTS/MATERIALS and METHODS

Patients who were scheduled for surgical treatment (temporary hemiepiphysiodesis) of idiopathic genua valga between 2012-2013 were considered for this retrospective study. From 40 patients functional movement data for determine the hip joint using the functional method was available. Age Ø12.75 (8-15) years, height: 156.66 cm ± 12.76 weight: 59.14 ± 17.03, BMI: 23.87 ±5.26. Before surgery all patients had routinely a 3-D gait analysis. For the regression method hip joint centre was calculated using the Harrington and Davis equation [1, 2]. As a functional method we used the SCORE method [3]. Location of the hip joint centre in relation of the pelvis coordinate system and all gait parameters (hip, knee: kinematic and kinetic, mean and single values of certain phases of the gait cycle) for all three methods were calculated. Calculating spearman's correlation coefficient between the methods for the hip joint centre location was used. Normal distribution was assessed and rANOVA was used to determine statistical significance.

RESULTS

No significant difference were found in terms of the overall vector from the pelvis coordinate system to the hip joint centre. Looking at the individual components all three components showed significant differences between the hip joint centre calculations. Significant differences were found mainly between Davis - SCORE and Harrington - SCORE in the sagittal hip joint kinematics and hip kinetics. All three methods had to each other significant differences for the frontal plane hip kinematics and kinetics. In the transverse plane for the hip joint angle we found only significant differences between Harrington to SCORE. Transversal knee joint kinematics, frontal and transversal kinetics were not influenced by the different methods. Sagittal and frontal knee angles were manly significant different between Harrington - SCORE.

DISCUSSION and CONCLUSIONS

The position of the hip joint is different depending on the calculation method, however, the total vector of the pelvic coordinate system to the hip joint centre is not significant different. When looking at the values we see that the difference in the kinematic parameters are small. The hip angle in the frontal plane at the beginning of the single support phase has 3.9° (Davis), 5° (Harrington) and 5.9° (SCORE). Two degree is a small amount and we have to asked if this difference is clinical relevant. This small differences between the calculations were found between all kinematic and kinetic parameters. Depending which model were compared, the differences in kinematic and kinetic parameters were significant different. Specifically, the differences between the models in the frontal plane in the hip joint can be seen.

The statistical analysis showed significant differences between the hip joint calculation methods. But when looking at the differences only small changes about 2 degree can be seen and the clinical relevance of this differences must be questioned.

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DESIGN OF A MODULAR SMALL DIMENSION FORCE PLATFORM FOR GAIT ANALYSIS OF CHILDREN AND NEUROLOGIC PATIENTS

Paola Tamburini(1), Rita Stagni(1,2), Angelo Cappello(2)
(1) Health Sciences and Technologies–Interdepartmental Center for Industrial Research (HST–ICIR), University of Bologna, Italy
(2) Department of Electric, Electronic and Information Engineering “Guglielmo Marconi”–DEI Università di Bologna Italy

Main topics: Analysis of gait and motor disorders, technical developments in movement science.

INTRODUCTION and AIM

Gait analysis of subjects with short and non-uniform gait, typical children, children with cerebral palsy, elderly and stroke patients, can result critical in terms of ground reaction force (GRF) quantification with traditional force platforms. The standard *de facto* of commercial force platforms dimension (0.60x0.40m) can determine problems resulting from the double contact of the foot on the same platform. The aim of this work is the design of a small modular, six components, force platform (0.40x0.40m) to solve the problem of double contact, maintaining the performance of commercial larger ones. The simplicity of the design and materials used allows the use of multiple force platforms at low cost. Electronics dedicated to the acquisition of the output signal is not required because a commercial evaluation board can be exploited, that is able to independently manage the output of the strain gauges. This solution simplifies the realization of instrumented corridors.

PATIENTS/MATERIALS and METHODS

The design of the proposed small modular force platform [1] was performed to obtain a performance comparable to that of commercial force platforms. The total dimension of the force platform is: 0.40x0.40x0.105 m. The minimum number of mono-axial strain gauges are used for deformation sensing: six for each post, longitudinally arranged. The output of each strain gauge is directly provided as input to a commercial evaluation board. This removes the need for *ad-hoc* electronics for signal acquisition. Static analysis was perform to estimate the platform calibration matrix. 576 simulations were implemented considering applied forces varying between -200 N and 200 N for Fx and Fy and between -2000 N and -200 N for Fz, in 9 different points of application. Which were used in order to cover most of the surface of the platform. Eighty-four additional simulations were performed to test the calibration matrix and quantify the error that the system commits in the estimation of applied loads and moments, which were not exploited in the estimation of the calibration matrix.

RESULTS

The median error made in the determination of the forces is between -0.0378% and 0.0041%. The maximum error made in the determination of the forces ranges from a minimum of 0.0325% to a maximum of 0.8075%.
The median error made in the determination of the moments is between 0.0028% and 0.0372%. The maximum error made in the determination of the moments is in Mx 0.1112% at -45 Nm, in My 0.2401% at 15 Nm and in Mz 3.435% at 10Nm. The median and the maximum error in the determination of the forces and moments, based on the calculated calibration matrix, resulting from the 84 additional simulations are illustrated in Tables 1 and 2.

DISCUSSION and CONCLUSIONS

The range of the forces used, and the resonance frequency are comparable to those of commercial platforms [2]. The low cost of mechanical structure and the use of commercial evaluation board encourages the creation of multiple platforms. An ad hoc support base is provided in such a way as to allow the isolation of the structure and then a proper measure. In addition, the support base allows to solve many of the critical issues related to the installation. The starter kit, which consists of two platforms, allows the standard balance analysis achieved with commercial platforms. Furthermore it allows us to distinguish the GRF of each foot e through integration techniques we are able to estimate a global GRF.

Table 1: Median and Maximum error in forces

Components of the force	Median Error %	Maximum Error %
Fx	-0.0378	0.8075
Fy	-0.0022	0.2137
Fz	0.0041	0.0325

Table 2: Median and Maximum error in moments

Components of moments	Median Error%	Maximum Error % Reference value (Nm)
Mx	0.0070	0.1112 -45
My	0.0028	0.2401 15
Mz	0.0372	3.435 10

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HOW COMPLEX SHOULD LOWER-LIMB JOINT MODELS BE FOR SUBJECT-SPECIFIC MUSCULOSKELETAL MODELING APPLICATIONS?

L. Pitto (1), G. Valente (1), R. Stagni (2), F. Taddei (1)
(1) Medical Technology Laboratory, Rizzoli Orthopaedic Institute, Bologna, Italy
(2) Department of Electrical, Electronic and Information Engineering, University of Bologna, Bologna, Italy

Main topics: Musculoskeletal modelling, Mathematical simulation in human movement science, Orthopaedics.

INTRODUCTION and AIM

Subject-specific musculoskeletal modelling can be applied to study musculoskeletal disorders, providing a valuable approach to calculating muscle and joint forces during movement. The choice of the lower-limb joint models can significantly affect joint contact loads during walking [1]; however, the degree of joint model complexity according to the application has not been extensively studied. The aim of this study is twofold: first, to compare muscle and joint contact forces during common daily activities, using four subject-specific models including different joint models; second, to investigate how the uncertainties in the identification of subject-specific kinematic constraints affect the model outputs using a probabilistic modelling approach.

PATIENTS/MATERIALS and METHODS

Experimental data were collected on a healthy volunteer subject, including lower-body MRI scans and gait data (marker trajectories, ground reaction forces and EMG recordings) during walking, chair rising, stair ascending and descending. A baseline musculoskeletal model (M1) was created, which included a 7-segment 3D articulated linkage with spherical joints at the hips, hinge joints at both knees and ankles [2], and 84 musculotendon actuators. More complex knee and ankle models were built upon the baseline model as follows: planar hinge and universal joint [3] (M2), modified spherical and universal joint [4] (M3), and subject-specific planar 4-bar-linkage knee and ankle [5,6] (M4). To test the sensitivity to parameter identification, five operators virtually palpated the anatomical landmarks necessary to create the M4 model. The joint parameters were statistically sampled according to inter-operator palpation variability, and a set of perturbed models was then created. Simulations of movements solving a typical inverse dynamics and static optimization problem were performed using OpenSim, to calculate muscle and joint contact forces. The predicted forces were compared between the different motor tasks and the robustness to the joint parameter identification was analyzed.

RESULTS

M2 and M4 tended to predict lower knee forces (Table 1), as coupling planar translations to flexion increased knee extensor moment arms. Forces obtained using M4 were more robust to palpation uncertainties at the knee than at the ankle, where, for high dorsiflexion angles (such as in stair descending), M4 predicted unrealistically high contact forces with high variability (Table 1). Hip contact forces were slightly affected by the degree of knee and ankle joint complexity, except for the M3 model, in all simulated motor tasks.

DISCUSSION and CONCLUSIONS

The models predicted different joint loads, and behaved differently in different motor tasks. In the absence of direct validation methods of the predicted forces, the choice of implementing complex subject-specific joints should be justified only when the predictions are robust to the uncertainties in parameter identification. Therefore, before implementing subject-specific kinematic constraints, it is advisable to analyze the sensitivity of predictions over the joint range of motion and, if this choice appears weak (as in the stair descending task), opting for less complex, but more robust and reproducible joint models.

Table 1: peak joint contact loads (BW). M4: mean ¤ SD

	Gait			Chair rising			Stair ascending			Stair descending		
	Hip	Knee	Ankle	Hip	Knee	Ankle	Hip	Knee	Ankle	Hip	Knee	Ankle
M1	3.63	3.40	5.44	3.15	2.96	1.21	3.68	5.30	4.88	4.08	5.13	7.04
M2	3.77	3.80	5.82	3.05	2.54	1.46	3.61	4.61	4.99	4.07	4.80	7.57
M3	4.47	5.80	5.58	3.23	2.59	1.50	3.88	5.87	5.05	3.83	4.39	7.18
M4	4.00 ±0.14	4.45 ±0.25	4.96 ±0.26	3.14 ±0.02	2.26 ±0.07	1.12 ±0.07	3.75 ±0.01	4.14 ±0.14	4.61 ±0.32	4.11 ±0.01	4.91 ±0.99	9.28 ±2.77

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Course and seminars

The ESMAC gait course provides a comprehensive overview of clinical gait analysis to those who are relatively new to the field. Participants will gain an understanding of normal walking gait, and learn how to describe this in a systematic way. Different elements of three-dimensional, instrumented gait analysis will covered in-depth, including kinematics, kinetics and electromyography. Real, clinical cases will be used to demonstrate how to interpret this data, as well as relating the findings back to clinical examination and patient history. In addition, topics such as gait analysis equipment and trouble-shooting in the gait lab, will equip participants to gain valuable knowledge in assessing the validity of gait data. The course will be comprised of a mixture of lectures and inter-active workshops. Participants will also have the opportunity to collect gait data in a clinical gait laboratory. The faculty includes engineers, physiotherapists and orthopaedic surgeons, all experienced in the field of clinical gait analysis.

Speakers
Julie Stebbins
Bertram Muller
Kaat Desloovere
Sebastian Wolf
Neil Postans
Andrew Roberts
Reinald Brunner
Martin Gough

Monday 29th September

9.00-9.10	Welcome and Introduce Teachers
9.10-9.30	Overview of Gait Analysis
9.30-10.00	Video observation of normal walking
10.00-10.30	Identifying and describing abnormal gait
10.30-11.00	Coffee break
11.00-11.45	Workshop 1 - systematic description of video
11.45-12:30	Clinical Examination
12.30-13.30	Lunch
13.30-1400	Why the Clinical Examination matters
14.00-14.30	Kinematics
14.30-15.30	Workshop 2 - draw kinematic graphs (Normal + simulated altered walking)
15.15-16.00	Coffee break
16.00-16.45	Workshop 3 - Relating abnormal kinematics and video to clinical exam
16.45-17.30	Options

Tuesday 30th September

9.00-9.15	Revision of Day 1
9.15-10.00	Introduction to Kinetics - Basic Principles
10.00-10.45	Kinetics during gait
10.45-11.15	Coffee break
11.15-12.00	EMG during gait
12.00-12.45	Workshop 4 - Draw kinetic graphs
12.45-13.30	Lunch
13.30-14.30	Integrating and interpreting data - general principles
14.30-17.30 Coffee after 1st two rotations	Practical Sessions: 1. Marker Placement and data collection 2. EMG placement and data collection 3. Identify problem with the data

Wednesday 1st October

9.00-9.30	Quality Assurance
9.30-10.30	Case Example - Tie everything together
10.30-11.00	Coffee break
11.00-12.30	Workshop 5: Practice putting everything together
12.30-13.30	Lunch (trade exhibition)
13.30-15.00	Workshop 6: Identifying outcome of intervention
15.00-15.30	Coffee break
15.30-17.00	Workshop 7: Clinical interpretation of gait data
17.00-17.15	Closure

Symposium 1 *Aula 2*	**THE MANY INTERPLAYING ASPECTS INFLUENCING BALANCE CONTROL**
14:15-15:00	Measuring verticality perception to explain postural and gait disorders *Dominic Pérennou*
15:00-15:45	Somato-sensory input in static and dynamic balance control: clues from peripheral neuropathies *Antonio Nardone and Marco Schieppati*
15:45-16:15	Coffee break
16:15-17:00	The effects of emotional state on human balance control *Mark G. Carpenter*
17:00-17:45	Recovery of balance after stroke. Disentangling the contribution of the paretic and non paretic leg to balance control in stroke patients during rehabilitation and in daily life *Jaap Buurke and Alexander Geurts*

Symposium 2 *Aula 3*	**GAIT ANALYSIS IN KNEE OSTEOARTHRITIS – RELEVANCE, RESEARCH AND PRACTICE**
14:15-15:00	An introduction to the biomechanics of knee osteoarthritis: why gait analysis matters *Martijn Steultjens*
15:00-15:45	Gait retraining in knee osteoarthritis *Kim Bennell*
15:45-16:15	Coffee break
16:15-17:00	Kinetic feedback is more effective than kinematic feedback in minimizing knee load *Josien van den Noor*
17:00-17:45	Biomechanics of knee joint and compensation strategies in different functional task *Carlo Frigo*

Symposium 3 ***Aula 2***	**FROM CEREBRAL PALSY TO SUBACROMIAL PAIN SYNDROME: NEW METHODS AND CLINICAL APPLICATIONS OF UPPER LIMB MOTION ANALYSIS**
9:15-10:00	Shoulder motion: modelling aspects, conventions and application *O. Rettig and S. Wolf*
10:00-10:45	Subacromial pain syndrome: Analysis of scapular dyskinesis and infraspinatus voluntary activation *P. McClure*
10:45-11:15	Coffee break
11:15-12:00	Objective upper limb assessment in adult stroke and unilateral CP: from measurement to interpretation *E. Jaspers and L. de Baets*
12:00-12:45	What do we really know about ‘normality bands’? Lessons learned from the analysis of the scapulo-humeral coordination *A.G. Cutti*

Symposium 4 ***Aula 3***	**HUMAN MOVEMENT SIMULATION AND MODELING**
9:15-10:00	Clinical applications of modeling and simulation: progress and challenge *S. Delp and J. Hicks*
10:00-10:45	Cerebral Palsy gait–our mission to unravel the interplay of musculoskeletal and neuromuscular factors *I. Jonkers*
10:45-11:15	Coffee break
11:15-12:00	The use of modeling and simulation for prosthetics design *C. Frigo*
12:00-12:45	On the modeling of cartilage mechanics and damage *C.C. van Donkelaar*

Symposium 5	**MOVEMENT ANALYSIS WITH INERTIAL SENSORS**
Aula 2	
14:15-15:00	Gait analysis by means of inertial sensors *A. Cereatti and D. Trojaniello*
15:00-15:45	Inertial sensor for balance and stability assessment *R. Stagni*
15:45-16:15	Coffee break
16:15-17:00	Activity monitoring: steps towards the assessment of disease-related behavioral features *I. Anisoara*
17:00-17:45	The use of inertial sensor in Sports biomechanics and performance assessment *M. Zok*

Symposium 6	**ORTHOSIS DESIGN**
Aula 3	*Moderator Jaap Harlaar*
14:15-15:00	Optimal type of AFO selection in Cerebral Palsy *A. Ries*
15:00-15:45	Alignment tuning of the AFO Footwear combination in Cerebral Palsy *E. Owen*
15:45-16:15	Coffee break
16:15-17:00	AFO stiffness tuning in adult neurological patients *V. de Groot*
17:00-17:45	KAFO selection based on gait analysis in Neuromuscular diseases *F. Nollet*

Symposium 7 | **CASE SERIES – ADULTS AND CHILDREN**
Aula 2

9:15-10:00 Clinical Gait analysis for surgical decision-making in adult. Case series
P. Zerbinati

10:00-10:45 Effect of Botulinum toxin injection in Rectus Femoris muscle on stiff-knee gait in stroke patients
G. Stoquart

10:45-11:15 Coffee break

11:15-12:00 Case series: children
R. Brunner

12:00-12:45 Case series: children
F. Miller

Symposium 8 | **ECOLOGICAL REHABILITATION (IN MEMORY OF MARCELLO MARIO PIERRO)**
Aula Minor | ***Joined session with GIPCI (Italian Group on Cerebral Palsy)***

9:00-9:30 Marcello Mario Pierro and the cultural background of the GIPCI Group
E. Fedrizzi

9:30-9:50 The Ecological rehabilitation in the treatment of cerebral palsy
A. Setaro

9:50-10:10 Ecological vision
F. Cappelli

10:10- 10:30 Coffee break

NEUROSCIENCE AND REHABILITATION

10:30-11:00	Cognitive strategies of locomotor navigation in normal development and cerebral palsy *G. Cioni, A Berthoz, V. Belmonti*
11:00-11:30	Rehabilitation and neuroscience *A. Ferrari*
11:30-12:00	New Technologies: the Roots and the Perspectives of Ecological Rehabilitation *M. Stortini*
12:00-12:30	Suiting an individual rehabilitative experience: updates in ecological approach *P. Giannarelli*
12:30- 13:30	Lunch

EVIDENCE BASED REHABILITATION

13:30-14:00	Evidence-based medicine and the rehabilitation of the child: a possible challenge *E. Castelli*
14:00-14:20	“Further evaluation is required…”: Orient ourselves in pediatric neurorehabilitation Evidence-Based Practice *M. Ventura*
14:20-14-40	A dynamic postural system for subjects with Dystonia: history and realization *F. Mattogno*
14:40-15:00	Evidence of the Ecological approach in rehabilitation: the experience of the movement analysis and robotics laboratory *M. Petrarca*
15:00	**Discussion**

Poster Abstracts

EFFECTS OF BILATERAL SUBTHALAMIC NUCLEUS DEEP BRAIN STIMULATION AND LEVODOPA ON SPATIOTEMPORAL VARIABLES OF GAIT IN PARKINSON'S DISEASE

Danielli Souza. Speciali (1), Natália Mariana. Luna (2), Rachael. Brant (2), Erich Talamoni. Fonoff (2), Manoel Jacobsen. Teixeira (2), Julia Maria D'Andrea. Greve (2), Wagner. Godoy (1), Richard. Baker (3), Paulo Roberto Garcia. Lucareli (4)

(1) Hospital Israelita Albert Einstein, São Paulo, Brazil
(2) Universidade de São Paulo, São Paulo, Brazil
(3) University of Salford, United Kingdom
(4) Universidade Nove de Julho, São Paulo, Brazil

INTRODUCTION and AIM

Levodopa has been shown to be efficient in treating Parkinson's disease (PD) in its initial phase [1]. High frequency deep brain stimulation (DBS) of the subthalamic nucleus (STN) is one of the surgical treatment methods recommended for advanced cases [2]. Three-dimensional gait analysis has been used to improve the characterization of specific alterations in the movement patters of these individuals, thereby allowing a quantitative assessment of pharmacological and/or surgical interventions. The aim of this study was to analyze and compare, through the spatiotemporal gait parameters, the influence of levodopa and/or high frequency deep brain stimulation of the subthalamic nucleus in patients with Parkinson's Disease.

PATIENTS/MATERIALS and METHODS

Sixteen patients with PD (11 male and 5 female) who were submitted to bilateral high frequency DBS of the STN participated in the study. The gait assessment was conducted using three-dimensional kinematics (SMART-D® BTS) in three conditions: without medication and with stimulation (OFF med / ON DBS); with medication and stimulation (ON med / ON DBS); with medication and without stimulation (ON med / OFF DBS). All the data obtained in the three-dimensional analysis were exported in C3D format using SMART-Tracker® software. The label of the markers and the processing of the biomechanical model to obtain linear kinematic data (speed, cadence, stride length, step length, single and double support values) were performed using Vicon Nexus® software and the Plug in Gait® model. The spatiotemporal data for each condition of the patients were exported to an Excel (Microsoft®) spreadsheet. The data were analyzed using the variance for repeated measures test (ANOVA), with the level of statistical significance set at $p < 0.05$. Cohen's _*d* was used to measure the effect size for treatments for power analysis purposes.

RESULTS

Statistical difference was observed between the treatments OFF Med / ON DBS vs ON Med / ON DBS for the spatiotemporal gait variables. In this comparison, the size effect was high in speed, stride length, cycle time and double support, however, the effect size was low for the cadence and stride length. During the comparison of treatments ON Med/ ON DBS and ON Med / OFF DBS we observed a medium effect size for stride length and step length; and a low effect size for time of cycle, single and double support. The effect size was low for all variables during the comparison of treatments OFF Med / ON DBS and ON Med / OFF DBS.

DISCUSSION and CONCLUSIONS

There is evidence that the symptoms that are most responsive to dopamine are also those that provide improved results under the influence of stimulation [3]. The exact mechanisms of stimulation are still unknown. The effect of DBS on the STN during walking can be partially measured by the interaction of pedunculopontine nucleus (PPN) and STN. It is believed that the effects of treatment with levodopa were potentiated by the addition of stimulation, suggesting a synergistic effect of the two treatments by different routes. We observed that the best scores were obtained when patients were under the effect of two treatments together.

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MOTOR STRATEGIES OF THE UNAFFECTED LOWER LIMB IN CHRONIC STROKE SURVIVORS

B.Nesi, B.Faraoni, A.Taviani, F. Benvenuti

Laboratorio Analisi del Movimento AUSL 11 Empoli (Fi)

BACKGROUND

One of the main characteristics of hemiparetic gait after stroke is asymmetry of progression of lower limbs. Gait is a multi-joint task in which each joint mechanism contributes to the global performance: in this context the unaffected lower limb (LL) is considered to play an important role in the compensation of impairments of the paretic side [1]. Non-lesioned motor cortex plays a key role in the development of adaptive strategies although a “motor conflict” may affect the hemiparetic LL motor function [2].

STUDY DESIGN

Observational study.

STUDY AIMS

To evaluate the relationship between motor strategies on the unaffected side influence gait motor performance.

MATERIALS AND METHODS

Sixteen hemiparetic chronic stroke survivors (aged 62-81years, time from stroke 65-120 months) underwent cinical assessment and intrumented gait analysis. Clinical assessment included, pain (visual analog scales), joint range of motion (degrees), muscle force (Muscle Manual Testing and Medical Research Council Scale), spasticity (Ashworth scale), functional limitations (Short Physical Performance Battery and Timed Up-and-Go Test), use of walking assistive devices, and disability (Barthel Index; Functional Ambulation Categories). Kinematic, kinetic and EMG (rectus femoris, gluteus medius, semimembranosis and medial gastrocnemious muscles) gait analysis was aimed at individuating the locomotor compensatory strategies adopted on the unaffected side to compensate the impairments of the affected side. In the analysis of the strategy of the unaffected side we considered the following characteristics: knee flexion attitude during initial contact, first bump of flexion and torque in loading response, timing of flexion in swing phase, peak power in pre-swing.

RESULTS

According with gait speed [3] eight patients were classified “slow” (<0.4 m/sec) and eight “fast” (≥0.4 m/sec). The two groups were similar for age, gender, time from stroke, type of stroke, side of the lesion and history of falls. On the other hand, the “slow” group patients presented more frequent or severe pain , alterations of joint range of motion, spasticity, functional limitations and disability, and use of walk assisting devices. In addition, at instrumented gait analysis, the “slow” group, in comparison with the “fast” one, presented in the unaffected LL increased kinematic and kinetic deviations of knee motion during loading response, altered time of activation of gluteus medius muscle and altered time of relaxation of semimembranosis and medial gastrocnemious muscles.

CONCLUSIONS

The study indicates that different motor patterns of the unaffected side are associated to “slow” and “fast” walking speed. The altered kinematics strategy used in the “slow” group may be less effective in compensating impairment of the affected side and cause chronic and excessive loading of the knee joints which may facilitate occurrence or worsening degenerative joint conditions and, hereinafter, pain.

DISCUSSION

Results indicate the importance of evaluating the function of the unaffected LL when planning an individually tailored rehabilitation program aimed at improving locomotor function in chronic stroke patients.

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MULTI-SEGMENT FOOT KINEMATICS AND PAIN INTENSITY COMPARISON IN WOMEN WITH AND WITHOUT PATTELOFEMORAL PAIN SYNDROME

BM. Lima (1), LBG. Contani (1), CL. Ferreira (2), NDA. Rabelo (1), AS. Bley (1), AC. Reis (1), Y. Liu (2), PRG. Lucareli (1)

1 Department of Rehabilitation Science, Human Motion Analysis Laboratory, Universidade Nove de Julho, São Paulo, Brazil
2 Universidade Federal de São Paulo, UNIFESP, São Paulo, Brazil

Main topics: Movement analysis in clinical practice; Clinical decision-making processes.

INTRODUCTION and AIM

Diffuse pain around the knee, which is characteristic of patellofemoral pain syndrome (PFPS), increases during the performance of activities in the closed kinetic chain, which can lead to kinematic changes in the lower limbs that enhance the compressive forces of the knee. The kinematic performance of the foot during weight-bearing activities is one of the possible changes, which is a field with few studies. Therefore, the aim of the present study was to assess the affect of pain intensity on foot kinematics in women with PFPS while performing the Anterior and Lateral Single Leg Step down Tasks (ASD and LSD).

PATIENTS/MATERIALS and METHODS Twenty-six women (mean age 25.4 ± 6.8) were included in this study: 10 healthy subjects (20 asymptomatic lower limbs) and 16 individuals with PFPS (32 symptomatic lower limbs). Subjects with PFPS were divided according to the Numerical Pain Rating Scale (NPRS). Subjects who had a score of ≤ 5 were allocated in the lower pain group (LPG), while subjects with a score of > 5 were allocated in the higher pain group (HPG). Nine trials for each ASD and LSD were collected bilaterally using the Oxford Foot Model[2] and 8 Vicon cameras. The range of motion (ROM) during the descent phase of the tests was considered for statistical analysis. One-way ANOVA and the post-hoc Tukey test were used, adopting a significance level of 1% ($p < 0.01$).

RESULTS

Significant differences were found between the pain groups (LPG and HPG) and the asymptomatic group (AG) in relation to ROM during the ASD and LSD tasks. Differences were also found between the pain groups, although the effect size was small. The pain groups exhibited a greater ROM for dorsiflexion, eversion/pronation and external rotation/abduction compared to the AG group during the ASD and LSD. Trivial to small differences were found between the pain groups for all variables.

DISCUSSION and CONCLUSIONS

Anterior knee pain affected foot kinematics. Women with PFPS had a higher ROM compared to asymptomatic women. However, the intensity of the pain wasn't a determinant factor to induce differences in the foot kinematics in both PFPS groups.

Table 1 - Differences in mean ROM and effect size between groups for ASD and LSD

	ANTERIOR SINGLE LEG STEP DOWN (ASD)						LATERAL SINGLE LEG STEP DOWN (LSD)					
	AG	LPG	HPG	Effect size			AG	LPG	HPG	Effect size		
	Mean (±SD)	Mean (±SD)	Mean (±SD)	AGx LPG	AGx HPG	LPGx HPG	Mean (±SD)	Mean (±SD)	Mean (±SD)	AGx LPG	AGx HPG	LPGx HPG
Sagittal Plane												
HFTBA (Dorsiflexion)[a,b,d,e]	22.97 (±5.33)	40.12 (±7.80)	38.146 (±5.67)	0.79	0.81	-	21.69 (±4.33)	36.93 (±6.61)	35.89 (±5.50)	0.81	0.82	-
FFTBA (Dorsiflexion)[a,b,c,d,e,f]	30.86 (±5.30)	47.01 (±6.91)	50.548 (±8.18)	0.8	0.82	0.23	30.10 (±4.23)	39.62 (±5.77)	45.82 (±7.08)	0.69	0.8	0.43
FFHFA (Dorsiflexion)[a,b,d,e]	8.15 (±3.29)	13.38 (±3.27)	12.390 (±4.48)	0.62	0.47	-	8.17 (±3.12)	10.82 (±4.19)	10.30 (±3.58)	0.34	0.3	-
Frontal Plane												
HFTBA (Eversion)[a,b,d,e]	17.60 (±6.77)	34.22 (±14.90)	31.422 (±11.62)	0.58	0.59	-	19.20 (±6.49)	34.28 (± 16.58)	32.63 (±12.51)	0.51	0.56	-
FFTBA (Pronation)[a,b,d,e,f]	17.16 (±6.49)	32.41 (±14.01)	34.950 (±14.84)	0.57	0.61	-	18.36 (±6.30)	33.28 (±12.97)	38.58 (±16.36)	0.59	0.63	0.18
FFHFA (Pronation)[a,b,c,d,e,f]	2.82 (±1.41)	9.55 (±5.49)	11.749 (±7.75)	0.64	0.63	0.16	2.16 (±1.41)	8.86 (±5.01)	12.25 (±8.44)	0.67	0.64	0.24
Transverse Plane												
HFTBA (Ext. Rotation)[a,b,d,e,f]	11.67 (±4.36)	22.36 (±12.04)	25.158 (±11.15)	0.51	0.62	-	11.14 (±4.26)	22.28 (±11.24)	25.74 (±10.58)	0.55	0.67	0.16
FFTBA (Abduction)[a,b,c,d,e,f]	13.27 (±5.20)	21.82 (±8.27)	26.096 (±10.84)	0.53	0.6	0.22	13.12 (±5.17)	21.75 (±6.60)	26.82 (±9.96)	0.59	0.65	0.29
FFHFA (Adduction)[a,b,c,d,e,f]	2.70 (±1.30)	10.24 (±5.09)	7.981 (±4.47)	0.71	0.63	0.23	2.63 (±1.60)	10.45 (±6.17)	7.66 (±4.59)	0.66	0.59	0.25

Abbreviations: The effect size was classified as follows: d< 0.2 = trivial; 0.2 to 0.5 = small; 0.5 to 0.8 = medium and > 0.8 = large.[a] Significant differences in mean values were found between AGxLPG in ASD; [b] AGxHPG in ASD; [c] LPGxHPG in ASD; [d] AGxLPG in ALD; [e] AGxHPG in ALD; [f] LPGxHPG in ALD.

POSTURAL STABILITY IN TRANSTIBIAL AMPUTEES ASSESSED BY LABORATORY AND CLINICAL TESTS

K. Ořechovská, Z. Svoboda, M. Janura, Z. Kováčiková

Faculty of Physical Culture, Palacký University, Olomouc, Czech Republic

Main topics: Analysis of physical movement data, Prosthetics

INTRODUCTION and AIM

Balance and postural control are the key aspects for people with lower limb amputation in activities of daily living [1]. The evaluation of postural stability in stance by laboratory methods is highly objective option, but has limited predicative value. In the evaluation of dynamic balance seems to be more appropriate using clinical tests in specific conditions, which reflects every day activities.

The aim of study was to determine differences in the evaluation of postural stability during measurement with laboratory methods and during measurement with clinical methods in transtibial amputees and healthy subjects.

PATIENTS/MATERIALS and METHODS

The experimental group (TTA) consists of 12 patients with a traumatic unilateral transtibial amputation (9 males, 3 females; average age 43.4 ± 9.5 years, height 178 ± 11.8 cm, and weight 89.9 ± 16.4 kg). The control group consists of 12 healthy subjects (9 males, 3 females; average age 43.9 ± 9.5 years, height 176.3 ± 8.6, and weight 77.5 ± 11.6 kg).

To determine the basic biomechanical parameters (COP sways and COP movement velocity) of the postural stability in stance, a force plate Kistler (9286AA, Kistler Instrumente AG, Winterthur, Switzerland) was used. The stability was tested in modifications: stance with eyes opened (EO), stance with eyes closed (EC), stance on a foam mat (EOM) and stance with eyes closed on a foam mat (ECM), each in duration 30 s. To assess the dynamic stability, five clinical tests were used: Timed Up and Go test (TUG), TUG with cognitive task (TUG c.), Four Square Step Test (4SST), Lateral Reach test (LRT) and Functional Reach Test (FRT). The measured data was statistically analyzed in Statistica 10.0 (Stat-Soft, Inc., Tulsa, OK, USA). Correlation between biomechanical and clinical parameters was assessed by the Spearman´s coefficient.

RESULTS

The results showed that there are statistically significant correlations between values of TUG/ TUG c. and COP movement deviation in mediolateral direction in EO (r= -0.69/ -0.71), between TUG c. and COP velocity movement in EO (r= -0.59), between TUG and COP movement deviation in anteroposterior direction in EOM (r= -0.75) and between LRT on prosthetic side and COP movement deviation in anteroposterior direction in EOM (r= -0.68). The correlations between 4SST/FRT on both sides/LRT on non affected side and all biomechanical parameters weren´t statistically significant.

In the control group there were found statistically significant correlations between FRT and COP velocity movement in EO on both sides (r= -0.63/ r= -0.62), and in EC (r= -0.72) and EOM (r= -0.79) on the right side. The correlations between TUG/TUG c./4SST/LRT and all biomechanical parameters weren´t statistically significant.

DISCUSSION and CONCLUSIONS

The outputs indicate that there is a small dependence between biomechanical and clinical tests, what shows the differences in postural control during static and dynamic tasks. For the evaluation of postural control there should be separately emphasized on both, static and dynamic parts of the stability. There are differences in postural stability between TTAs and healthy people, which are caused by using different postural strategies during common tasks [1, 2]. Further research with a larger number of subjects would be appropriate.

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THE VALUE OF TRIDIMENSIONAL GAIT ANALYSIS IN FUNCTIONAL DIAGNOSIS OF LUMBAR SPINAL STENOSIS

S.A. Garbelotti Jr. (1), P.R.G. Lucareli (3), W. Godoy (2), D.S. Speciali (2), A. Ramalho Jr. (2), J.M.D. Greve (1)

(1) Dept. of Experimental Physiopathology, Univ. de São Paulo, São Paulo, Brazil.
(2) Human Motion Analysis Lab., Albert Einstein Hosp., São Paulo, Brazil.
(3) Dept. of Rehabilitation Science, Human Motion Analysis Lab., Univ. Nove de Julho, São Paulo, Brazil.

Main topics: Analysis of gait and motor disorders, Functional outcome measures in mobility.

INTRODUCTION and AIM

Back pain is a common complaint especially among older patients.The spinal stenosis term is based on the fact that a minimum space of the spinal canal is necessary for normal functioning of the nervous structures, and when this space becomes narrow, results in nerve compression symptoms such as pain, lower limbs numbness and weakness and neurogenic claudication, which increase with stress and decreases with rest ^{1,2,3}. The aim of this study was to evaluate the kinematic gait changes after physical effort, make a correlation with the perception of pain and lumbar stenosis degree and evaluate the influence of the tridimensional gait analysis as a tool in the differential diagnosis of lumbar spinal stenosis.

PATIENTS/MATERIALS and METHODS

14 subjects were evaluated with diagnostic of lumbar stenosis with a mean age of 74,5 (9,8) years and average size of the spinal canal was 43.86 (28.76) mm². Were used for kinematic analysis Vicon MX 40 system and Nexus software for images tridimensional reconstruction. The exam consisted of three phases: 1) Capture of six gait cycles after a rest period; 2) Walk on treadmill for a maximum of 20 minutes; 3) New capture of other 6 gait cycles immediately after the effort. From these data, temporal-spatial and angular variables were extracted and analyzed individually and compared to the pain perception obtained by visual analog scale at the beginning and the end of the exam and the cross-sectional area of the spinal canal obtained from the nuclear magnetic resonance.

RESULTS

Most of the correlations were weak and the most significant results are reported to GDI when we observed decrease in medians for both lower limbs to moderate negative correlation when compared to pain perception after effort for both left ($r = -0.64$, $p = 0.014$) and right limb ($r = -0.53$, $p = 0.05$), which means that there is a significant reduction in the global function of the lower limbs according the symptom of pain increases ($p = 0.002$). This fact may be reflected in decreased cadence and gait speed and also the times of single support (significant for the left limb, $p = 0.019$) and balance (significant for the right limb, $p = 0.013$).

DISCUSSION and CONCLUSIONS

Compression of nerve roots and physical stress are factors that increase the sensitivity of the motor evoked potential causing decreased overall function of the gait ⁴. We observe changing of the speed, cadence and time of single and double support for compensation of pain ^{5,6,7}. However, most of correlations were weak and showed that the most significant results are reported by the Gait Deviation Index (GDI) that demonstrated moderate negative correlation with the perception of pain after effort was made by both limbs. This situation may be interpreted as part of a strategy to protect against pain and imbalance. We found no correlation between gait or pain perception with the cross sectional area of the spinal canal, similar to Zeifang et al. studies ⁸. Therefore, we believe that there is no advantage for the patient to make a three-dimensional gait analysis because the analysis does not add relevant information to clinical diagnosis.

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USABILITY STUDY OF A WEARABLE AUDIO-FEEDBACK SYSTEM FOR GAIT REHABILITATION IN PERSONS WITH PARKINSON'S DISEASE

A. Ferrari (1), P. Ginis (2), A. Mirelman (3), E. Gazit (3), A. Nieuwboer (2), M. Dorfman (3), J.M. Hausdorff (3), L. Rocchi (1), L. Chiari (1)

(1) Department of Electrical, Electronic, and Information Engineering, University of Bologna, Italy
(2) KU Leuven, Department of Rehabilitation Sciences, Neuromotor Research Group, Belgium
(3) Laboratory for Gait and Neurodynamics, Depart. of Neurology, Tel-Aviv Sourasky Medical Center, Israel

Main topics: Biofeedback, Assistive devices, Analysis of gait and motor disorders, Motor control and motor learning.

INTRODUCTION and AIM

Parkinson's disease (PD) is one of the most common degenerative diseases in the general population with an incidence between 8 and 18 per 100.000 person–years. Gait impairments provoked by PD range from festination and freezing of gait, to stable alterations such as short shuffling steps, high stride-to-stride variability and stooped trunk posture [1]. PD impairs the semi-automatic nature of gait, curtailing the patient's ability to walk while thinking or planning or carrying out other activities [2]. Within the FP7 CuPiD project, a wearable and stand-alone system able to carry out an accurate gait analysis and, at the same time, act as a gait tutoring system has been developed using auditory bio-feedback, ABF (see Fig 1, [3]). The ABF system is able to provide customized feedback to patients on how to maintain an effective and safe walking pattern, acting as a "virtual clinician", continuously assessing and vocally correcting patients' errors. The aims of the present study were to technically evaluate the functionality of the ABF system and to assess its usability and feasibility in patients.

PATIENTS/MATERIALS and METHODS

To make the system usable during daily life, an easy-to-use system based on a user-friendly smartphone app was developed. The system builds on a sensing stack including a body area network with 3 inertial measurement units (IMUs; Exel, IT), placed on each shoe and on the lower trunk. The ABF app displays a single button that, once pressed, automatically connects the 3 IMUs and then computes, by processing signals on the smartphone: step length, step duration, cadence, gait speed, asymmetry, foot clearance and trunk posture. These parameters are assessed in real time. If the parameters fail to remain within a clinically defined confidence interval, an error instance generates a vocal request encourages the patient to correct the gait pattern. The ABF system is also equipped with a telemedicine service that allows uploading of data via Wi-Fi to a server, enabling remote data analysis and report visualization. 8 persons with PD were enrolled for this pilot study (age: 66 ± 8 years, Hoehn&Yahr 2-3, ON L-Dopa). Patients used the system 3 times for 30 min within one week; at the end of the week patients were asked to fill in an ad-hoc questionnaire similar to QUEST and TSQ.

RESULTS

The system layout is shown in Fig. 1. The average scores obtained on a Likert scale 1 (totally disagree)-5 (fully agree) for system usability and feasibility are reported in Table 1. The vocal feedback met patients' needs.

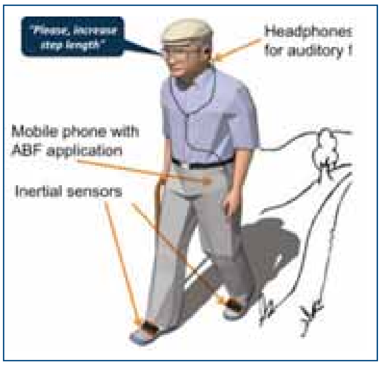

Figure 1: ABF system

Table 1: Average scores on ABF system feasibility and usability from pilot study (1 = low - 5 = high satisfaction)

ABF – Usability	
The system reacts well to gait changes	4
Feedback provided is easy to understand	4.7
ABF - Feasibility	
I think I can use the system independently	3.9
I think the system is suitable for PD patients	3.8
I feel safe using the system	4.7
I think feedback can improve my walking	4
The system acts as a challenging training	3.5

DISCUSSION and CONCLUSIONS

An Android application was developed based on the use of 3 IMUs. It is able to perform online gait analysis and generate tutoring vocal messages to correct ineffective gait patterns. The system proves to be easy to use and face validity seems high for PD patients'. *The research leading to these results has been partially founded by the European Union - FP7/2007-2013 under grant agreement n°288516 (CuPiD project)*

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INFLUENCE OF TEMPORAL NORMALIZATION ON GAIT SCORES

S. Armand (1), A. Bonnefoy-Mazure (1), G. De Coulon (1), F. Leboeuf (2)

(1) Geneva University Hospitals and Geneva University, Geneva, Switzerland.
(2) CHU de Nantes, Nantes, France

INTRODUCTION and AIM

Indexes of overall gait pathology such as Gait Profile Score (GPS)[1] or the Gait Deviation Index (GDI)[2] become essential in the analysis of pathological gait. The computation of these scores is based on the comparison point to point between a reference curve and a curve of a given patient for each joint. For this computation, a time normalization of the kinematics with respect to the gait cycle is performed. However, patients have different temporal walking characteristics than healthy subjects (longer stance phase, etc.) that makes the comparison point to point with a reference curve inappropriate. To improve this comparison, several methods of temporal data normalization have been proposed in the literature[3]. Therefore, the purpose of this study was to evaluate the influence of different methods of temporal data normalization on the calculation of indexes of overall gait pathology (GPS). We hypothesized that methods of normalisation based on temporal walking characteristics decrease the gait scores of patients.

PATIENTS/MATERIALS and METHODS

Three methods of time normalization were tested in this study: 1) conventional normalization throughout the gait cycle, 2) normalization in sub-phases considering the stance and swing phases, 3) normalization in sub-phases considering the two phases of single support, the double support phase and the swing phase. The GPS (equivalent to GDI) score was calculated with the three methods for 211 Clinical Gait Analysis performed in patients with cerebral palsy. GPS scores from the three methods were compared with repeated measures ANOVA ($p < .05$). The influence of the relative duration of the gait phases on the difference in scores was analyzed using a Pearson correlation.

RESULTS

GPS scores with the three methods were significantly different (Table 1). The absolute mean differences between the methods were 0.27° between the methods 1-2 and 0.30° between methods 1-3. The largest difference was 2.2° for a patient with a stance phase of 80%. The relative durations of the sub-phases were significantly correlated with the differences of the scores with a R^2 of 0.43 for the duration of the stance phase (Figure 1). The distribution of the difference between the conventional methods and the two other methods showed that 96% had a difference inferior to 1° and 99% had a difference inferior to 1.6 (minimal clinically important difference[4]).

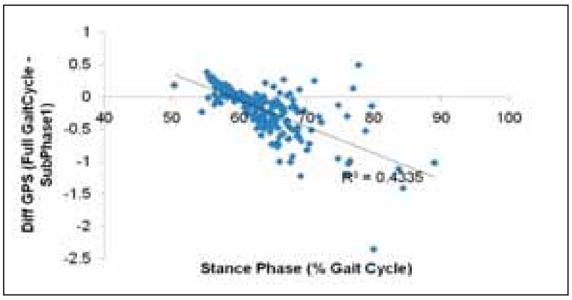

Figure 1: Relationship between the duration of the stance phase and the difference between the two methods of normalization (Conventional, SubPhase 1)

Table 1: GPS scores with the 3 methods of normalization		
Conventional FullGait Cycle Means ± SD	**SubPhase1** Stance/Swing Means ± SD	**Subphase2** Single-Double Support/Swing Means ± SD
GPS°	9.75±3.84	9.67±3.90

Table 1: GPS scores with the 3 methods of normalization

DISCUSSION and CONCLUSIONS

Normalization in sub-phases significantly influences the calculation of indexes of overall gait pathology and especially when temporal characteristics of walking patients are different from those of asymptomatic subjects. However, this difference appears to have little influence on the clinical interpretation of the scores.

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GAIT ANALYSIS DRIVEN FINITE ELEMENT SIMULATIONS: TOWARDS THE USE OF OPENSIM OUTPUT AS BOUNDARY CONDITION

A. Scarton (1), W. Aerts (2), A. Guiotto (1), Z. Sawacha (1), I. Jonkers (3), J. Vander Sloten(2), C. Cobelli (1)

(1) Department of Information Engineering, University of Padova, Padova, Italy
(2) Department of Mechanical Engineering, KU Leuven, Leuven
(3) Department of Kinesiolog, KU Leuven, Leuven

Main topics: musculoskeletal modeling, mathematical simulation in human movement science.

INTRODUCTION and AIM

Foot ulcerations are one of the most common and invalidating complications that affect the diabetic patients and can lead to amputations. Several three-dimensional (3D) finite element (FE) models (Ms) of the foot have been developed in the last decades in order to improve prevention therapies [1]. A preliminary 3DFEM has been developed by the authors and gait analysis data have been adopted as input for the simulations [2]. The future aim is to include muscles forces from Opensim in the FE simulations. With this purpose a framework that enables running FE simulations considering as boundary conditions either experimental ground reaction forces and kinematics or musculoskeletal modeling (MSM)-derived joint kinetics and kinematics has been established. Patient- specific model should also include patient-specific geometries, which were not available for all the subjects. However while considering that foot geometry may change notably between healthy and pathological conditions, for this study two 3DFEMs were developed, one with the data of a healthy subject (HS) for running HS FEMs and one with the data of a diabetic neuropathic subject (DNS) for the DNS ones.

PATIENTS/MATERIALS and METHODS

3D FE simulations were performed on 5 DNS (mean age 62.8 ± 7.1 years, mean BMI 24.3 ± 2.9 kg/m^2) and 5 HS (mean age 57.2 ± 4.1 years, mean BMI 24.16 ± 1.8 kg/m^2).

The experimental, setup included a 6 cameras BTS stereophotogrammetric system, synchronized with 2 Bertec force plates and 2 plantar pressure (PP) systems (Imagortesi) [1]. 3D kinematics, kinetics and PP were calculated for each patient's hindfoot, midfoot, forefoot subsegments and tibia.

Foot MRI (Philips Achieva and Siemens Avanto) were also acquired for two subjects and 30 bones, cartilages and the foot skin (as contour of the soft tissues) were segmented in order to get a 3D representation of the whole foot and ankle using Simpleware-ScanIP (v.5.0). The models were meshed in Simpleware-scanFE and simulations driven in ABAQUS as defined in [1]. 10 subject-specific MSM were created in Opensim using experimentally measured kinematics and kinetics [3]. The output of inverse kinematics and joint reaction analysis at four different instances of stance (heel strike, loading response, midstance, push off) were used as input for the 3DFE simulations. The PP peaks were calculated with the two different approaches and compared with the experimentally measured ones.

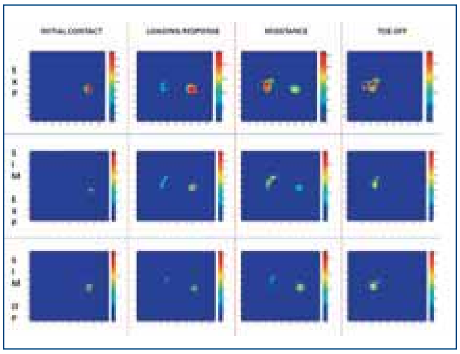

Figure 1:The figure shows the comparison between the pressure maps obtained at different instants for one of the DNS (1° row experimental, 2° simulated with experimental forces, 3° simulated with Opensim forces).

RESULTS

An agreement was found between PP experimentally measured and results of FEMs performed with both approaches [Table 1]. Figure 1 shows the PP maps results of the simulations of one of the DNS' 3DFEMs. In Table 1 RMSD estimated across different methods has been reported.

Table 1: In the table the mean of the RMSD between experimental and simulated peak PP values are reported for each subphase of the gait cycle [KPa]. Furthermore also the percentages with respect to the PP peak value are shown.

	NEUROPATHICS				CONTROLS			
	PP EXP FORCE [KPA]	% PP MAX	PP OPENSIM FORCE [KPA]	% PP MAX	PP EXP FORCE [KPA]	% PP MAX	PP OPENSIM FORCE [KPA]	% PP MAX
IC	102.13	48.26%	48.33	22.80%	85.51	48.31%	42.20	23.84%
LR	52.25	21.30%	146.73	59.82%	31.47	15.02%	150.47	61.10%
MID	42.67	17.92%	80.75	33.91%	33.71	14.38%	46.16	19.68%
PO	90.35	35.94%	43.42	17.27%	185.11	74.57%	69.65	27.76%

DISCUSSION and CONCLUSIONS

Although the geometry was not subject specific but only condition-specific, preliminary results showed feasibility of using MSM-based rather than experimentally defined boundary conditions mostly with the neuropathic subject probably because of the foot geometry. Better results could be obtained by including specific geometries and muscle forces as input in the FE simulation.

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DECOUPLING THE EXTRAPOLATED CENTRE OF MASS (XCoM) AND CENTRE OF PRESSURE (CoP) DURING GAIT INITIATION. INTRODUCTION OF A NEW VARIABLE.

Eric C Prinsen, PT1,, Marc J Nederhand MD, PhD 1, Hans J Rietman, MD, PhD 1

(1) Roessingh Research & Development, Enschede, the Netherlands**.**

INTRODUCTION and AIM:
Ambulation in household functioning in small indoor spaces is a continuous process of starting and stopping gait. The propulsive and braking forces for initiating and terminating gait require complex motor strategies. The propulsive forces required for gait initiation (GI) are generated by decoupling the centre of pressure (CoP) and centre of mass (CoM). To correct for CoM velocity and for subjects' height we calculated the extrapolated centre of mass (XcoM), which incorporates the CoM velocity (1), and determined the inclination angle (2) between the XCoM and CoP. We studied the feasibility of this variable to quantify decoupling during gait initiation by determining the sensitivity to changes in walking speed and pathology.

PATIENTS/MATERIALS and METHODS:
Nine able-bodied (AB) and 5 patients with a transfemoral amputation (TF) were selected. Measurements included instrumented gait analysis, using a six camera Vicon system and two AMTI force plates. The modified Helen-Hayes marker set was used in combination with the Vicon full-body plug in gait model to determine the CoM trajectory. Data were collected at a self-selected walking speed (SSWS) and at maximal walking speed (MWS). The patients with an amputation performed trials leading with the intact and prosthetic leg. Five trials were analyzed for each condition. Outcome measures included (1) peak inclination angle CoP-XcoM, (2) peak inclination angle CoP-CoM (3) step length first step.

RESULTS:

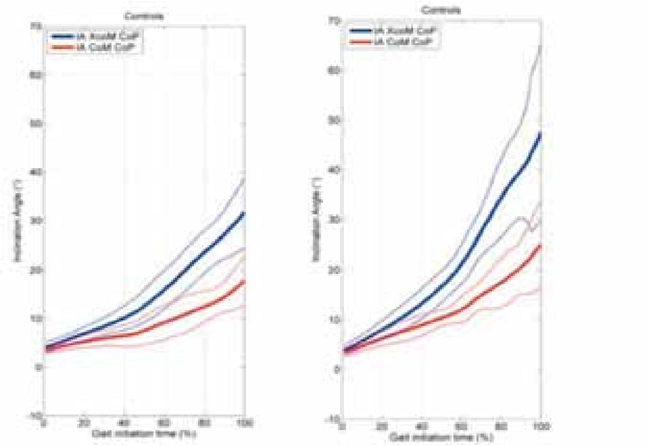

Fig 1: In the trials of AB the peak inclination angle CoP-XcoM was significantly higher during the MWS trials (mean 47.45^0 sd 8.98^0 : in figure on the right) when compared with the SSWS trials: (mean 31.68^0 sd 3.53^0, in figure on the left. The difference in peak inclination angle CoP-XcoM (15.77^0) differed more across speed than the inclination angle CoP-CoM (7.29^0).

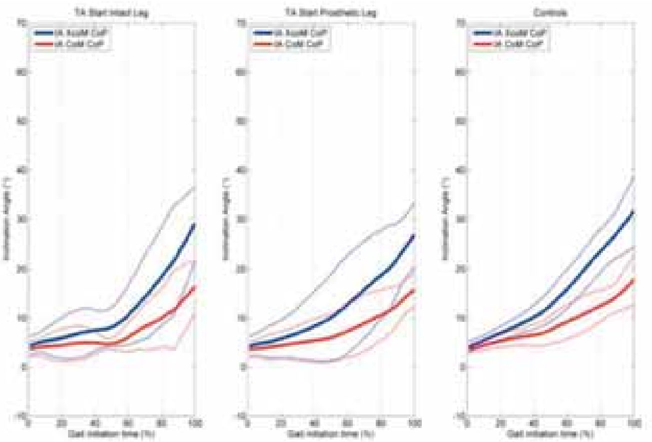

Fig 2: In the SSWS trials the peak inclination angle CoP-XcoM of AB (mean 31.68^0 sd 3.53^0, figure on the right) was higher than in the group TF subjects irrespective of starting leg (intact leg: mean 29.01^0 sd $3{,}73^0$, in figure left) prosthetic leg: mean $26{,}87^0$ sd 3.21^0, in figure middle). Step length in both groups was comparable.

DISCUSSION and CONCLUSIONS:
The inclination angle between the CoP and XcoM is a feasible measure to quantify decoupling during gait initiation. This variable seems sensitive to changes in walking velocity and pathology. This new variable may also be applicable to quantify the influence of therapeutic interventions (chemodenervation, orthosis, shoe adjustments etc) on gait initiation in neurological disease. This may help to understand the (dis) advantages of these interventions for ambulation in small indoor spaces.

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STUDY OF MECHANICAL ENERGY RECOVERY IN PARKINSONIAN GAIT

M. Dipaola (1, 2), A. Cattaneo (2) I.U. Isaias (2, 3), and C. Frigo (1)

(1) Movement Biomechanics and Motor Control, TBM lab DEIB - Politecnico di Milano, Milan, Italy
(2) Laboratorio per l'Analisi del Movimento (LAMB), DePT, Univ. degli Studi di Milano, Milan, Italy
(3) Neurologische Klinik und Poliklinik Universitätsklinik Würzburg, Würzburg, Germany

Main topics: analysis of gait and motor disorders, movement deviation indexes.

INTRODUCTION and AIM

Gait disturbance is a key component of motor disability in subjects affect with Parkinson's disease (PD). In this study we describe the centre of mass (CoM) potential energy variations *ΔEp* in PD and control subjects (CO) and investigate the energetic expenditure in PD patients' walking, calculating the total mechanical work of body.

PATIENTS/MATERIALS and METHODS

Six CO (4 M; mean age: 63±3.6) and seven PD patients (5 M; mean age: 62±7.8 years; disease duration: 6.2±3.4 years; UPDRS-III score: 18±6.2; L-Dopa daily dose: 245.7±240.8 mg; total L-Dopa Equivalent Daily Dose, including L-Dopa: 423±214mg) were asked to walk at different velocities (their own normal velocity, slower and faster) along a straight trajectory of about 11.5m. We use an optoelectronic system (SMART, E-Motion, Italy), consisting of six video cameras (sampling rate: 60 Hz; calibrated volume 4x1.5x1.5m). The position of the subjects' main body segments was determined by means of 29 retro-reflective markers (diameter: 12mm) [1]. The CoM was defined as the weighted average of the centre of masses of all body segments. The parameters were obtained from Zatsiorski and Seluyanov [2]. The variations of potential energy (*ΔEp*), kinetic energy (*ΔEk*) and global energy (*ΔEg*) were computed as the sum of the rising amounts of each energy form during the stride. Energy Recovery index (*ER*) was defined according to [3]: . It represents the losing percentage of mechanical energy in the transformation of kinetic energy into potential energy and vice-versa during walking.

RESULTS

PD patients showed an higher ΔEp respect to CO particularly at gait velocities higher than 45%BH/s (Figure), while ΔEg was always lower in PD than in CO. The results concerning the ER values are shown in Table. Note that in PD subjects we obtained an ER value higher than in CO group. Our data also showed that in both populations ΔEk was similar and increased with the velocity. Furthermore the ΔEg was always smaller in PD than CO.

Table: Energy Recovery Index (Wilcoxon test *<0.05).

Velocity (%BH/s)	ER CO (%)	ER PD (%)
20 - 45	38.5±7.1	48.5±2.8*
45 - 65	62.2±6.1	63.2±5
65 - 100	62.6±7.5	66.1±5.6*

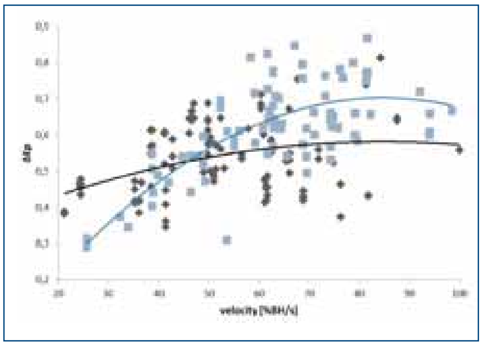

Figure: Potential energy variations (ΔEp) as function of normalised velocity. CO trials=grey rhombus, PD trials=light blue squares.

DISCUSSION and CONCLUSIONS

The higher values of *ΔEp* with the change of gait velocity in PD subjects should suggested a bigger energy expenditure. On the contrary the trend of *ΔEg* indicated a better strategy for energy conservation in PD patients. The *ER* calculation quantifies this phenomenon: while the trend of *ER* as function of gait velocity was the same in both populations, PD subjects showed higher values at all three different ranges of velocity. This could be interpreted as a tendency of the PD patients to adopt the inverse pendulum scheme of walking more strictly than CO subjects. The *ER* is a specific indicator of this tendency.

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STRIDE FREQUENCY AND LENGTH ADJUSTMENTS IN POST-STROKE INDIVIDUALS; THE INFLUENCE ON THE MARGINS OF STABILITY

L. Hak (1), H. Houdijk (1,2), P. Van der Wurff (3), M.R. Prins (1,3), P.J. Beek (1), J.H. Van Dieën (1)

(1) Research Institute MOVE, Faculty of Human Movement Sciences, VU University Amsterdam, The Netherlands
(2) Center for Augmented Motor Learning and Training, National Military Rehabilitation Center Aardenburg, Doorn, The Netherlands
(3) Heliomare Rehabilitation Center, Wijk aan Zee, The Netherlands

Main topics: please, select at least two topics from the long list of the topics of the conference.

INTRODUCTION and AIM

Post-stroke individuals adapt their step pattern differently from able bodied persons when exposed to challenging walking conditions[1]. These differences result in smaller margins of stability (MoS) for post-stroke individuals, which implies a larger probability of a loss of balance[2,3]. It is, however, not known whether post-stroke individuals are not able to use the same strategy as able-bodied persons, or whether they just do not select this strategy. The aim of this study was to investigate whether post-stroke participants are physically able to walk at different combinations of stride frequency and stride length and how these adaptations affect the MoS.

PATIENTS/MATERIALS and METHODS

Ten post-stroke individuals performed 6 walking trials of 2 minutes on the treadmill of a CAREN system at different combinations of stride frequency and stride length, expressed as a percentage of their comfortable value (90%-100%-111%). Treadmill speed was set at the resultant speed, and subjects received visual feedback about the required and actual stride length.

RESULTS

The results of GEE regression models showed that subjects were fully able to increase stride length when this was required. However, when subjects had to increase their stride frequency, they did so only to about 75% of the required value. Therefore, for these trials subjects also increased stride length to maintain the required treadmill speed. Because post-stroke individuals were not able to increase their stride frequency up to 111% of their comfortable stride frequency, the increase in MoS was on average 37% smaller than the increase in MoS that could have been reached at the imposed stride frequency.

DISCUSSION and CONCLUSIONS

Post-stroke individuals are able to increase stride length and frequency during walking, but the ability to increase stride frequency is limited compared to able-bodied individuals. As a result, also the capacity to increase the MoS is limited. The exact cause underlying the observed limitation in stride frequency adjustments can however not be derived from this study. This should be further investigated. However, the results of this study indicate that training post-stroke individuals to increase stride frequency during walking might be beneficial for these people to further increase MoS during walking.

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CORRELATIONS BETWEEN 3D SUBJECT-SPECIFIC MUSCULOSKELETAL PARAMETERS AND GAIT ANALYSIS IN PATIENTS WITH CEREBRAL PALSY

A. Assi (1,2,3), A. Massaad (1,2), Z. Bakouny (1), C. Sauret (3), W. Skalli (3), I. Ghanem (1,2,4)

(1) School of Medicine, Saint-Joseph University, Beirut, Lebanon
(2) Gait lab, SESOBEL, Beirut, Lebanon
(3) Laboratoire de Biomécanique, Arts et Métiers ParisTech, Paris, France
(4) Hôtel Dieu de France Hospital, Beirut, Lebanon

Main Topics: 3D musculoskeletal parameters, subject-specific, gait analysis, cerebral palsy, EOS, MRI, correlation

INTRODUCTION and AIM

Gait alteration in Cerebral Palsy (CP) is due to muscle spasticity which can lead to muscle shortening, joint contractures, and skeletal malalignments occurring in 3D during growth. The causal relationship between the different factors is complex and not yet fully understood. The aim of this study is to evaluate the correlation that exists between muscular parameters, skeletal architecture and gait behavior in children with CP, using a 3D subject-specific approach.

PATIENTS/MATERIALS and METHODS

Fifteen CP children (mean age 11±3 years old, N= 13 with spastic diplegia, N=2 with spastic hemiplegia) with no medical or surgical history had undergone a physical exam as well as 3D Gait Analysis, where kinematic parameters and the gait deviation index (GDI) were calculated [1]. An EOS® biplanar Xray exam was performed, allowing 3D subject-specific reconstructions of the skeletal segments of the lower limbs, from which different parameters were calculated such as femoral anteversion, neck shaft angle, tibial torsion and the pelvic parameters [2]. MRI acquisitions of the lower limbs were also performed, allowing 3D subject-specific reconstructions of 18 muscles in each limb, in order to evaluate each muscle's length, cross sectional area and volume (normalized to lower limb length or body mass) [3]. Correlations between the parameters of the physical exam, gait analysis, 3D skeletal and muscular reconstructions were evaluated using both Pearson and Spearman tests. Only variables that were significantly correlated to each other ($p<0.05$) were retained. Multiple linear regressions were performed between these variables, which were each judged to be either dependant or independent based on clinical relevance.

RESULTS

Significant correlations were found between adductor magnus length and femoral anteversion (r=-0.55) as well as with pelvic incidence (r=0.89). Pelvic tilt was significantly correlated with the lengths of the gracilis (r=-0.62), the adductor magnus (r=0.44), the sartorius (r=-0.52), the semi-membranosus (r=-0.68) and the semi-tendinosus (r=-0.78). The GDI was significantly correlated to the lengths of the hamstrings (r=0.5), the adductor longus (r=0.7), brevis (r=0.6), gastrocnemii (r=0.65) and the sacral slope (r=0.67). Moreover, muscle lengths were significantly correlated with physical exam parameters. Multiple linear regression models were used in order to estimate different muscles' lengths based on physical exam parameters. As an example, the regression model which estimates the length of the gracilis is as follows (adjusted R^2=0.7):

Normalized Gracilis length = 0,21 + 6,47.10^{-4} * *Unilateral popliteal angle* - 7,56.10^{-4} * *Bilateral popliteal angle* + 9,92.10^{-4} * *Hip Abduction in flexed knee* + 1,44.10^{-3} * *Hip Abduction in extended knee* + 0,03 * *Hip Ext Rotation/Hip Int Rotation*

DISCUSSION and CONCLUSIONS

A larger number of subjects will help confirm the correlations found between parameters obtained from the physical exam, the 3D subject-specific reconstructions of the muscles and of the skeletal lower limbs as well as from the gait analysis. Regression formulas could help evaluate subject-specific muscle lengths and skeletal malalignments based on clinical parameters.

Fig 1- Example of a 3D subject-specific musculoskeletal reconstruction obtained from MRI and EOS® of an 11 year-old female patient with CP

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EVALUATION OF THE INITIATION OF LEVEL WALKING AND STAIR ASCENDING IN PARKINSON'S DISEASE: AN INSTRUMENTED METHOD BASED ON INERTIAL SENSORS

G. Bonora (1), I. Carpinella (1) D. Cattaneo (2), L. Chiari (3), M. Ferrarin (1),

(1) Biomedical Technology Department, Found. Don C. Gnocchi Onlus, IRCCS, Milan, Italy
(2) Department of Neurorehabilitation, Found. Don C. Gnocchi Onlus, IRCCS, Milan, Italy
(3) Department of Electrical, Electronic and Information Engineering, University of Bologna, Bologna, Italy

Main topics: Analysis of clinical movement data, analysis of gait and motor disorders.

INTRODUCTION and AIM

The ability to move safely during level walking and stair negotiation is a crucial factor to guarantee self-confidence and autonomous living in the elder and frail population. In particular, people affected by Parkinson's Disease (PD) suffer of gait disturbances that can lead to a relevant degradation of motor capability with a reduction of autonomy and an increase of the risk of falling.

In this study, an instrumented method based on wearable inertial sensors is applied to PD subjects to investigate the Anticipatory Postural Adjustments (APAs) during initiation of level walking and stair ascending.

PATIENTS/MATERIALS and METHODS

Seven PD subjects (mean age 74.0 ± 1.7 yo, 3 females) and ten age-matched healthy controls (mean age 66.6 ± 6.1 yo, 5 females) participated voluntarily to the study: all the PD subjects presented H&Y values equal or greater than 2 and were under L-dopa pharmacological effects.

All the subjects were asked to execute two different transitional tasks: 1) quite standing to level walking ($LW_{initiation}$); 2) quite standing to single step ascending ($SA_{initiation}$). All the subjects wore two inertial sensors (TMA, Tecnobody, Italy), placed on the posterior trunk (L2-L4) and laterally on the right shank with one of the sensing axis oriented along the body medio-lateral direction; each sensor contains a 3D accelerometer, a 3D gyroscope and a 3D magnetometer and transmits data to the PC (fs = 50Hz) through a Bluetooth connection.

The registered signals were analysed off-line through the adoption of a previously developed algorithm [1]: APA onset, heel-off and toe-off instants were estimated and the APAs were divided into an Imbalance Phase (IP, from APA onset to heel-off) and an Unloading Phase (UP, from heel-off to toe-off) as proposed in Carpinella et al. [2]. For each task the phase durations and the corresponding Centre Of Mass medio-lateral acceleration amplitude were extracted, as proposed by Mancini et al. [3].

RESULTS

APAs of all the subjects were detected. In the IP, PD subjects showed a significant reduction of acceleration amplitude in the medio-lateral direction both in the $LW_{initiation}$ and $SA_{initiation}$ tasks ($p < 0.05$) while no statistically relevant differences were found in the IP durations in both tasks. A tendency ($p = 0.087$) towards a reduction of medio-lateral acceleration amplitude in the UP was observed in the $LW_{initiation}$ task.

The reduced values of the acceleration in the IP and the consequent reduction of the sway is consistent with typical bradykinetic step initiation in PD subjects and with the results of previous published studies [2][3].

DISCUSSION and CONCLUSIONS

Patients with PD show impaired locomotion performance, particularly during transitional tasks (i.e. gait initiation, gait steering) which were shown to be affected even at the very early stage of PD [2]. Moreover stair ascending/descending are common - although particularly demanding - tasks, which can undermine PD patients and, if not correctly tackled, can lead to falls with serious consequences.

The capability of the proposed method to differentiate between PD in the ON pharmacological state and healthy subjects through the analysis of APAs suggests the possibility of using wearable sensors for a fast, easy to administer and cost-effective evaluation of the APAs outside a typical motion analysis laboratory. The possibility to evaluate the initiation of stair ascending is a novel feature that can give significant information for a correct evaluation of the patients and for developing rehabilitation exercises focused in this transitional and highly demanding motor task.

		healthy	PD	p-value
LWini	Amplitude [m/s^2]	0.22 ± 0.10	0.09 ± 0.12	0.043*
	Duration [s]	0.40 ± 0.18	0.29 ± 0.15	0.109
SAini	Amplitude [m/s^2]	0.25 ± 0.08	0.11 ± 0.12	0.014*
	Duration [s]	0.41 ± 0.15	0.52 ± 0.44	0.733

Table 1: IP medio-lateral acceleration amplitude and duration (mean ± SD) in level walking (LWini) and step ascending (SAini) tasks.

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FUNCTIONAL AND RADIOGRAPHIC CONSIDERATION OF LOWER LIMB MALALIGNMENT IN CHILDREN AND ADOLESCENTS WITH IDIOPATHIC GENUA VALGA

Kranzl A.[*], Farr S.[+], Pablik E.[ŧ], Ganger R.[+]

[*]Laboratory for Gait and Movement Analysis - Orthopaedic Hospital Speising, Vienna
[+]Department of Pediatric Orthopaedics - Orthopaedic Hospital Speising, Vienna
[ŧ]Center for Medical Statistics, Informatics and Intelligent Systems, Medical University of Vienna; Vienna, Austria

Main topics: Orthopaedics, Analysis of clinical movement data, Analysis of gait and motor disorders

INTRODUCTION and AIM

Genua valga are among the most common reasons for paediatric orthopaedic consultations. Besides cosmetics, the true detriment of valgus malalignment remains yet to be determined and thus, indication for corrective surgery differs widely among paediatric orthopaedic surgeons. Many surgeons tend to indicate surgery based on radiographic features to avoid potential knee osteoarthritis in the long-term. This study aimed to determine dynamic knee joint loading, possible compensatory mechanisms and their effects on standard radiographic measurements in a consecutive series of children with idiopathic genua valga.

PATIENTS/MATERIALS and METHODS

Patients who were scheduled for surgical treatment (temporary hemiepiphysiodesis) of idiopathic genua valga between 2010-2013 were considered. Thirty-three patients (mean age 12.3 years) were retrospectively reviewed fulfilling the inclusion criteria. Otherwise healthy children and adolescents (male and female) between 8-16 years of age were considered appropriate for inclusion in this study to serve as a control group (n=11). 3-D gait analysis data was available for the control group. All patients who were included in this study routinely underwent one preoperative anteroposterior (AP) full-length standing radiograph of the lower extremity and standardized preoperative three-dimensional gait analysis. The relationship between the angles measured in the X-ray (MAD, MPTA, LDFA, LDTA, mechanical axis alignment) and gait parameters was first tested in a univariate mixed model (including a random effect for each patient) and visualized with scatter plots. In the second step x-ray angles and gait parameters which showed an effect in the univariate models were combined in multiple regression mixed models with the additional variables BMI, age and sex and a random effect for each patient. The correlation between the angles measured in the X-ray and the gait parameters was tested by calculating spearman's correlation coefficient and also visualized in scatter plots.

RESULTS

Walking speed was not significant different between the groups. All mean and maximum internal knee moments were significantly lower in the patient group than in the control group ($p = 0.004$, $p = 0.038$, $p = 0.003$, respectively), indicating a statistically significant reduced valgus moment (internal moments). However, neither age nor BMI of the patient cohort were correlated with the observed knee moment values. Overall, the mean knee rotation in the patient group was significantly reduced ($p < 0.001$), external hip rotation was significantly increased ($p < 0.001$). All radiographic baseline measurements except MPTA ($p = 0.974$) showed a low but significant correlation with the knee moments in the frontal plane (MAD, $p = 0.039$; LDFA, $p = 0.009$ and LDTA, $p = 0.025$, respectively). Pearson correlation showed a trend towards significance ($p = 0.053$) when correlating radiographic mechanical tibiofemoral axis (mTFA) with the knee varus/valgus angle obtained by gait analysis. Furthermore, MAD showed a low positive, and MPTA a low negative correlation with the knee varus/valgus angle ($p = 0.032$ and $p = 0.041$).

DISCUSSION & CONCLUSIONS

The correlation between commonly used radiographic measurements (i.e. MAD) and findings of the gait analysis was only low. Therefore, no threshold for surgical indication setting based on radiographic disease severity could be established. Besides showing decreased valgus moment, our results suggest that considerable compensatory gait mechanisms may be present in children with idiopathic genua valga. A reduced external knee rotation and increased external hip rotation can be seen as a compensatory gait mechanisms to transfer the knee moment to normal.

3D UNDERWATER GAIT ANALYSIS: COMPARISON AMONG 3 DIFFERENT PROTOCOLS

Z. Sawacha (1), F. Minelle (1), M. Cortesi (2), G. Gatta (2), C. Cobelli (1), S. Fantozzi (3)

(1) Department of Information Engineering, University of Padova, Padova, Italy
(2) Department for Life Quality Studies, University of Bologna, Bologna, Italy
(3) Health Sciences and Technologies - CIRI, University of Bologna, Bologna, Italy

Main topics: Experimental studies in human movement science, Reliability and service development

INTRODUCTION and AIM

This investigation compared application of 2 well established gait analysis protocols ([1] referred as CAST, [2] as IOr_gait) for 3D joints angles estimation and a method for direct tracking of joint centers (DTJC) [3] to reconstruct 3 subjects' underwater (UW) and out of water (OW) gait. Although water environment has been employed for different rehabilitation therapies, little is known regarding the repeatability of state of art gait analysis protocols in underwater conditions; where constraints of the environment lead to the diffusion of video based techniques for tracking of features (TOF) in order to perform joints kinematics analysis [3].

PATIENTS/MATERIALS and METHODS

Three healthy subjects (mean±SD age 27.3±5.5 and BMI 21.3±2.6) participated in the study. After signing informed consent subjects were instructed to walk at their preferred speed within two different set up: UW within a swimming pool (water height of 1.2m) and OW in a gait lab (3 trials per subject and in each condition were collected). Indelible ink marker was used to trace the 2 different markersets [1,2] (Figure 1). Conventional UW analogic cameras (Sony Hyper Had, TS-6021PSC, Japan, 50 Hz) were connected to a computer and used to acquire both the UW and OW, thus avoiding differences in the extraction of OW joint kinematics parameters. The cameras were automatically synchronized with an ad-hoc software application [3]. In regards to the geometric distortion correction, the calibration of the cameras' intrinsic parameters was achieved from a dry land acquisition of a checkerboard pattern that was corrected for underwater application [3]. A software developed for automatic tracking of UW movements [3], was used for TOF. Afterward data were processed (Matlab R.13) and anatomical landmarks, JC trajectories, and joint rotations, were extracted with each technique in both conditions. Inter-operator repeatability (3 different operators executed TOF of the same subject's 3 video sequences) and intra-operator repeatability (the same operator executed 3 times TOF of the same subject's 3 video sequences) were assessed. Root mean square distance (RMSD) was adopted in comparing the 3 different techniques outcome measures (as applied to 1 trial) and in comparing the ones related to the repeatability tests.

RESULTS

Inter-operator and intra-operator (Table 1) repeatability results showed better performance of CAST with a RMSDmax=38° on ankle joint internal/external rotation (I/E) for IOR_gait inter-operator repeatability test, and RMSDmin=1.0 on hip flexion/extension (F/E) for CAST inter-operator repeatability test. Comparison among methodologies showed good to poor results with a RMSDmax of 60° for the ankle I/E and of 3.3° for the hip F/E when comparing CAST vs IOR_gait OW. CAST showed better results also in presence of occlusion and low resolution images. DTJC showed compressively the worse performance in term of repeatability analysis, even though it allowed kinematics parameters estimation of each joint on the sagittal plane for the complete dataset.

Figure 1: 1 subject TOF, UW and OW gait.

Intra-operatort [RMSD]	hip F/E	hip A/A	hip I/E	knee F/E	ankle F/E	ankle A/A	ankle I/E
[2] tracking 1-2	1,0	1,5	5,6	1,5	2,7	3,0	6,9
[2] tracking 1-3	3,7	1,9	10,1	2,2	2,0	2,0	6,3
[2] tracking 3-2	3,1	1,7	5,2	1,3	3,1	2,3	6,1
[1] tracking 1-2	1,7	0,5	3,3	1,0	2,0	2,9	2,0
[1] tracking l 1-3	3,5	1,1	17,1	2,1	2,3	2,1	2,6
[1] tracking 3-2	3,8	1,4	19,8	1,3	3,1	2,6	3,0

Table 1: Intra-operator repeatability results ([1]vs[2]). A/A=abd-adduction.

DISCUSSION and CONCLUSIONS

Based on these results both CAST and IOR_gait showed their ability to lead to reliable results in term of joints angle rotations (good repeatability) thus suggesting their application in UW gait analysis. Finally compared to DTJC, they enabled estimation of 3D joint angles according to gait analysis standard conventions. Surprisingly enough UW data processing showed better results than OW. This could be explained with a better quality of UW images which can only be ascribed to the specific experimental set up.

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SENSORIMOTOR CONTROL IS BILATERALLY ALTERED FOR SHOULDER ABDUCTION AND FLEXION IN CHRONIC HEMIPARETIC INDIVIDUALS

GL. Santos (1), LFG. Salazar (1), AB. Oliveira (1), AC. Lazarin (1), GC. Zanca (1), ST, Matiello (1), TL. Russo (1)

Federal University of São Carlos - Department of Physiotherapy, São Carlos, Brazil.

Main topics: Movement deviation indexes, Motor Control and Motor Learning.

INTRODUCTION and AIM

The appropriate sensorimotor control of shoulder is required for performing functions of upper extremity[1, 2] and can be identified as the ability to generate and modulate forces effectively during muscle contractions while matching a given force level[3]. Nevertheless, the sensorimotor strategies of shoulder in chronic hemiparetic subjects remain unclear on the literature, because they are relevant to support neurorehabilitation management.

Aims: The aim of the study was to evaluate shoulder sensorimotor control and maximal shoulder muscle strength during isometric abduction and flexion in chronic hemiparetic subjects.

PATIENTS/MATERIALS and METHODS

Thirteen individuals with chronic hemiparesis due to ischemic stroke and thirteen healthy subjects matched for gender and age. Peak torque (PT) and torque steadiness was measured during isometric abduction and flexion of shoulder at 45° of range of motion using Biodex System III dynamometer. Standard deviation (SD) and coefficient of variation (CV) were measured from the steadiness trial. Difference between dominant and non dominant limbs in both movements (flexion and abduction) was performed using Anova Two-Way. As no differences were found between dominant and non dominant limbs for all the variables, a pool of data was performed. Difference between control, paretic and non-paretic limbs for the SD and CV was performed using Kruskall Wallis Test following Mann-Whitney considering a significance level of 0.017, due to Bonferroni adjustment. For PT variable, Anova Two-Way, considering a significance level of 0.05, was performed.

RESULTS

Both paretic and non paretic limbs reduced PT compared to control (paretic - deficit for flexion:50,27% and abduction: 56,56%; non paretic - deficit for flexion: 84,01%; and abduction: 71,49%). Paretic limb PT was lower than non paretic one ($p<0.05$). to control limb ($p<0.05$). During abduction, higher values of CV and SD were observed in paretic and non-paretic limbs than during shoulder´s flexion.

DISCUSSION and CONCLUSIONS

The sensorimotor control is bilaterally altered in hemiparetic individuals, according the movement performed. Thus, the results demonstrate the need to include interventions in the rehabilitation program including, for example, bilateral upper extremity exercises, muscle strengthening, exercises with visual feedback, and functional manual tasks training, as reaching movements.

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ASSESSMENT OF A MODEL-BASED METHOD FOR SCAPULA KINEMATICS MEASUREMENT

S. Duprey (1,2,3), PY. Lagacé (4, 5), T. Cresson (5), W. Skalli (4), N. Hagemeister (5)

(1) Université de Lyon, F-69622, Lyon, France ; (2) Université Claude Bernard Lyon 1, Villeurbanne, France
(3) IFSTTAR, UMR_T9406, LBMC Laboratoire de Biomécanique et Mécanique des Chocs, F69675, Bron, France ; (4) Laboratoire de biomécanique, ENSAM Paris-tech ; (5) Laboratoire de recherche en imagerie et orthopédie, École de technologie supérieure, Montréal, Canada

Main topics: Experimental studies in human movement science; Technical developments in movement science; Musculoskeletal imaging

INTRODUCTION and AIM

In vivo measurement of scapula kinematics remains challenging since soft tissue artefacts strongly affect scapula measurements based on skin sensors. Model-based tracking techniques can provide accurate results [1], however, quite often, these techniques imply a high radiation dose for the patient. Recently, a model-based approach allowing shoulder bone tracking from low dose biplanar X-ray images has been developed [2-3]. The aim of the present study is to assess the accuracy of this model-based method for scapula kinematics measurements.

MATERIALS and METHODS

Shoulders (scapula and humerus) from 5 cadaveric specimens were scanned (every 5mm) and 3D-reconstructed. Then, for each specimen, the scapula was embedded in a polyester bloc, while a specific set-up allowed elevating the humerus in the EOS environment while the scapula rotated. Acquisitions of biplanar radiographies were performed for 9 arm elevations. The scapula model was reconstructed as described in [2-3] allowing the tracking of the scapula on each set of images. Thanks to tantalum beads glued on the bones and on the polyester bloc, the CT-model was also superimposed on the EOS images (Fig.1). The bony landmarks AA, AI, TS (acromion angle, inferior angle and the root of the scapula spine) were detected on each model.

Figure 1: a) EOS image of a shoulder specimen. b) Scapula model superposed on the EOS image. C) CT reconstructed model superposed on the EOS image.

The CT-reconstructed model was used as reference to assess the accuracy of the scapula model orientation: differences between landmarks positions and rotations (vs the global framework, using a cardan angle sequence) were calculated for each arm elevation. Results were averaged over the 5 specimen and 9 postures.

RESULTS

The average differences of positions for AA, AI and TS were respectively 5.11mm, 2.54mm and 5.41mm. Orientations showed small mean discrepancies: 2.11°, 1.14° and 2.57°.

DISCUSSION and CONCLUSIONS

The ability of the model-based method described in [2-3] to provide accurate scapula orientation and position has been assessed here. Inaccuracies of less than 6mm in position and less than 3° in rotation were obtained. It is expected that results would be slightly less accurate with patients, since their ribcage would hinder scapula visualization. However, given that this method is advantageously less irradiant than standard X-rays, it should be considered as a reliable technique for scapula kinematics measurements.

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OF VISUAL, PROPRIOCEPTIVE, OR AUDITORY FEEDBACK ON KINEMATICS OF POURING WATER FROM KETTLE TO CUP

Sigal Portnoy, Orli Halaby, Dotan Dekel-Chen

Department of Occupational Therapy, Tel Aviv University, Tel Aviv, Israel

INTRODUCTION and AIM:

Pouring hot water from a kettle may prove a hazardous task for the visually-impaired, who usually control this task with both hands, relaying on proprioceptive information of the upper limbs. The proximity of the hot water to the hand holding the cup endangers it. An in-house technology providing auditory feedback indication that the kettle is safely above the cup, may allow the person to perform the task singlehandedly, thereby preventing injury. In order to assess the feasibility of learning to use such a feedback system, we quantified the performance and kinematics of pouring water in the presence of three isolated feedbacks: visual, proprioceptive, or auditory.

METHODS:

Twenty healthy right-handed subjects (mean and SD age of 27.6±3.3 years) participated in this study. Fourteen reflective markers were placed on the torso, upper arm and forearm of the subjects. Also, four markers were located on a kettle. A 6-camera motion capture system (Qualisys Medical AB, Sweden) was used to automatically identify the markers coordinates in real time and stream them to a LabView plugin (V12, National Instruments, USA). The coordinates of a fifth virtual marker of the tip of the kettle were calculated in real-time. The LabView code was used to produce an audible tone when the tip and the kettle entered the boundaries of a pre-determined "safety zone" of the cup, in which the probability for water spilling is minimal (Fig. 1). Each subject lifted the kettle from a marked position and poured its content to a fixed cup. The subject repeated this activity 13 times blindfolded while holding the cup with the free hand (proprioceptive feedback), then 13 times blindfolded with a auditory feedback activated when the kettle was at a safe location above the cup, and finally, 3 times with only visual feedback. This was a randomized AB/BA design where 10 subjects first performed the task with the proprioceptive feedback and then with the auditory feedback and 10 subjects performed the reversed order. The subjects filled a subjective questionnaire on the difficulty of each feedback and we compared the success (reduction in weight of spilled water), movement time, movement kinematics, kettle path and movement smoothness by calculation of the normalized jerk score of movement (NJSM).

RESULTS:

Motor learning was observed by reduced spilling, movement time and NJSM. Elbow flexion and shoulder adduction ranges were higher when first attempting to use auditory feedback, however after a short learning process there were no significant differences between kinematics calculated during the 3 feedback types.

CONCLUSIONS:

We conclude that following practice, monitoring in-house activity via motion capturing to classify movements, i.e. liquid pouring, can assist the visually-impaired with daily activities via auditory feedback.

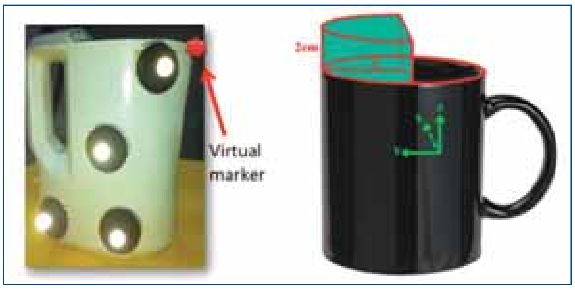

Figure 1: The setup of 6-DOF kettle defined by 4 markers. A virtual marker is defined at the tip. The predefined "safety zone" is also depicted above the cup.

EFFECTS OF ANKLE DEFORMITIES ON ACTIVITY AND PARTICIPATION LEVELS IN ADULT STROKE PATIENTS

M. Longhi (1), D. Mazzoli (1), A. Merlo (1), P. Prati (1)

(1) Gait & Motion Analysis Laboratory, Sol et Salus Hospital, Rimini, Italy

Main topics: Movement analysis in clinical practice

INTRODUCTION and AIM

The international classification of functioning (ICF) promotes the assessment of functions and body structures (F&S) and of activities and participation (A&P). In hemiparetic patients' gait, however, F&S impairments of affected side may not directly cause A&P limitations, because of contralateral side compensatory contributions. The aim was to investigate the relationships among scores of F&S impairment, overall walking ability (WA) and A&P.

PATIENTS/MATERIALS and METHODS

We retrospectively analyzed 26 adult stroke patients (Table 1). F&S measures were: ankle passive and active dorsiflexion (pDF, aDF) measured at flexed and extended knee, ankle and knee extensors triceps surae (TS) spasticity assessed by the Tardieu scale. A&P assessments were: Functional Ambulation Categories (FAC), Rivermead Mobility Index (RMI) and Walking Handicap Scale (WHS). Dynamic loading and propulsion ability (DLA and DPA) during gait were computed based on ground reaction force data [1] (Figure 1). Relationships were assessed by Spearman's correlation coefficient.

RESULTS

aDFs were correlated with all A&P measurements and pDFs were correlated with FAC and WHS, the rho value approaching all cases. Ankle TS spasticity did not affected any A&P and WA measurements. The strongest correlations ($p<0.001$) were found between DLA and DPA indices and all A&P scores, with rho as high as 0.75. Walking speed was explained by DLA (rho=0.8, $p<0.001$) and DPA (rho=0.7, $p<0.001$), as in [1]. Noteworthy, DLA was correlated with aDF (foot prepositioning) and DPA with pDF (tibia forward rotation).

DISCUSSION and CONCLUSIONS

Adult stroke patients' A&P relies on ankle deformities rather than spasticity. S&F impairments altering foot prepositioning at contact and tibia forward rotation should be considered since early rehabilitation.

The concurrent validity of DLA and DPA indices with A&P scores and their effect on walking speed support the use of these simple and quick indices to monitor rehabilitation efficacy.

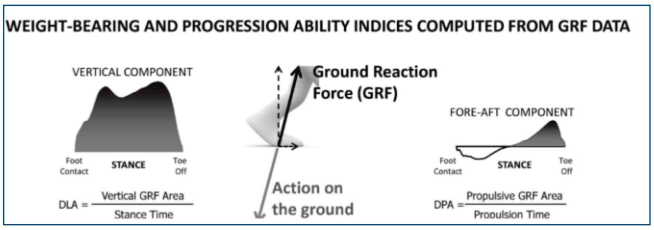

Figure 1: The analysis of foot-ground force exchange provides objective measurement of weight-bearing and progression ability. DLA and DPA have been proven be to a reliable tool to assess the weight-bearing and propulsive abilities in stroke patients [1]

Men/women	15/11
Affected Side L/R	10/16
Age	50 +/- 14
Years from lesion	4 +/- 3
aDF at extended knee	-11 +/- 14 deg
aDF at flexed knee	3 +/- 14 deg
pDF at extended knee	2 +/- 10 deg
pDF at flexed knee	12 +/- 8 deg
Ankle Mod. Tardieu Scale	0 - 5
Knee Mod. Tardieu Scale	0 - 3
FAC range	4-5
RMI range	10-15
WHS range	3-6
Walking speed	0,56 +/- 0,23 m/s
DLA	66 +/- 9 %Body Weight
DPA	3 +/- 2 %Body Weight

Table 1: sample characteristics

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PREVENTION OF GENU RECURVATUM IN POST STROKE PATIENTS

Sigal Portnoy,[1] Asaf Frechtel,[1] Eitan Raveh,[2] Isabella Schwartz,[1]

[1]Department of Physical Medicine and Rehabilitation, Hadassah Medical Center, Jerusalem, Israel
[2]Chemitec Advanced Medical Solutions, Hod Hasharon, Israel

INTRODUCTION and AIM: Knee hyperextension may alter the gait pattern and cause pain and falls in post stroke patients. Since current solutions by orthotics are frequently abandoned due to the difficulty of donning them, unaesthetic appearance, frequently excessive weight perceived by the patient and sometimes undesirable confinement of the ankle, we aimed to evaluate the effect of a hinged soft knee orthosis on the gait pattern and symmetry of chronic post stroke patients with knee hyperextension.

METHODS: Spatiotemporal gait parameters and symmetry, paretic knee angle and bilateral muscle activation patterns of 31 post stroke individual with knee hyperextension were measured with and without the orthosis. Also, the Berg Balance Scale (BBS), the 6-minute walk test, the 10-meter walk test, the timed-up-and-go (TUG) test were administered.

RESULTS: The orthosis successfully prevented the paretic knee from hyperextending and greater knee flexion was achieved during the swing phase (Fig. 1), potentially increasing foot clearance and contributing to the prevention of falls. The results of the BBS, 10MWT, 6MWT and TUG significantly improved ($p<0.02$). Although no significant differences were found in spatiotemporal parameters and symmetry of gait, 67.7% of the subjects increased their gait velocity by more than 0.1m/s calculated from the 10MWT, which is considered a clinically meaningful difference on short distance walks. Average muscle activity of the semitendinosus and gastrocnemius muscles during the loading response was reduced compared to the non-paretic limb.

CONCLUSIONS: Using a hinged soft knee orthosis to prevent genu recurvatum post-stroke may be considered a viable option to alleviate excessive stress from the posterior soft tissues of the paretic knee and prevent falls and fall-related injuries by restoring balance and confidence in the patient and increasing swing knee angle which may increase the foot clearance.

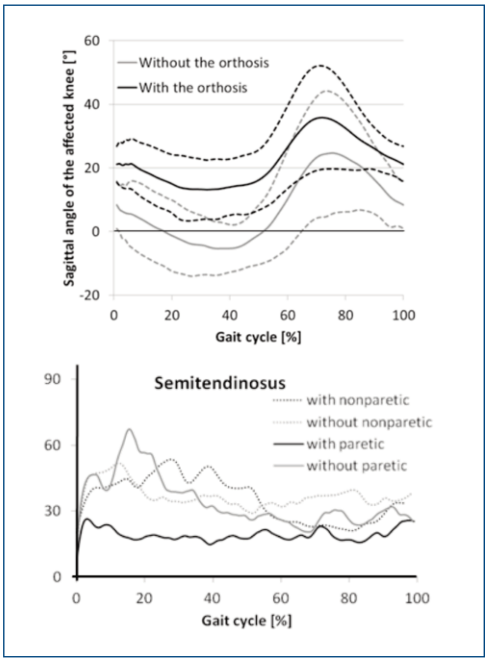

Figure 1: The paretic knee angle in the sagittal plane with and without the orthosis (top) and the average RMS [μV] values of the EMG recording from the semitendinosus muscle bilaterally, with and without the orthosis.

REPEATABILITY STUDY OF THE CAST MODEL FOR GAIT ANALYSIS

Ornella Pinzone[1], Richard Baker[1], Preece Stephen[1], Richard Jones[1]

[1]University of Salford, UK
e-mail: O.Pinzone@salford.ac.uk; ornellapinzone@hotmail.it

Main topics: Analysis of clinical movement data and Technical developments in movement science.

INTRODUCTION and AIM

Repeatability studies are particularly important in clinical gait analysis because measurements techniques are heavily dependent on the repeatable placement of markers on a given subject relative to anatomical landmarks. Ongoing care to understand and reduce measurement variability are an essential part of routine clinical practice, however there are very few repeatability studies on the CAST technique which is the one employed in the author's laboratory. The present study describes a methodology to quantify variability and assess the measurements repeatability of key kinematic parameters.

PATIENTS/MATERIALS and METHODS

Five healthy subject were seen by 3 assessors on one occasion and data from 3 trials were collected from each. A CAST model approach was undertaken.

Data were collected using 16 OQUS (Qualisys) three-dimensional motion analysis cameras and four AMTI force plates. All data were digitised in Qualisys Track Manager and exported as a *.c3d format to Visual 3D (C-motion Inc, USA). Statistical analysis was conducted using Excel 2013 and MATLAB 2010.

To evaluate the variability (and hence to assess the repeatability) of clinically important kinematic variables (Table 1), the Standard Error of Measurement (SEM) was estimated using analysis of variance components. SEM has been considered to arise from different factors [1], among which a) assessor (between assessor variability, σ_a^2); b) session (within assessor variability, σ_s^2) and c) trial or residual (between trial variability, σ_t^2). In the specific case of this study, only one data collection session has been performed, therefore the within assessor variability was not estimated.

Between participants variance (σ_p^2) was also calculated to assess differences between healthy subjects.

The units of variance are different to those of the original measurement therefore, although the analysis is based upon the variance, these are always converted to standard deviations (by taking the square root) before reporting results.

RESULTS

The results of the analysis are showed in Table 1.

Table 1: Standard deviation of individual variance components and SEM of key kinematic variables

Standard Deviation & SEM	Pelvic Tilt	Pelvic Obliquity	Pelvic Rotation	Hip Flexion	Hip Adduction	Hip Rotation	Knee Flexion	Ankle Dorsiflexion	Foot progression
Trial (σt)	1.3°	0.7°	1.4°	1.7°	0.9°	1.5°	2.1°	1.7°	1.8°
Assessor (σa)	3.0°	1.3°	1.6°	3.5°	1.8°	5.6°	2.3°	2.0°	2.0°
Participant (σp)	5.0°	2.2°	2.0°	5.5°	2.5°	4.4°	3.2°	3.1°	7.3°
SEM	3.3°	1.4°	2.2°	3.9°	2.0°	5.8°	3.1°	2.6°	2.7°

DISCUSSION and CONCLUSIONS

A range of studies now summarised by McGinley et al. [2] suggest that an acceptable measurement is something with SEM between 2 and 5 . Results show that SEM for all gait parameters, except from hip rotation, are within this range, and they are all broadly compatible with the other studies.

These results suggest therefore that repeatability of the CAST model is appropriate for clinical gait analysis.

The results also show that SEM is most of the time smaller than or equal to differences between healthy subjects. This suggest SEM is sufficiently small to detect differences between healthy subjects and therefore should be appropriate for the larger deviation seen in patients.

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FERRARI'S CLASSIFICATION OF DIPLEGIC FORMS OF CEREBRAL PALSY: VALIDATION BY MEANS OF ARTIFICIAL NEURAL NETWORKS

Al. Ferrari (1), R. Neviani (2), D. Pandarese (2), Ad. Ferrari (2)

(1) Department of Electrical, Electronic, and Information Engineering, University of Bologna, Italy
(2) Motion Analysis Laboratory LAMBDA, Santa Maria Nuova Hospital, Reggio Emilia, Italy

Main topics: Analysis of gait and motor disorders, Analysis of clinical movement data, Motor control and motor learning

INTRODUCTION and AIM

Classifications systems of gait deviations in Diplegic children with Cerebral Palsy (DCP) are aimed at assisting in diagnosis and clinical decision-making. Qualitative and quantitative gait classification systems have been proposed in literature; the firsts lack of evidence in terms of validity, the seconds, of groups clinical interpretability [1]. The (qualitative) classification proposed by Ferrari et al. [2], differentiates DCP into four forms by addressing the main top-down features of motor organization. Aim of the study is to provide a validity measure of Ferrari's classification by means of gait analysis and artificial neural networks (ANNs).

PATIENTS/MATERIALS and METHODS

122 DCP underwent a standard Gait Analysis exam on a 12m walkway by means of an 8 cameras VICON MX+ set at 100Hz (Oxford Metrics, UK). 28 markers were positioned on the lower limbs according to [3]. Aside, clinical experts familiar with the Ferrari's classification, classified patients into the four forms according to [2], assigning 13 subjects to form I, 38 to II, 25 to III and 46 to IV. At least 2 trials each containing 3 gait cycles (GCs) per subject were acquired. For each trial 5 statistical descriptor were computed: i) total distance covered with 3 GCs normalized to the subject height; on the single GC, on the three anatomical planes for hips, trunk and pelvis, and the sagittal for knees and ankles, ii) median, iii) variance, iv) peak-to-peak and v) peak to root mean square. Left values were averaged to right, generating 45 parameters per trial. ANN used was a perceptron with back propagation having as input the 45 parameters. Patients' trials were randomly separated in training, and validation and test (10% of subjects for each form), avoiding having patients belonging to more than one dataset.

RESULTS

Different configurations of the ANN have been tested. The best results were achieved with an ANN having 2 hidden layers with 23 and 8 neurons, transfer function Hyperbolic tangent sigmoid and training function Levenberg-Marquardt. Fig 1 and Fig 2 report confusion matrix and the ROC curves for the test trials.

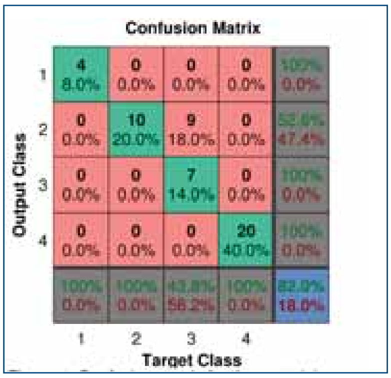

Figure 1: Confusion matrix for the test trials.

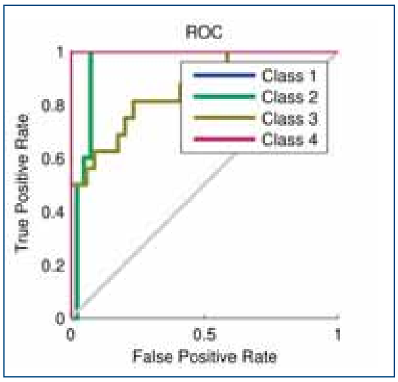

Figure 2: ROC curves for the test trials of the four forms as classified from the ANN

DISCUSSION and CONCLUSIONS

The ANN reported a total percentage of success of 82%, no error in classification of forms IV and I and 9 false negative in form III. These performances are probably affected by the fact that patients of forms III and I are underrepresented with respect to others two forms. In conclusion, this study contributes to demonstrate the validity of Ferrari's classification showing how the four diplegic forms are successfully separable on a quantitative basis by means of ANN.

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MUSCLE CONTRIBUTIONS TO CENTRE OF MASS ACCELERATION DURING TURNING GAIT IN TYPICALLY DEVELOPING CHILDREN: A SIMULATION STUDY

PC. Dixon (1), K. Jansen (2), I. Jonkers (2), J. Stebbins (3), T. Theologis (3), AB. Zavatsky (1)

(1) University of Oxford, Oxford, United Kingdom
(2) KU Leuven, Leuven, Belgium
(3) Nuffield Orthopaedic Centre, Oxford, United Kingdom

INTRODUCTION and AIM

Turning while walking is an essential task [1]; yet, most gait research focuses on the straight-line condition. Although studies have identified substantial adaptations during turning [2, 3], none has explored the contribution of muscles to the acceleration of the body towards the new walking direction. The aim of this study was to establish how typically developing children use their muscles to turn. Understanding of turning strategies in this group may be relevant in the clinical management of gait in paediatric populations with restricted mobility.

PATIENTS/MATERIALS and METHODS

Data from nine typically developing children (10.8 ± 2.6 years, 1.49 ± 0.16 m, 41.6 ± 11.2 kg) fit with the Plug-in Gait and Oxford Foot model markers and having performed straight and 90° turn trials were analysed. Motion capture data (kinematics, kinetics, and muscle activity of rectus femoris, hamstrings, lateral gastrocnemius, and tibialis anterior) were recorded (Vicon, Oxford Metrics, Oxford, UK). Data were exported to Matlab (v2011b, The Mathworks Inc., Natick, USA) in order to generate input files [4] for dynamic simulations in OpenSim [5]. A generic 23-degree-of-freedom lower-limb and torso model (Gait2392), along with a dedicated workflow was used to determine the contribution of muscles, gravity, and other forces to the medio-lateral acceleration of the centre of mass (COM) [5]. Trials were analysed over two steps. For turning, the first step (approach) is performed with the contralateral limb (with respect to the turning direction), while the second step (turn) is ipsilateral to the turning direction. Thus, for straight trials approach and turn phase refer to the first and second step, respectively. Differences in average acceleration contribution of the dominant muscle groups over each step were assessed via a one-way ANOVA and post-hoc pairwise comparisons (SPSS 21, IBM. Armonk, NY, USA).

RESULTS

During the approach, turning was mainly induced by a decrease of the contralateral triceps surae contributions (p=0.0027), while contributions of contralateral abductors remained similar to straight walking. During the turn phase, ipsilateral abductors decreased (p=0.035) and ipsilateral triceps surae increased contribution (p<0.001) (Fig.1). No changes were seen in the swing limb (ipsilateral during approach and contralateral during turn).

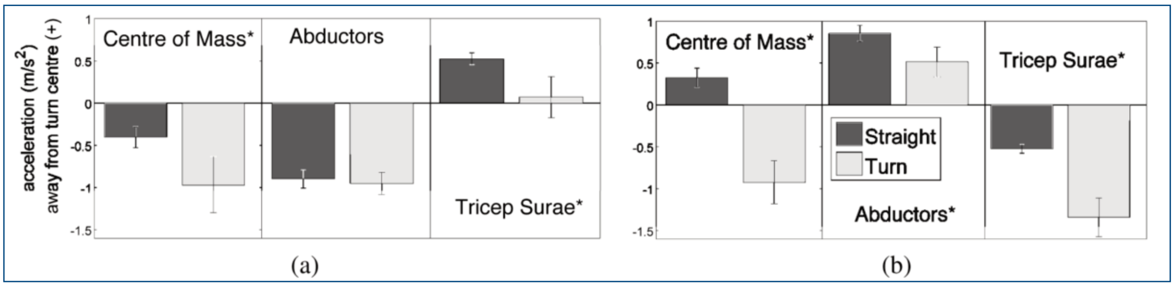

Fig.1: Contributions of dominant muscle groups to COM acceleration during the (a) approach and (b) turn phase. The gluteus medius and minimus were combined to form the hip abductors, while gastrocnemii and soleus formed the tricep surae.

DISCUSSION and CONCLUSIONS

Our analysis reveals that typically developing children modulate proximal and distal leg muscle groups during turning to redirect the COM. This strategy may challenge medio-lateral stability as a substantial contribution to acceleration occurs over the inside (turn step) limb. It is unknown if children with gait disabilities, such as those with cerebral palsy, would adopt a similar strategy as they often present with weak abductors and plantarflexors as well as decreased balance. Future investigations of adaptive turning strategies in this population are needed.

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EVALUATION OF MEDIAL LONGITUDINAL ARCH HEIGHT OF JUVENILE IDIOPATHIC ARTHRITIS INDUCED PES PLANOVALGUS DURING GAIT

Josephine Merker [1,2], Matthias Hartmann[2], Florian Kreuzpointner[1], Johannes-Peter Haas[2], Ansgar Schwirtz[1]

[1]Department of Biomechanics in Sports, Technische Universität Munchen, Munich, Germany
[2]German Center for Pediatric and Adolescent Rheumatology, Garmisch-Partenkirchen, Germany

INTRODUCTION and AIM

Patients with Juvenile Idiopathic Arthritis often have affected ankle joints, which could lead to foot deformities like pes planovalgus (JIA-PPV) [1]. In general, JIA-PPV is characterised by an excessive hindfoot eversion and by a flattening of medial longitudinal arch [1]. These characteristics could be documented in a pilot study [2] with quantitative data during gait by using the Oxford Foot Model (OFM) [3]. In a recent unpublished work [4] we found different results in a larger cohort: the excessive hindfoot eversion position of JIA-PPV remained, confirming one generally observed JIA-PPV-characteristic. But no difference could be observed in arch height between JIA-PPV and healthy feet, suggesting that no pes planovalgus but pes valgus were examined. Therefore, the aim of this study was to verify the arch height results from the OFM by using the arch index of plantar pressure measurements as indirect measure of arch height [5].

PATIENTS/MATERIALS and METHODS

The patient group (JIA-PPV) included eleven individuals (Mdn values for age: 11 yr, height: 1.5 m, weight: 44 kg, BMI: 19.0 kg/m^2) with at least one affected ankle joint and fixed pes planovalgus (≥ 5° and heel valgus also on tiptoe). That the individuals fulfilled the inclusion criteria was evaluated by one experienced physiotherapist. Fourteen voluntary, healthy peers (Mdn values for age: 10 yr, height: 1.5 m, weight: 40 kg, BMI: 17.7 kg/m^2) served as control group (CG). None of them had rheumatic, orthopaedic or neurological diseases nor any lower limb surgeries or orthopaedic insoles.

The arch height data of both groups were collected during barefoot walking at self-selected speed (1.1-1.3 m/s) with an 8-camera 3d-motion analysis system (200 Hz) (Vicon) and a four-sensor/cm2 pressure distribution plate (Emed). For the analysis of minimum longitudinal arch height 44 reflective markers were attached as required by the OFM [4]. Arch height was then calculated as the perpendicular distance of the P1M-marker away from the forefoot plane normalised to foot length. For plantar pressure analysis, the arch index [6] was determined as the ratio of the midfoot area relative to the total area excluding the toes.

Differences between JIA-PPV and CG which met the 0.05 level in Mann-Whitney-U-test were considered statistical significant.

RESULTS

No significant differences could be noted between JIA-PPV and CG in anthropometric characteristics and spatio-temporal parameters ($p > 0.05$). The OFM calculations of minimum longitudinal arch height were similar in mid stance in both groups (JIA-PPV Mdn: 21.4 % (Q25:18.0/Q75:23.6)), CG Mdn: 20.4 % (19.5/21.5); $p > 0.05$). Foot pressure measurements of the arch index (dimensionless) differed significantly between JIA-PPV (Mdn: 0.25 (0.23/0.27)) and CG (Mdn: 0.22 (0.17/0.23)); $p < 0.05$).

DISCUSSION and CONCLUSIONS

The plantar foot pressure data showed that JIA-PPV had a significantly higher arch index, which is associated with a lowered medial longitudinal arch [6]. This confirms the second general JIA-PPV-characteristic and we can assure the analysis of pes planovalgus, which is in contrast to the data of the OFM. Thus, it is advised that arch height calculations by the OFM should be interpreted with caution and that a revision of the OFM might even be needed.

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COMPARISON BETWEEN SELF-PACED AND FIXED VELOCITY GAIT IN AN IMMERSIVE VR ENVIRONMENT

A.C. Turconi (1), E. Biffi (1), C. Maghini (1) and L. Piccinini (1)

(1) IRCCS E: Medea, Bosisio Parini (LC), Italy

INTRODUCTION and AIM

During the last few years, novel instrumented treadmills for gait training and assessment have been introduced in the clinical practice. The main drawback of these platforms is the role of constraints imposed by the fixed walking speed which doesn't resemble the overground walking variability. Few authors faced this problem by developing feedback-controlled systems that adapt treadmill speed to the user (self-paced walking). A novel integrated platform which implements this solution is the GRAIL (Gait Real-time Analysis Interactive Lab, Motek Medical BV, the Netherlands) whose self-paced features have been recently investigated [2]. Authors observed some differences between self-paced and fixed-velocity walking but ascribed them to the absence of a sufficient adaptation period. Therefore, the present study aims at defining the minimum familiarization period required to obtain reliable data and comparing gait parameters during self-paced and fixed-velocity walking over GRAIL.

PATIENTS/MATERIALS and METHODS

10 healthy walked on a split-belt instrumented treadmill in a virtual environment (GRAIL, Motek Medical BV, the Netherlands). Subjects were asked to walk at fixed-speed and in self-paced configuration. Consecutive measurements in both conditions were performed to define the minimum familiarization period required. Gait data were analyzed in real-time and statistically compared. The research protocol was approved by the Ethical Committee of our Institute.

RESULTS

Our results show that 3 minutes are the minimum familiarization period required to obtain reliable data, i.e. with no significant variations between consecutive measurements, when walking at fixed-velocity. In contrast, our results show that a longer training is needed when walking in self-paced mode (about 10 minutes). Moreover, self-paced walking led to an improved gait pattern in terms of kinematic and kinetic data after the habituation period.

DISCUSSION and CONCLUSION

Self-paced and fixed-speed treadmill walking can be considered similar. Moreover, self-paced walking gives more freedom to subjects which can select and change their own preferred walking speed, resembling the overground walking variability. Finally, GRAIL system coupled with self-paced walking allows to measure stride variability or endurance, while reducing measurement and time required to perform data analysis.

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MUSCLE STRENGTH AND POSTURAL CONTROL DURING SIT-TO-STAND MOVEMENT IN CHILDREN

Authors: S.L. Pavão (1), A.N. dos Santos (1), N.A.C.F. Rocha (1)

Federal University of São Carlos, São Carlos, Brazil

Main Topics: Analysis of clinical movement data; Experimental studies in human movement science

INTRODUCTION AND AIM: Muscular strength is an important determinant of motor performance and social participation in activities of daily living. Therefore it may also be related with postural control. Previous studies with adults have suggested that quadriceps weakness could be related with postural instability determining difficulties to stand up from a chair. Studies addressing elderly women with osteoporosis verified strong relation between quadriceps extensor torque and dynamic postural control. However there is a lack of studies addressing this relationship in children. In addition, the majority of studies addressing this issue in children population analyzed static postures. None of the observed studies have addressed postural control during the performance of functional activities, such as the sit-to-stand (STS) movement. When applied to rehabilitation, this relationship provides significant contributions to clinical practice regarding force training in order to improve postural control. Thus, we aimed to investigate the relationship between knee extensors' and flexors' strength and PC during STS movement in children with typical development.

PATIENTS/MATERIALL and METHODS: This is cross sectional study. We assessed 21 children with typical development, mean age 8 (±2.2) years-old. The study was approved by the local Institutional review board (case# 363/2010). Initially, the child was placed seated on a stool, with feet resting on a force plate sampling at 100Hz. The child was instructed to stand up 5 times: 2 of these were adaptation trials and 3 were valid trials. The STS movement was divided into 3 phases: (1) preparation, (2) rising and (3) stabilization. Muscle strength was measured by means of isokinetic dynamometry on concentric passive mode, at an angular velocity of 60°/s. The lower limbs were bilaterally assessed. The participants performed 3 submaximal familiarization muscle contractions, and after 2 min of rest, 5 maximal voluntary contractions were performed. The variables analyzed were: anterior-posterior and medial-lateral amplitude of center of pressure (COP) displacement (AP amp and ML amp), area and mean velocity of COP oscillation in all STS phases; and knee extensors' and flexors' peak torque bilaterally. Since the statistic data analysis showed absence of normal distribution, Spearman's correlation test was used.

RESULTS:

Spearman's correlation showed significant correlation between extensors' peak torque bilaterally and the follow variables: ML amplitude of CoP displacement, area and mean velocity of CoP oscilation during the preparation phase of the STS movement, and means velocity of CoP oscilation during the rising phase of STS movement.

	Pico extensor Membro de apoio	Pico extensor Membro dominante
Amplitude ML STDP1	r= -0.536; p<0.05	r= -0.566; p<0.05
Área STDP1	r= -0.456; p<0.05	(r= -0.457; p<0.05
Vel Média STDP1	r= -0.570; p<0.05	r= -0.616; p<0.05
Vel Média STDP2	r= -0.490; p<0.05	r= -0.494; p<0.05

DISCUSSION and CONCLUSION: The results indicate the relationship between knee extensor torque and postural control during STS movement. The observed relation between strength and postural control could be observed during the two initial phases of the STS movement which involves anti-gravity movements and demands quadriceps strength. Thus, the improvement of strength around the knee joint is expected to be related with a decrease in postural oscilation during STS movement. However, further studies are needed involving children with neuromotor impairments, such as cerebral palsy.

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CRAWLERS VERSUS BOTTOM SHUFFLERS: DIFFERENCES IN CONTROL OF THE TRUNK

A. Hallemans (1,2), P. Van de Walle (1), E. Verbecque (1), N. Op de Beeck (3), L. Vereeck (1), P. Aerts (2)
(1) Department of Rehabilitation Sciences and Physiotherapy, Faculty of Medicine and Health Science, University of Antwerp, Belgium
(2) Department of Biology, Faculty of Sciences, University of Antwerp, Belgium
(3) Department of Children's Neurology, University Hospital of Antwerp, Belgium

Main topics: Motor control and motor learning - Experimental studies in human movement science

INTRODUCTION and AIM

Locomotion starts when a baby begins crawling around the mean age of 9 months (range 5 – 13 months) [1]. Typical crawling is performed on hands and knees, however, in about 18 - 34% of the population a different movement pattern is observed such as creeping, bottom shuffling or not crawling [2]. Bottom shuffling is often associated with motor and developmental problems, although only limited evidence exists. In this study we investigate whether bottom shufflers differ from crawlers in trunk movements during crawling/shuffling and during walking. We hypothesize that bottom shufflers have less control over their trunk and therefore show a more rigid movement pattern with less out of phase movements between thorax and pelvis.

PATIENTS/MATERIALS and METHODS

Movements of crawlers (n = 6, 9 – 13 months) and bottom shufflers (n = 8, 11 – 24 months) were recorded using a Vicon Mcam 460 system (6 camera's, 120 Hz.). The participating children were subjected to follow-up and gait analysis was performed at 1 week, 6 months and 1 year after the onset of independent walking.

3D Euler/Cardan rotations of the thorax and pelvis (modelled in Visual 3D v4) were calculated based on the coordinates of markers placed over the processus xiphoideus (sternum), T10, left and right acromion, left and right iliac crest and midway between the spinae iliaca posterior superior. Control of trunk movement was characterized by calculating ranges of motion (ROM) of the thorax and pelvis, as well as by calculating Pearson correlations (*r*) between the angular time profiles of thorax and pelvis rotations in each anatomical plane. If r = 1 thorax and pelvis are moving exactly in phase, r = -1 indicates that thorax and pelvis are moving exactly out of phase. Differences in ROM and *r* between the crawlers and bottom shufflers were investigated using the Kruskall-Wallis test, significance was set at $p < 0.05$.

RESULTS

Crawling and shuffling differ significantly in ROM of the thorax and pelvis (see table 1) and in *r* between thorax and pelvis in the sagittal and transverse plane (see table 1). During walking (even at 6 months and 1 year of walking experience), the *r* between thorax and pelvis in the sagittal plane is significantly larger in the group of ex - shufflers (*r* = 0.70±0.07) compared to the group of ex – crawlers (*r* =0.37±0.14). No other differences were observed in kinematics of thorax and pelvis.

Table 1: Thorax & Pelvis Kinematics: ROM (sagittal plane) and correlations of thorax and pelvis kinematics (sagittal & transverse plane) compared between crawling and shuffling (* p < 0.05, ** p < 0.01, *** p < 0.001)

Pattern	ROM_thor sag (°) ***	ROM_thor front (°) *	ROM_thor trans (°)	ROM_pel sag (°)**	ROM_pel front (°)***	ROM_pel trans (°)	r_thor_pel sag *	r_thor_pel trans **
Crawling 6.4±	6.3	<u>25.5±7.6</u>	11.1± 5.5	12.2± 6.5	<u>19.9±8.4</u>	18.3±8.9	*0.05±0.3* -	*0.21±0.4*
Bottom shuffling	<u>23.3± 11.2</u>	11.7± 10.0	13.0± 10.6	<u>27.3±10.2</u>	7.6±4.0	14.2±12.2	*0.61±0.3*	*0.72±0.4*

DISCUSSION and CONCLUSIONS

Crawlers and bottom shufflers differ in trunk kinematics. Crawling is characterized by large movements in the frontal plane (lateroflexion) and the negative correlation coefficients indicate a (partial) out of phase movement of thorax and pelvis. Bottom shuffling on the other hand, shows the largest movement in the sagittal plane and the correlation coefficients are large and positive indicating an in phase movement of thorax and pelvis. This rigidity of the trunk observed in bottom shuffling seems to persist during walking in these children. These results suggest that limited control of the trunk might be an issue for (ex) bottom shufflers. The question remains whether limited trunk control is cause or effect of the bottom shuffling. More research is necessary to answer this question.

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DIFFERENCES IN JOINT MOMENT AND POWER IN CHILDREN WITH CEREBRAL PALSY AND LEG LENGTH DISCREPANCY

R. Zügner[1], R. Tranberg[1], I. Stefansdottir[2], M. Nyström Eek[2]

[1]Department of Orthopaedics, Institute of Clinical Sciences, Sahlgrenska Academy, University of Gothenburg, Sahlgrenska University, SE 413 45 Göteborg, Sweden
[2]Regional rehabilitation centre, Queen Silvia Children's hospital, Gothenburg, Sweden

Main topics: Outcomes after clinical intervention and analysis of gait and motor disorders

INTRODUCTION and AIM

Leg length discrepancy is common in patients with cerebral palsy (CP). There is no consensus about the effect of elevation of one shoe. The aim was to examine the influence on gait pattern, with focus on changes in joint moment and power [1-3].

PATIENTS/MATERIALS and METHODS

Ten children with spastic CP (six boys, four girls) mean age 10.6 (7.8-12.8) at GMFCS level I-II. The children with CP had a leg length discrepancy of 1.73 cm (0.7-2.5).

A 3D gait analysis was performed barefoot, with shoes and with shoes + extra sole on the short side. The maximum moment and power of the hip-, knee- and ankle joint in the sagittal plane were chosen for statistical analysis. Muscle strength in the legs was measured with a handheld myometer.

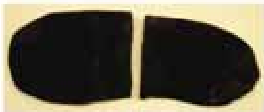

Figure 1. Extra insole of EVA

RESULTS

Walking barefoot, the children with CP showed differences in moment between the short and the long leg in the sagittal plane in all three joints (p<0.05). With shoes the difference was reduced and with shoe+extra sole the only difference left was in the ankle moment.

The generated power in the sagittal plane resulted in differences at all three conditions (p<0.05). Barefoot walking and with shoe+extra sole showed differences in the knee and hip joint respectively.

Muscle weakness was present in muscles around the hip and in ankle dorsiflexors, the long leg was stronger than the short.

Figure 2. Test person without and with shoes + extra sole

DISCUSSION and CONCLUSIONS

The hip and knee moments in the sagittal plane slightly improved with shoes and increased further with shoes+extra sole. This implies that a sole can be an easy and cost-effective intervention for children with CP. No changes were seen in moments for the ankle joint, which may reflect the presence of muscle weakness around the ankle.

Conclusion: Joint moments in the sagittal plane improved with shoe+extra sole in the hip- and knee joints, but ankle moments and generated power remained the same in children with CP and leg length discrepancy.

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UTILITY BELT OR LOAD BEARING VEST? AN ANALYSIS OF PELVIC KINEMATICS IN SWEDISH POLICE

L B. Larsen (1), R. Tranberg (2) N. Ramstrand (1)

(1) School of Health Sciences, Jönköping, Sweden
(2) Sahlgrenska Academy, Gothenburg, Sweden

Main topics: Experimental studies in human movement science, Technical developments in movement science.

INTRODUCTION and AIM

Police officers are commonly reported to have a high prevalence of lower back pain (1) which has been associated with use of heavy utility belts together with body amour (2, 3). Offloading the lower back and pelvic region by relocating equipment from the utility belt to a load bearing vest and leg holster has been suggested as an alternative means of carrying equipment required by police (2). The relative effects of load bearing vests on pelvic kinematics in currently unclear. It is hypothesized that anterior placement of equipment on a utility belt will provoke an increase in anterior pelvic tilt. The aim of the study was to compare pelvic kinematics in a sample of Swedish police officers while wearing a utility belt versus a load bearing vest.

PATIENTS/MATERIALS and METHODS

Nineteen participants (F=10/M=9) were recruited for the study. All worked as active duty police officers in a middle sized municipality in Sweden. Participants had no musculoskeletal problems at the time of data collection. All participants were tested under three conditions wearing: a) standard utility belt with standard body amour, b) a load bearing vest with standard body amour and thigh holster and c) no equipment. Testing conditions were randomised. Participant walked at self-selected speed on an 8 metre walkway. Kinematic data was collected using a three-dimensional gait analysis system (Qualisys Medical AB). A surface cluster marker model was used to collect data. Due to placement of equipment around the pelvic region reflective markers could not be placed directly onto pelvic landmarks. As a result a u-shaped rigid carbon fibre frame containing a cluster of three markers was manufactured to partially fit under the equipment belt. This frame was mounted on the sacrum and tracked movement of the pelvis during dynamic trials.

RESULTS

Pelvic kinematics during stance and swing phase was calculated and compared across the three conditions using Friedmans ANOVA. A significant difference was observed in maximum pelvic tilt when comparing the standard utility belt and the load bearing vest conditions (Table 1). When wearing the load bearing vest the pelvis was found to be tilted more posteriorly relative to the utility belt condition ($p \leq 0.05$). No differences were observed in the other planes or in range of motion of the pelvis.

Table 1: Maximum pelvic tilt (mean of three walking trial)

	standard utility belt	no equipment	load bearing vest	P≤0.05
Max angle stance	-1,82*	-2,68	-4,11*	0,050
Max angle swing	-2,50*	-3,32	- 4,23*	0,036

DISCUSSION and CONCLUSIONS

The results demonstrated a significant difference in sagittal plane pelvic kinematics when comparing the load bearing vest to the standard utility belt. Angular differences were however relatively small and their clinical relevance in terms of low back pain is yet to be determined. Further analysis should investigate kinematic changes at the hip and trunk to see if any differences at these levels, combined with the pelvic tilt results presented in this study may have a cumulative effect which results in an increased risk of low back pain.

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EFFECT OF SUBJECT-SPECIFIC MUSCULOSKELETAL MODELLING ON KINEMATICS AND DYNAMICS OF JUMPING IN POWER ATHLETES

S. Van Rossom(1), L. Bosmans(1), A. Van Campen(2), F. De Groote(2), J. De Schutter(2), I. Jonkers(1)

(1) Department of Kinesiology, Katholieke Universiteit Leuven, Heverlee, Belgium
(2) Department of Mechanical Engineering, Katholieke Universiteit Leuven, Division PMA, Heverlee, Belgium

Main topics: musculoskeletal modelling, musculoskeletal imaging, Analysis of clinical movement data

INTRODUCTION and AIM

Parameters deduced from movement analysis such as muscle-tendon (MT) forces are known to be sensitive to anatomical variability [1]. Currently the generic models do not account for this subject variability. We studied the added value of a musculoskeletal model based on magnetic resonance imaging (MRI) during a countermovement jump for the calculation of kinematics, kinetics and muscle activations. We hypothesize that MRI-based models are more suitable to reproduce this explosive movement, because musculoskeletal parameters are determined more subject-specifically compared to the generic model.

PATIENTS/MATERIALS and METHODS

Four subjects (3 males, 1 female, 21yrs) performed three countermovement jumps. 3D marker trajectories were captured using Vicon (Oxford Metrics, UK, 200Hz) and force data was recorded using 2 AMTI force plates (Watertown, USA, 1000Hz). Simultaneously, muscle activity was recorded using surface EMG (ZeroWire, EMG, Aurion, Italy, 1000Hz). For each subject a rescaled generic model and an MRI-based model was created. Using each model dynamic simulations of five countermovement jumps were performed using computed muscle control implemented in OpenSim 2.4.0. [2]. Joint angles in the hip and knee were calculated using the Kalman Smoothing algorithm [3]. Joint moments were calculated using inverse dynamics implemented in OpenSim 2.4.0 [2]. Differences between the calculated kinematics, kinetics and muscle activations were expressed by a root mean square error (RMS). Similarity between the two models was expressed by a Pearson correlation coefficient ($\alpha < 0.05$).

RESULTS

In the MRI-based models joint angles were increased, but were significantly correlated with the generic models ($p<0.001$) (table 1). Highest difference was found in hip flexion (RMS = 8.8 ± 4.1°). Furthermore joint moments were increased, with the highest difference in hip adduction (RMS = 13.3±25.6Nm). However high to medium positive significant ($p<0.001$) correlations were found between the two models in all subjects. Only for hip adduction a low non-significant correlation was found in one subject ($p=0.33$) and a negative correlation in one subject. Both models activated the reserve actuators in order to perform the measured motion. However, reserve actuators in the generic model generated more torque in hip flexion (37.47 vs. 27.13Nm), knee flexion (-30.12 vs. -10.83 Nm) and ankle flexion (-15.15 vs. -5.83 Nm) compared to the MRI-based model.

DISCUSSION and CONCLUSIONS

MRI-based models reproduce kinematics more accurately in comparison to the widely used scaled generic models. Mainly because the segmental coordinate systems and joint centre locations are determined more accurately. Both models are too weak to reproduce the countermovement jump. Since the reserve actuator torque of the MRI-based model is smaller in the important degrees of freedom, we conclude that the MRI-based models are more suited in reproducing this movement. The more subject-specific geometry in the MRI-based models leads to more accurate moment arms and fibre lengths resulting in the lower contributions of the reserve actuators. This finding supports the use of MRI-based models especially to simulate high demanding tasks.

Table 1: Minimal and maximal inter-model correlations between the calculated joint angles joint moments
*not significant p>0.05

	Minimal correlation Joint angle	Maximal correlation Joint angle	Minimal correlation Joint moment	Maximal correlation Joint moment
Hip flexion	0.9967	0.9997	0.8683	0.9853
Hip adduction	0.8991	0.9577	-0.0979*	0.8772
Hip rotation	0.9009	0.9989	-0.6880	0.9801
Knee flexion	0.9998	0.9989	0.7183	0.9980

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LOWER LIMB JOINT MOMENTS DURING STAIR ASCENT IN OLDER ADULTS WITH DIFFERENT FUNCTIONAL FITNESS LEVELS

V. Moniz-Pereira (1), S. Cabral (1), F. Carnide (1), A. P. Veloso (1)
(1) BFML – CIPER – Faculdade de Morticidade Humana – Universidade de Lisboa, Lisboa, Portugal

Main topics: Analysis of clinical movement data, Functional outcome measures in mobility.

INTRODUCTION and AIM

Stair negotiation is necessary to perform daily activities and therefore important for independent living. Consequently, comparisons between young and older adults have been done to identify the age-related changes in stair performance [1, 2]. However, functional fitness levels greatly differ among older adults, even within those living in the community and/or with the same age. Thus, the purpose of this study was to analyze the influence of functional fitness level on the lower limb joint moments applied during stair ascent in a sample of community-dwelling older adults.

PATIENTS/MATERIALS and METHODS

Twenty seven community-dwelling older adults over 60 years (71.4 ± 5.4 y), without any condition that would affect their gait pattern, volunteered to participate in this study.
Functional fitness tests included: the 8 foot Up&Go and the Chair Stand test from Senior Fitness Test battery [3]; and items 4 – step up and over, 5 – tandem walk, 6 – stand on one leg and 7 – stand on foam eyes closed, from Fullerton Advanced Balance Scale [4]. A total score considering the results of all tests was computed and used to divide the sample in two groups (LFFL – low functional fitness level; HFFL – high functional fitness level).
Kinematic and kinetic data were collected using 8 infrared, high speed cameras (Qualisys Oqus 300) working at a frequency of 200Hz and synchronized with 2 Kistler force plates (9281B, 9283U014), one in front of the stairs and the other embedded below the first step. Participants were asked to walk at their comfortable pace.
Data processing was performed using Visual 3D software (Professional Version v4.80.00, C-Motion, Inc). Three cycles were analyzed. A 4th order Butterworth filter was applied to both kinematic and kinetic data. The CAST marker set [5] was used and an 8 segments model (feet, shanks, thighs, pelvis and trunk) was built and optimized through global optimization [6]. Joint moment peaks and rotational impulses in the sagittal plane were computed for each trial and average for each subject.
Statistical analysis was performed in IBM SPSS Statistics 20. Differences between groups were determined using the un-paired t-test (significance level $p<0.05$) and complemented with an effect size analysis (|d|).

RESULTS

With the exception of functional fitness level, the two groups did not differed in terms of age, body mass index and stride velocity. Joint moment differences between groups were higher during the weight acceptance and the pull up phases. The LFFL group showed to re-distribute their joint moments by applying lower extensor joint moments at the knee and the ankle joints ($p<0.05$) and a higher extensor moment at the hip (|d|>0.50) (Table 1).

DISCUSSION and CONCLUSIONS

Even within a group of older adults living in the community, differences in joint moments were found between subjects with different functional fitness levels. These differences are in accordance with previous studies which compared young and older adults [1, 2]. When performing studies involving older adults, functional fitness level, rather than age alone, should be taken into account.

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Table 1: Joint moment differences between groups

Joint moments (Nm/Kg) and rotational impulses (Nms/Kg)	LFFL n =14	HFFL n =13	p-value	|d|
Hip extensor rotational impulse (weight acceptance + pull up)	0.20±0.05	0.16±0.05	0.061	0.74
Max knee extensor joint moment	0.94±0.15	1.08±0.15	0.019	0.96
Ankle extensor rotational impulse (weight acceptance + pull up)	0.17±0.07	0.23±0.07	0.036	0.85

ESTIMATION OF THE ANKLE STIFFNESS OF PEOPLE WITH TRANSFEMORAL AMPUTATION DURING SLOPE AND STAIR WALKING

H. Pillet (1), X. Drevelle (2), C. Villa (1), X. Bonnet (3), B. Dauriac (1), I. Loiret (4), F. Lavaste (1)

(1) Arts et Métiers ParisTech, LBM, Paris, France
(2) INI/ Centre d'Etude et de Recherche sur l'Appareillage des Handicapés, Créteil, France
(3) Proteor, Seurre, France
(4) Centre de médecine physique et de réadaptation Louis Pierquin IRR-UGECAM Nord – Est, Nancy, France

Main topics: Prosthetics, Analysis of clinical movement data, Analysis of gait and motors disorders

INTRODUCTION and AIM

Locomotion of people with transfemoral amputation has been shown to be altered particularly when walking in challenging situations such as slopes or stairs [1]. Part of the difficulties can be attributed to a lack of adaptation of the prosthetic ankle between walking conditions resulting from the constant stiffness of conventional prosthetic foot. One way to improve prosthetic ankle design should be found in mimicking the evolution of the physiological ankle stiffness of non-amputee subjects in these situations [2]. The calculation of this parameter is easy from conventional gait analysis [3]. The aim of the study is to provide the quantification of the ankle stiffness during level, slope and stairs walking for people with amputation compared to a control group.

PATIENTS/MATERIALS and METHODS

Eighteen asymptomatic subjects and fourteen transfemoral amputees participated in data collection. A kinematic and kinetic gait analysis was performed with an optoelectronic system and force platforms for level walking, 5% and 12% inclined slopes and a 4-steps stair. Average ankle stiffness was calculated for each group of patients as the linear coefficient linking the ankle moment and the ankle angle over the dorsiflexion motion of the ankle during stance.

RESULTS

Table 1 gives the ankle dorsiflexion stiffness for both groups of subjects. For the control group, the curve bilinear and two values could be determined for each part.

Table 1: Values (average and standard deviation) of K: averaged ankle stiffness during the whole dorsiflexion movement for transfemoral amputee and K1: averaged ankle stiffness during the first part of the dorsiflexion movement and K2: averaged ankle stiffness during the first part of the dorsiflexion movement for the population of non-amputee subjects (NA not available)

	Transfemoral amputee		Control group			
Mean ; SD	K (Nm/kg/°)		K1 (Nm/kg/°)		K2 (Nm/kg/°)	
Level walking	0,08	0,02	0,06	0,02	0,15	0,05
Ramp descent (5%)	0,07	0,02	0,07	0,02	0,11	0,09
Ramp descent (12%)	0,07	0,02	0,07	0,02	0,06	0,07
Ramp ascent (5%)	0,08	0,02	0,04	0,02	0,20	0,10
Ramp ascent (12%)	0,08	0,02	0,04	0,02	0,31	0,19
Stair descent	NA	NA	NA	NA	0,03	0,03

DISCUSSION and CONCLUSIONS

Results showed that prosthetic ankle stiffness is independent on the walking conditions. In particular, it prevents transfemoral amputee descending stairs with the foot flat on the stair leading the majority of them to avoid step-by-step descent. Adaptive ankle design reproducing non-amputee evolution of stiffness should therefore be a major improvement for both function and safety.

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GAIT DEVIATIONS IN THE INTACT SIDE OF PATIENTS AFTER POLYTRAUMA WITH LOWER LIMB INJURES CONSEQUENCES

R. Jakusonoka (1), Z. Pavare (1,2), A. Jumtins (1), T. Ananjeva (1,2), A. Smolovs (2), J. Vinogradova (2)

(1) Riga Stradins University, Riga, Latvia (2) National Rehabilitation Centre 'Vaivari', Jurmala, Latvia

Main topics: polytrauma, instrumented gait analysis, rehabilitation

INTRODUCTION and AIM

The evaluation of the gait of patients after polytrauma is important as it shows patients possibility to return to the previous activities and work. Spatio-temporal, kinematic and kinetic data of gait cycle analyses are important to find out patterns of gait deviations in the joints of lower extremities during gait cycle [1]. The aim of the study was to analyze the gait deviations in the intact side in patients with lower limb injuries consequences in the medium-term after polytrauma.

PATIENTS/MATERIALS and METHODS

Retrospective analysis of 154 polytrauma patients with musculoskeletal injuries treated in two Riga hospitals during 2008-2010 year period was made. Out of the retrospective study group, patients aged 18–60 were selected for the clinical examination and the instrumented 3-dimensional gait analysis (3DGA) if they had at least one severe lower limb injury in one side and had not lower limb amputation. The study was conducted on 26 polytrauma patients, age range 23–59 years (New Injury Severity Score 17–48), who suffered from unilateral lower limb injuries during the medium-term (12 to 41 months) after the trauma. The spatio-temporal parameters, motions in pelvis and lower extremities joints in sagittal and frontal plane and vertical load ground reaction force were analyzed [2]. Gait parameters in polytrauma patients were compared with healthy control group of 26 healthy volunteers (17 women and 9 men; age range 19–65 years). 3DGA was performed using an array of six Qualisys (Sweden) ProReflex MCU (240 Hz) cameras and the AMTI (USA) force plate. Patients walked barefoot at a self selected speed.

RESULTS

The results of the study using 3DGA show that gait cycle spatio-temporal parameters of the polytrauma patients group in the injured and intact side were different from the parameters of the same lower extremity of the control group. In the injured side of polytrauma patients step length was shorter, stance time was increased, cadence was decreased ($p<0.05$). In the intact side also step length (0.55 ± 0.12 m vs. 0.65 ± 0.06 m, $p = 0.001$) was shorter; stance time (66.70 ± 5.64% vs. 61.81 ± 1.26% of gait cycle, $p = 0.000$) was increased; cadence (94.00 ± 14.25 steps/min vs. 113.00 ± 9.86 steps/min, $p = 0.000$) was decreased. Analysis of the motions in the sagittal and frontal plane showed that in the injured side was increased pelvic anterior tilt, decreased hip extension and knee maximum flexion ($p<0.05$). In the intact side was significantly decreased knee maximum flexion and inversion in the subtalar joint ($p<0.05$). The patients had decreased vertical load GRF during loading response ($p<0.05$) in the both sides.

DISCUSSION and CONCLUSIONS

The study indicates that the polytrauma patients with lower limbs injuries in the medium-term after polytrauma have pathological changes in the injured side and secondary changes in the intact side. The results of the study show the need to develop the early rehabilitation measures to strengthen the quadriceps muscle and hamstrings, thus improve the stabilization of the knee joint during the loading response and knee flexion during the terminal stance. Increasing of the strength of the plantar flexor muscles would improve the push of the foot against the walking surface. Thus 3DGA makes it possible to identify the gait deviations in the intact lower extremity, which cannot be diagnosed with clinical examination methods only. Early rehabilitation measures for these patients can be used to improve the strength of the quadriceps muscle, hamstrings and plantar flexor muscles in the intact side.

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THE IMPACT OF VISION ON THE DYNAMIC CHARACTERISTICS OF THE GAIT: STRATEGIES IN CHILDREN WITH CONGENITAL BLINDNESS

S Gazzellini (1), ML Lispi (1), E Castelli (1), A Trombetti (2), G Vasco (1), S Carniel (1), M Petrarca (1)

(1) MARlab (Movement Analysis and Robotics Laboratory), Department of Neuroscience and Neurorehabilitation, Bambino Gesù Children's Hospital, IRCCS, Rome, Italy
(2) Regional Centre for blind people "S. Alessio", Rome, Italy

Main topics: Motor control and motor learning, Analysis of clinical movement data, Rehabilitation

INTRODUCTION and AIM

Visually impaired persons present an atypical gait pattern characterized by slower walking speed, shorter stride length and longer time of stance. Three explanatory hypotheses have been advanced in the literature: balance deficit, lack of an anticipatory mechanism and foot probing the ground. Since previous studies employed heterogeneous samples of low vision and blind persons, in the present study we compared these three hypotheses by executing a gait analysis of children with complete congenital blindness, without neurological impairment, and compared their performance with that of an age-matched control group.

PATIENTS/MATERIALS and METHODS

Thirteen participants with congenital blindness (CB) (age 7.6±3 range 3-13, 7 males) and ten normally developed (ND) children (age 8.6±2 range 6-12, 4 males) participated to the study. The inclusion criteria for the recruitment of children with visual impairment were the presence of blindness from birth, absence of neurologic deficit or orthopedic pathology. Exclusion criterion was the presence of cerebral visual impairment. Participants were asked to walk barefoot at self-selected speed in a large room (7 m x 14 m) along a walkway of 10 meters that was free of obstructions. An optoelectronic system (Vicon MX, UK, with 8 cameras operating at 200Hz) and two force platform (AMTI, US, or6-6), hidden in the floor at the centre of the walkway, were used to gathered kinematic and kinetic data of whole body. T-test comparing independent samples (CB vs. ND) were conducted.

RESULTS

The more remarkable differences consisted in a reduced walking velocity (0.82m/s vs 1.18m/s, $p<.001$), step length (0.39m vs 0.57m, $p<.001$), increased step width (0.18m vs 0.12m, $p<.001$) and external rotation of the foot progression angle (-17.7° vs -2.0°, $p<.001$) in CB vs ND. Moreover, CB patients showed reduced ground reaction force (97.9% vs 104.6%, $p<.05$) and ankle maximum angle, moment and power in only late stance (18.3° vs 15.8°, $p<.05$), increased head mean flexion (1.72° vs -8°, $p<.05$), decreased mean thorax flexion (0.7° vs 2.2°, $p<.01$) and pelvis mean anteversion (8.6° vs 12.2°, $p<.005$), compared with the control group.

DISCUSSION and CONCLUSIONS

In addition to the reduction of the thorax anterior-flexion previously described[1], we also observed a reduced pelvic anterior tilt (6°), wider than that of the thorax (3°). In our series, pelvis showed adequate tilt range and mean rotation angle. These results, in association with reduced ground reaction force and ankle maximum angle, moment and power in late stance, supported the hypothesis of a reduced forward dynamic projection of the body. This attitude is also associated with the reduction of walking velocity and step length. Furthermore, the decreased mean and range of the shoulder flexion angle results in a reduced anterior projection of the upper limb that contributed to the reduction in the forwards dynamics of gait.

The use of a foot probing the ground in place of visual input in blind children was suggested[1,2]. Two strategies were described: a) the research of foot/terrain contact with the toe instead of the heel; b) the systematic forward projections of one foot that anticipates the terrain tactile exploration. We did not observe none of the behaviours above described. Indeed, such behaviour was not expected considering that the participants walked on an even terrain. The ankle angles at terrain contact and during load responses phase were similar in the two studied groups. Furthermore, in the congenital blind children all the three ankle rockers were preserved as evidenced by the three studied angles peaks.

Overall, our findings did not prove the presence of balance deficit in blind children but can be explained by the lack of visually driven anticipatory control mechanisms.

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INT-/EXTERNAL ROTATION OF BILATERAL SHOULDER AB-/ADDUCTION AND ANTE-/RETROVERSION MOVEMENTS DESCRIBED AS CONJUNCT AND ADJUNCT ROTATION

Oliver Rettig[1], Britta Krautwurst[1], Sebastian I. Wolf[1]

[1]Department of Orthopaedics and Trauma Surgery Heidelberg University Hospital

Main topics: Experimental studies in human movement science, Orthopaedics

INTRODUCTION and AIM

The glenohumeral joint allows rotations around the humeral longitudinal axis called int-/external rotation. If there is additional movement simultaneously in other degrees of freedom of the shoulder its description is difficult. Typically Euler-/Cardan-parameterizations are used to describe the complex movements and one of the three angles is assigned to int-/external rotation. Such a description does not describe how much rotation is really done around the longitudinal axis because it is based on a fictive path, dependent on a rotation sequence. The discrepance to the real axial rotation yields to the so called Codman paradox, where adjunct rotation describes the real axial rotation and conjunct rotation describes a path independent rotation attitude. The aim of this study is to show the characteristics of int-/external shoulder rotation during bilateral shoulder ab-/adduction and ante-/retroversion described as conjunct and adjunct rotation.

PATIENTS/MATERIALS and METHODS

Eight healthy volunteers (29.1±12.0 years, 4/4 male/female) with no shoulder problems took part in the study. They are advised for three repetitions of bilateral elevation / depression of the arms a) in the frontal plane and b) in the sagittal plane. Each movement starts with the hanging arm and was lead back to this position. No advice was given about int-/external rotation during these movements. Data were recorded using a 12 camera-Vicon 612 motion capture system running at 120Hz. The protocol is based on the HUX measurement protocol [1]. Coordinate systems are defined following the ISB recommendations [2]. Adjunct rotation is determined by integration of the angular velocity component, which corresponds to the rotation around the longitudinal axis of the humerus. Conjunct rotation is determined as described in [3] as a gimbal lock free angle description and an Euler-decomposition with rotation order yxy is determined according to the globe convention [4] following [2]. CMC values [5] are determined to describe inter- and intra-subject repeatability.

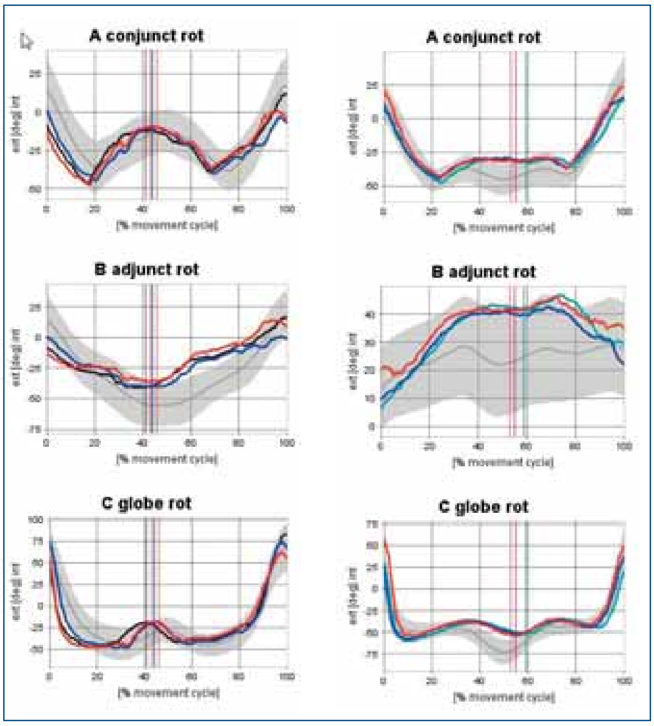

Fig. 1 Int-/ext. rotation during bilateral ab-/adduction. Upright lines = maximum of SG elevation.

Fig. 2: Int-/ext. rotation during bilateral ante-/retro. Upright lines = maximum of SG elevation.

Tab.1: Intra- and inter-subject CMC values for int-/external rotation during ab-/adduction and ante-/retroversion for different angle conventions.

	conjunct	adjunct	globe
Abduk	0.94/0.67	0.97/0.76	0.99/0.86
Ante	0.97/0.87	0.97/0.89	0.92/0.81

RESULTS

The figures show conjunct-, adjunct- and int-/external-rotation in terms of the globe convention for ab-/adduction (fig. 1) and for ante-/retroversion (fig. 2). Mean±SD is shown as gray band and three repetitions for one example volunteer are shown as continuous lines. CMC values are shown in tab.1.

DISCUSSION and CONCLUSION

The adjunct rotation curves (B in Fig.1, 2) show that real axial rotation with a consistent pattern is done during shoulder ab-/adduction only. Real axial rotation during ante-/retroversion is subject more specific. Conjunct rotation curves (A) are less steep than for globe (C) for first and last 10% of the movement, which better fits to the view. Altogether, conjunct- and adjunct rotation description gives more insight into the characteristics of int-/external rotation during bilateral shoulder movements in different planes.

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ACCLIMATIZATION OF THE WALKING PATTERN WITH A NEW ANKLE FOOT ORTHOSIS IN CHILDREN WITH CEREBRAL PALSY

KU. van Hutten (1), YL. Kerkum (1,2), AI. Buizer (1), J. Harlaar (1,2), JC. van der Noort (1,2) MA. Brehm (1,2)

(1) Department of Rehabilitation Medicine, VU University Medical Center, Amsterdam, The Netherlands
(2) MOVE Research Institute Amsterdam, Faculty of Human Movement Sciences, VU University, Amsterdam, The Netherlands

Main topics: Analysis of clinical movement data, orthotics, rehabilitation.

INTRODUCTION and AIM

Gait of children with spastic Cerebral Palsy (SCP) is often hampered by excessive knee flexion during the stance phase of gait. This may lead to walking limitations in terms of an increased walking energy cost and/or a decreased speed [1]. To counteract excessive knee flexion and improve gait, children with SCP are commonly provided with a floor reaction orthosis (FRO). Acclimatization to the new orthosis, i.e. ensuring that the walking pattern adapted to the provided FRO, is recommended for patients daily use [2]. Yet, although most testing protocols in previous studies permitted acclimatization time, varying from less than one day to more than four weeks [2], it is unknown whether acclimatization is indeed needed to adapt to the provided FRO. The aim of this study therefore was to investigate whether gait kinematics and kinetics in children with SPC, change within an acclimatization period of four weeks after being provided with a new FRO.

PATIENTS/MATERIALS and METHODS

A consecutive series of eight children with bilateral SCP walking with excessive knee flexion in midstance (7 boys, age 10±2, GMFCS I (2), II (5) and III (1)) were provided with a prepeg carbon FRO, with integrated NeuroSwing® ankle hinge. The FRO was worn in combination with the child's shoes, referred to as the FRO-FC. The FRO-FC was tuned based on the alignment of the ground reaction force with respect to the knee and hip joints in midstance and terminal stance. Directly after tuning (T0) and four weeks later (T1), a 3D-gait analysis was performed using an optoelectronic marker tracking system combined with a forceplate. For each participant, walking speed and six kinematic and kinetic gait parameters that were considered relevant were determined for three successful strides of the most affected leg. Differences in these parameters between T0 and T1 were analyzed using paired t-tests ($p<0.05$).

RESULTS

Over these four weeks, no significant differences ($p\geq0.093$) were observed for any of the investigated gait parameters (see table 1). However a rather large spread of individual responses was seen.

DISCUSSION and CONCLUSIONS

An acclimatization period of four weeks did not affect considered kinematic and kinetic gait parameters. This suggests that an acclimatization period is not needed for adaptation of the gait pattern to a new FRO.

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Table 1 Mean (SD) of considered gait parameters

Parameter	T0 (mean (SD))	T1 (mean (SD))	P
Walking speed m s^{-1}	1.17 (0.18)	1.05 (0.18)	0.093
SVA in Mst deg	22.08 (6.81)	20.33 (4.73)	0.368
Peak Knee extension in SSF deg	15.80 (9,98)	16.99 (8.62)	0.612
Knee extension Moment Mst Nm kg^{-1}	-0.15 (0.17)	-0.07 (0.11)	0.159
Peak Ankle Power W kg^{-1}	1.28 (0.42)	1.35 (0.70)	0.765
COP progression mm	226.2 (82.3)	211.8 (46.1)	0.521

SVA; shank to vertical angle, Mst; midstance, SSF; single support fase, COP; Centre of pressure

STATISTICAL PARAMETRIC MAPPING TO IDENTIFY GAIT PATTERN FEATURES IN CHILDREN WITH CEREBRAL PALSY

AN Angela. Nieuwenhuys (1), DM Davide. Monari (2), KD Kevin. Deschamps (1), TDL Tinne. De Laet (2), GM Guy. Molenaers (3), KD Kaat. Desloovere (3)

(1) KU Leuven, Dept. of Rehabilitation Sciences (2) KU Leuven, Dept. of Mechanical Engineering
(3) University Hospital Leuven, Clinical Motion Analysis Laboratory [Leuven, Belgium].

Main topics: Cerebral palsy, gait feature detection

INTRODUCTION and AIM

The aim of this pilot study was to introduce a new methodology to the field of cerebral palsy (CP), called 1D-Statistical Parametric Mapping (SPM). With SPM, two research questions can be answered: (1) are there significant differences in the lower limb kinematics between various clinical gait patterns and (2) what is the temporal behaviour of these differences within the gait cycle?

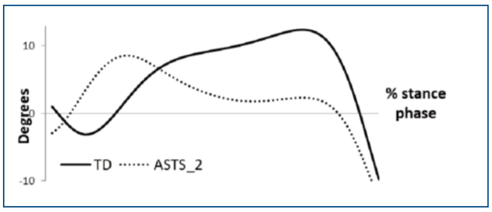
In CP, the extensive amount of three-dimensional gait analysis (3DGA) data is often reduced by defining gait classifications or gait features, e.g. knee angle at initial contact. 'A priori' data reduction, whether it is based on qualitative or quantitative techniques may lead to many sources of bias, may cause one to overlook relevant information, or may present an outcome with little clinical meaning[1], [2]. SPM can perform non-directed hypothesis testing on 3DGA data in a continuous manner, thus avoiding a priori data reduction. To illustrate the methodology, we applied SPM on five ankle joint patterns in CP that were previously described in literature[3].

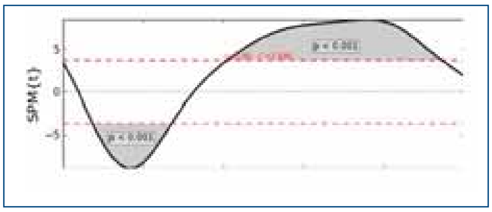
PATIENTS/MATERIALS and METHODS

A retrospective sample of 60 children (9.2 ± 2.2years) with spastic CP (unilateral n=22, bilateral n=38, GMFCS level I-II) as well as 36 age-related typical children were included. Exclusion criteria were previous orthopedic surgery or Botulinum toxin treatment within six months prior to 3DGA. All children underwent 3DGA and for each pathological side, three trials of the ankle kinematics during stance were classified according to the classification rules of Van Gestel et al.[3]. SPM was applied using open-source Python software[4]. A one-way ANOVA ($\alpha=0.05$) was carried out and was significant, after which post-hoc t-tests were conducted to evaluate between-group comparisons. Calculating the critical threshold and p-values, random field theory is applied to correct for multiple t-testing and for temporal correlation of the data points within one gait cycle[2], [4].

RESULTS

SPM(F) exceeded the critical F value over the entire stance phase. Post-hoc, all pathological ankle patterns differed significantly from typical gait, mostly during the second half of the stance phase (all p-values ≤0.001). Significant differences were also found in-between all pathological patterns (all p-values ≤0.002), except between ASTS 0 (only minor deviations) and ASTS 1 (horizontal second ankle rocker). Five out of ten between-group comparisons of pathological patterns differed significantly between each other over the entire stance phase. Notably, parts of the first 30% of the stance phase were very frequently highlighted as an area of interest to separate pathological from typical gait (see lower figure).





Upper fig: mean ankle angle in stance for 'typical gait' (TD, n=47) and 'reversed second ankle rocker' (ASTS_2, n=33).
Lower fig: SPM(t) shows a significant difference between both groups between 8-27% and 40-94% of the stance phase.

DISCUSSION and CONCLUSIONS

SPM has provided objective, statistical evidence that feature-based ankle patterns, defined by a clinical expert group, indeed differ from typical gait. The areas of difference coincide well with the subjective classification rules, but additional suggestions can be made, e.g. adding features for the first ankle rocker. SPM may serve as a means to improve the classification rules for these patterns and as a result, improve the automated classification using Bayesian Networks, described in detail by Van Gestel et al.[3]. Further, results are displayed in their original sampling space, making them easy to interpret. This makes SPM a very attractive tool for clinicians.

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THE CROSS-TRAINING EFFECT ON MUSCLE PERFORMANCE IN PATIENTS WITH MULTIPLE SCLEROSIS: A PILOT STUDY

A. Manca[1], M.P. Cabboi[1], E. Ortu[2], D. Dragone[1], A. Peruzzi[2], A. Cereatti[2], G. Mureddu[3], G. Bua[3] and F. Deriu[1]

(1) Dept. of Biomedical Sciences – University of Sassari, Sassari, Italy
(2) Information Engineering Unit, POLCOMING Department, Interuniversity Centre, University of Sassari, Sassari, Italy
(3) O.U. of Neuromotor Rehabilitation – Policlinico Sassarese, Sassari, Italy

Main topics: Rehabilitation; Outcomes after clinical intervention.

INTRODUCTION and AIM

Fatigue and muscle weakness dramatically affect the quality of life (QoL) of patients with MS[1]. Research has shown that resistance training has a significant positive effect on the level of daily living activities in people with MS, resulting in an increased QoL. Several methods are currently employed for reducing strength impairment in MS but no one regimen has been portrayed as superior to others[2]. When weakness is markedly lateralized to one side, training is not always viable through standard procedures, as the affected limb may be too compromised to sustain a conventional exercise program. In these cases, a Cross-Training (CT) approach may prove helpful in achieving an indirect muscle strength gain in the most-affected (MA) limb, through training of the less-affected (LA) contralateral limb[3]. Surprisingly, no data are currently available whether CT takes place and to which extent in MS. Therefore, the present study aims at investigating in MS the occurrence of CT and its efficacy on ankle dorsiflexor muscles' performance in comparison with a Standard-Training (ST).

PATIENTS/MATERIALS and METHODS

Design was set as a parallel-group case-control study. Eight patients with relapsing-remitting MS (5 females, 3 males; 46.5±11.2 y.o.; 64.5±14 kg) presenting with a predominantly unilateral strength impairment of the ankle dorsiflexor muscles (strength asymmetry score on the Medical Research Council Scale ≥ 1) were studied. Patients were randomized in two groups: Cross-Training (CT; $n = 4$) and Standard-Training (ST; $n = 4$), with training addressed to the LA or MA side, respectively. Intervention consisted of a 6-week unilateral isokinetic/concentric training (3 times/week for a total of 18 sessions at two angular velocities: 45 and 10°/s) of the tibialis anterior muscle (TA). Peak torque (PT) was measured on a Biodex isokinetic dynamometer before (pre), after 3 weeks (intermediate) and after 6 weeks (post) of intervention. A repeated-measures analysis of variance as well as paired and independent t-test were employed to process data from small samples.

RESULTS

After 6 weeks of training, in the CT group, where the LA side was trained, it was found that PT was significantly increased (+28.4% at 45°/s and +20% at 10°/s; $p<0.05$) in comparison to baseline; in the ST group, where the MA side was directly trained, PT showed a trend of increase (+18.2%; $p=0.29$) at 45°/s, while no change was observed at 10°/s. Interestingly, at the intermediate assessment, CT group showed no significant increase at both angular velocities tested, suggesting that the transfer of strength to the untrained side, observed at the 6th week, had not occurred yet. Differently, ST group showed the highest, though non-significant, percent change at 3 weeks (+16%; $p=0.15$), then levelled off (at 45°/s) or decreased to baseline levels (at 10°/s) at the end of the training period.

DISCUSSION and CONCLUSIONS

This study reports, for the first time, that in MS the CT-effect occurs. Our preliminary data suggest that in patients with a strength asymmetry, the indirect training of the weaker leg, via CT, is more effective than a direct ST approach in improving strength. Notably, the time course of strength improvement induced by both CT and ST was different. In fact, the PT constantly increased up to significance in the CT group, while in the ST group it showed a trend to plateau after an initial increase. Although further studies are needed to draw conclusive assumptions, these preliminary findings shed new insights on the cost-effectiveness of a direct *versus* indirect training of the MA limb in MS, where dealing with fatigue remains a challenge in neurorehabilitation.

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MONITORING FREEZING OF GAIT WITH A SMARTPHONE

L. Pepa (1), F. Verdini (1), M. Capecci (2), F. Maracci (2), M. G. Ceravolo (2), T. Leo (1)

(1) Dipartimento di Ingegneria dell'Informazione-UNIVPM, Ancona, Italia
(2) Dipartimento di Medicina Sperimentale e Clinica-UNIVPM, Ancona, Italia

Main topics: Movement analysis in clinical practice, Clinical decision making processes.

INTRODUCTION and AIM

The freezing of gait (FOG) is a common and highly distressing motor symptom of patients with Parkinson's Disease (PD). FOG pathogenesis is largely unclear, because of its episodic, heterogeneous and erratic nature, that makes it difficult to be observed in the clinical setting and clinical management is limited by the difficult nature of assessing FOG severity [1]. In literature a large number of studies propose the use of wireless body sensor networks to monitor FOG and provide a quantitative and objective assessment, see e.g. [2,3]. The use of such technologies, placing sensors on patient's body [4], do not often satisfy usability and acceptability requirements. The spread diffusion of smartphones and other mobile technologies in everyday life can represent an optimal solution to avoid oppressive or embarrassing feelings for patients. On the same time smartphones offer customizable user interface to increment perceived ease of use and inertial sensors to collect motion data. Only, Mazilu et al. [5] proposed a wearable assistant, composed of a smartphone as wearable computer and wearable accelerometers (hip, knee, ankle), for online detecting of FOG.

The purpose of this work is to present a system to on line monitor FOG during daily living respecting acceptability and usability requirements.

MATERIALS and METHODS

The on line monitoring system is implemented on a smartphone. We developed an application to acquire acceleration data from the internal sensor and then compute the same features proposed in [2] (a freeze index defined in [3] and energy) with the addition of the cadence by taking the second component of the power spectrum. We consider step cadence, an important feature in FOG monitoring, according to studies [6] that demonstrate the relation of FOG to the disruption of temporal, other than spatial, characteristics of gait. FOG detection occurs when freeze index and energy exceed their threshold during a cadence variation. The system also releases auditory cues contextually to FOG detection. All information collected by the smartphone app (features calculated, FOG events detected and threshold values) are stored locally and can be furthermore used off line for statistical analysis.

Thirteen patients were recruited to test the reliability of the system in FOG detection. Patients performed three kinds of Time Up and Go tasks designed to provoke FOG on a standardized course of 5 meters.

System performances, concerning the sensibility and specificity of the detection, were evaluated.

RESULTS

We observed 75 FOG events, as recognized by clinicians based on video recordings. The application correctly identified 73 of them. The Specificity reached the 98.49% and the Sensitivity the 88.47%.

DISCUSSION and CONCLUSIONS

Both the high score of performance results and the unobtrusiveness demonstrate the potential use of the architecture in monitoring, gait assistance during daily living and rehabilitation therapy.

The proposed architecture can be easily applied to similar scenarios involving patients affected by atypical parkinsonisms. Clinicians can benefit from the information brought by aggregate and synthetic clinically important parameters, improving their knowledge and patient management.

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OBJECTIVELY ASSESSED SPASTICITY OF THE CALF VERSUS IMPEDING MUSCLE ACTIVITY DURING GAIT IN SPASTIC CEREBRAL PALSY

LH. Sloot (1), M.M. van der Krogt (1), E. de Vlugt (2), J. Harlaar (1)

(1) Department of Rehabilitation Medicine, MOVE Research Institute Amsterdam, VU University Medical Center, Amsterdam, The Netherlands
(2) Department of Biomedical Engineering, Delft University of Technology, Delft, The Netherlands

Main topics: Analysis of clinical movement data; Musculoskeletal modelling

INTRODUCTION and AIM

Exaggerated stretch reflex activity is generally thought to be a main cause of spastic movement disorders. Therefore, antispastic treatments are often administered to reduce hyperreflexia during gait. However, growing evidence suggests that exaggerated reflexes have a minor effect on gait, in contrast to increased muscle stiffness and altered central drive [1]. Also, studies have shown a poor ability of manual passive spasticity measures to predict gait parameters [2]. Recently, an instrumented method was developed to separate muscle stiffness from exaggerated stretch reflex activity for the passive triceps surea muscles [3]. This study evaluated the relation between this new passive spasticity assessment (PSA) and dynamic spasticity (DS) during gait in children with spastic Cerebral Palsy (CP).

PATIENTS/MATERIALS and METHODS

Nine children with spastic CP (12.4±3.5 yr, GMFCS 1-3) were included. For PSA, their foot was fixed to a motor driven single axis footplate, aligned with their ankle axis. Two passive ramp-and-hold rotations were applied over the full range of ankle motion (ROM) at 100 º/s towards dorsal flexion. Ankle angle and EMG of the gastrocnemius and soleus muscles were used to optimize a nonlinear neuromuscular model to match the measured ankle torque. Measurements were performed at two knee angles (20º and 70º) to discriminate between the gastrocnemius and muscle soleus responses. Reflex activity was defined as the root-mean-square of the modelled reflex torque over the rotation. Furthermore, 3D gait assessment was performed at 3 different walking speeds, ranging from preferred, faster and fastest speed. DS was calculated as the slope of the relation between walking speed and the root-mean-square of the EMG measured during the swing phase normalized to the maximum EMG during the stance phase. Spearman's rho was used to assess the relation between PSA and DS.

RESULTS

One subject was excluded for inability to comply with the protocol. A poor relation was found between the PSA and DS for both the gastrocnemius (ρ=0,57, *p*=0,15) and soleus (ρ=0,52, *p*=0,20) muscle (see figure 1).

DISCUSSION and CONCLUSIONS

The poor relation between the PSA and the DS supports the idea that passively measured spasticity is independent of exaggerated reflex activity during functional tasks, due to the different roles of reflexes during active and passive conditions [1]. It should be noted that a more advanced quantification of the DS and a larger sample-size can alter the relation. As a next step, muscle-tendon lengths will be calculated using musculoskeletal modelling in order to compare DS as the ratio between peak EMG and peak stretch velocity to the PSA assessment. In addition, further measurements are currently taken place to increase the power of the study.

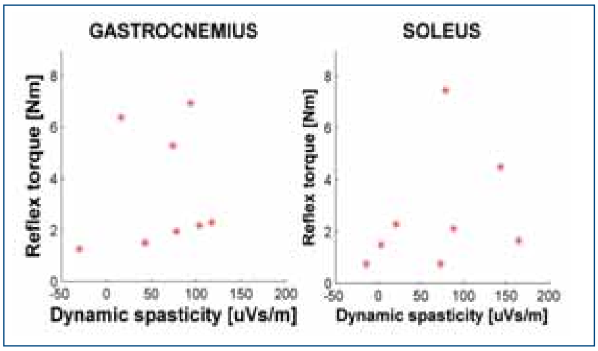

Figure 1: DS measures versus PSA spasticity assessment

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FUNCTIONAL EVALUATION OF FLAT FOOT IN CHILDREN: COMPARISON OF TWO DIFFERENT BIOREABSORBABLE IMPLANTS FOR SURGICAL TREATMENT

L. Berti (1), G. Lullini (1), P. Caravaggi (1), A. Leardini (1), S. Tamarri (1), V. Persiani (2), S. Giannini (2)

(1) Movement Analysis Laboratory, Istituto Ortopedico Rizzoli, Bologna, Italy
(2) Orthopaedic Clinic I, Istituto Ortopedico Rizzoli, Bologna, Italy

Main topics: Orthopaedics, Analysis of Clinical Movement data

INTRODUCTION and AIM

The flat foot is a frequent deformity in children and results in various levels of functional alterations. A diagnosis based on foot morphology is not sufficient to define the therapeutic approach. In fact, the degree of severity of the deformity and the effects of treatments require careful functional assessment. In case of functional flatfoot, subtalar arthroereisis is the surgical treatment of choice. The aim of this study is to evaluate and compare the functional outcomes of two different bioabsorbable implants designed for subtalar arthroereisis in childhood severe flat foot by means of thorough gait analysis.

PATIENTS/MATERIALS and METHODS

Ten children (11.3 ± 1.6 yrs, 19.7 ± 2.8 BMI) were operated for flat foot correction [1,2] in both feet, one with the calcaneo-stop method, i.e. a screw implanted into the calcaneus, the other with an endoprosthesis implanted into the sinus-tarsi. Gait analysis was performed pre- and 12 month post-operatively using a 8-camera motion system (,) and a surface EMG system (Cometa, Italy) to detect muscular activation of key leg muscles. A combination of established protocols, for lower limb [3] and multi-segment foot [4] kinematic analysis, was used to calculate joint rotations and moments during three walking trials for each patient.

RESULTS

Significant differences in standard X-ray measurements were observed between pre- and post-op, but not between the two treatment groups. Analysis of the kinematic variables revealed functional improvements after surgery. In particular, a reduction of eversion between the shank and calcaneus (Figure 1, left) and a reduction of inversion between metatarsus and calcaneus (Figure 1, right) were detected between pre- and post-op after both treatments. Activation of the main plantar/dorsiflexor muscles was similar at both pre- and post-op assessments with both implants.

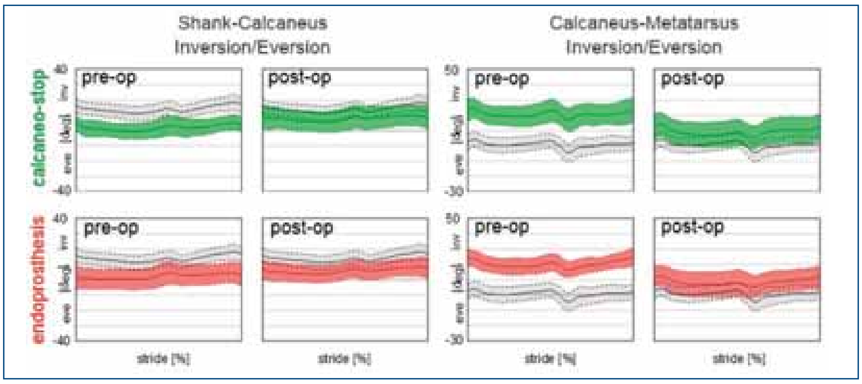

Figure 1: Patterns of joint rotations between calcaneus and shank (two left columns), and between metatarsus and calcaneus (two right columns), during pre-op and at 12 month post-op. Where in red is the calcaneo-stop group, in green is the endoprosthesis group, and in grey is the control group.

DISCUSSION and CONCLUSIONS

The combined lower limb and multi-segment foot kinematic analyses were found adequate to provide accurate functional assessment of the feet and of the lower limbs. Both surgical treatments restored nearly normal kinematics of the foot and of the lower limb joints, associated also to a physiologic muscular activation.

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LUMBAR REPOSITIONING IS INFLUENCED BY NONSPECIFIC LOW BACK PAIN, TEST SETUP AND BODY MASS INDEX

CM Bauer (1,2), FM Rast (2), S Oetiker (2), MJ Ernst (2), J Kool (2), J Suni (3), M Kankaanpää (1)

(1) University of Tampere, School of Medicine, Tampere, Finland
(2) ZHAW, Department of Health Sciences, Winterthur, Switzerland
(3) UKK Institute Tampere, Finland

Main topics:

Experimental studies in human movement science, Analysis of clinical movement data

INTRODUCTION and AIM

Low back pain (LBP) affects up to 84% of people in industrialized countries [1]. In 2005 the total direct costs of LBP in Switzerland amounted €2.6 billion [2]. Several studies have investigated deficits in proprioception in non-specific LBP (NSLBP) patients by investigating lumbar spine position sense. These studies measured lumbar repositioning error (RE), with conflicting results regarding the association of LBP and RE [3-4]. Comparison between these studies is difficult as there are large differences in the measurement procedure. The aim of this study therefore was to analyze if RE is influenced by sub-acute nonspecific low back pain (NSLBP), the test setup and individual factors and to propose a good test setup.

PATIENTS/MATERIALS and METHODS

We measured lumbar RE (absolute, constant, variable & mean squared) with three test setups in a cross-sectional, laboratory study. 60 patients with NSLBP and 31 healthy participants were included. All participants were instructed to move from neutral position through half of their maximal lumbar range of motion and to reproduce the neutral position. We analyzed Group, Test & GroupXTest effects on RE and adjusted for individual factors such as body mass index (BMI), by fitting a linear mixed model for every main outcome measure.

RESULTS

NSLBP patients produced a greater absolute (38% difference between groups), constant (60%) and mean squared error (70%) compared to controls. There was no group effect on variable error (8%). NSLBP patients were less accurate but not less consistent. The test setup influenced the magnitude and direction of RE. BMI influenced absolute and mean squared error. The magnitude and direction of RE depended on the test setup.

DISCUSSION and CONCLUSIONS

Tests for lumbar RE discriminate NSLBP patients from healthy participants but should be viewed with caution as their outcome depends on the test setup and BMI. We recommend two test setups and normalization for BMI for further use in clinical studies.

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GAIT ANALYSIS IN CHILDREN WITH HEMIPLEGIC CEREBRAL PALSY: FOOT-FLOOR CONTACT AND EMG ACTIVATION PATTERNS

V. Agostini (1), A. Nascimbeni (2), A. Gaffuri (2), M. Knaflitz (1)

(1) Dipartimento di Elettronica e Telecomunicazioni, Politecnico di Torino, Torino, Italy
(2) Rehabilitation Unit, S. Croce Hospital, A.S.L. TO5, Moncalieri (TO), Italy

Main topics: •Analysis of gait and motor disorders •Technical developments in movement science •Functional outcome measures in mobility.

INTRODUCTION and AIM

In children, hemiplegia is a common consequence of cerebral palsy (CP) and causes altered selective motor control, weakness and spasticity. A correct classification of children with CP is important to assist diagnosis and clinical decision-making [1]. The classification of spastic hemiplegia proposed by Winters et al. [2] is widely accepted in literature. Type I is defined by the presence of drop foot in swing, type II by the persistence of equinism throughout the gait cycle, with a possible knee hyperextension in stance.

Foot-contact event detection is fundamental in clinical gait analysis, but it is particularly challenging in children with CP due to initial toe-contact. In a recent work, we described an algorithm for the automatic segmentation of gait cycles from the foot-switch signal that it is applicable also to pathological gait [3]. The aim of this contribution is to apply this method to a population of CP children to study their foot-floor contact sequences, considering also the sub-phases of stance. The activation patterns of tibialis anterior (TA) and gastrocnemius lateralis (GL) helped us in the interpretation of the results.

PATIENTS/MATERIALS and METHODS

Children were equipped with: footswitches, ankle and knee goniometers, TA and GL electromyographic probes, bilaterally (STEP32 system, DemItalia, Italy). They were asked to walk barefoot for 2.5 minutes along a 10m-walkway. We analyzed, retrospectively, the gait of 38 CP children aged from 4 to 15 years: 16 type I and 22 type II. Gait data from 100 normal developing children were available from a previous study [4], and have been used for reference.

RESULTS

The two CP groups showed distinct foot-floor contact sequences. Type I showed cycles with preserved heel-rocker (but abnormal timing) in 35% of strides and cycles formed by the sequence toe-initial-contact/flat-foot-contact/push-off/swing in 44% of strides. Type II also showed the latter sequence (43% of strides), but their flat-foot phase was very shortened with respect to type I (12.1 ± 7.3 vs. 36.6 ± 8.1 % of gait cycle, $p = 10^{-9}$). In addition, type II showed cycles in which the flat-foot phase (40% of strides) was missing. In type I, the progressively diminished TA-activity around initial contact explained the shortened heel-contact and the initial-toe contact observed in the two main sequences. The progressively anticipated activity of GL explained the gradual worsening of the foot-floor contact sequences from the cycles of type I with preserved heel-contact to those of type II with flat-foot phase completely lost.

DISCUSSION and CONCLUSIONS

This work studied the foot-floor contact of CP children considering also the sub-phases of stance: this was never documented before in this population. This approach may be useful to obtain a better classification of hemiplegic CP children in the mildest form (type I and II), which are the more frequently observed in the clinical practice.

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DYNAMIC MOTOR CONTROL PREDICTS TREATMENT OUTCOME FOR CHILDREN WITH CEREBRAL PALSY

Michael H. Schwartz, Ph.D.[1,2] , Adam Rozumalski, M.S.[1], and Katherine M. Steele, Ph.D.[3]

[1] Gillette Children's Specialty Healthcare, St. Paul, USA
[2] University of Minnesota – Dept. of Orthopaedic Surgery, Minneapolis, USA
[3] University of Washington – Dept. of Mechanical Engineering, Seattle, USA

INTRODUCTION

Among children with cerebral palsy (CP), gait outcomes following treatment are highly variable, and depend on the amount of pre-treatment deformity [1]. We hypothesized that motor control would also be an important factor in predicting outcome. We used using EMG synergy analysis to define a measure of dynamic motor control (walk-DMC), and then examined the effect of motor control on treatment outcome.

METHODS

Our center's database was queried for individuals with a diagnosis of diplegic cerebral palsy, age < 21 years, initial gait analysis including surface EMG (rectus femoris, medial gastrocnemius, anterior tibialis, medial hamstrings) and follow-up gait analysis 9-36 months later. The EMG data from each participant's initial visit was processed using nonnegative matrix factorization to identify weighted groups of muscles that are consistently activated together (synergies) [2]. The variance accounted for by one synergy was scaled to form the walk-DMC metric:, is the z-score relative to typically-developing children. For normal dynamic motor control during gait walk-DMC > 100. Each 10 point decrement of walk-DMC reflects a 1-SD reduction.

A stepwise linear regression model was computed predicting the change in gait deviation index (GDI) from initial to follow-up gait analysis [3]. A constant model was initially assumed, with $p < 0.05$ for variable entry, and $p < 0.10$ for variable removal. Possible predictors were walk-DMC, initial GDI, age, prior surgery (yes/no), and treatment group (none, casting/botulinum toxin, single-level surgery, single-event multi-level surgery, rhizotomy).

RESULTS

The query returned 518 individuals. The final model ($r^2 = 0.31$) included initial GDI, walk-DMC, treatment group, and interaction between initial GDI and treatment group [Table 1]. The effect sizes for initial GDI and walk-DMC were similar in magnitude, but had opposite signs.

Table 1. Stepwise Linear Regression Results

	Variable	Estimate	SE	pValue
Main Effects	*Intercept*	-2.83	6.08	6.4E-01
	Initial GDI	-0.26	0.08	5.5E-04
	walk-DMC	0.27	0.05	3.7E-07
	Cast/Botulinum	5.00	13.15	7.0E-01
	Single-Level Surg.	12.86	10.06	2.0E-01
	Multi-Level Surg.	23.70	6.56	3.3E-04
	Rhizotomy	30.90	6.62	3.9E-06
Interactions	*Initial GDI x Cast/Botulinum*	-0.07	0.18	7.1E-01
	Initial GDI x Single-Level Surg	-0.17	0.14	2.3E-01
	Initial GDI x Multi-Level Surg	-0.27	0.09	3.9E-03
	Initial GDI x Rhizotomy	-0.39	0.09	2.9E-05

DISCUSSION

Dynamic motor control plays a significant and sizeable role in predicting gait outcomes. For example, among individuals undergoing single-event multi-level surgery, those with the highest walk-DMC improved nearly 12 GDI points more than those with the lowest walk-DMC.

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A NOVEL DEVICE FOR TESTING THE DYNAMIC PERFORMANCE OF IN SITU FORCE PLATES

R.H. East (1),

(1) Guy's Hospital, London, United Kingdom

INTRODUCTION and AIM

Confidence in the output of force plates is integral to gait analysis. Force plates are calibrated by manufacturers under different conditions to those relied upon clinically. The project created a system that could be used to dynamically calibrate force plates, in situ, against a theoretical solution; hence minimising the induction of error within the calibration process. The proposed solution involved the design and development of an eccentrically loaded wheel mounted on a weighted frame.

MATERIALS and METHODS

The frame was designed to hold a quick release Invacare wheel mounted in 2 orthogonal positions (Fig 1). Lead masses add weight so that the overall dynamics of the system better simulate that of paediatric gait. Castor wheels allow the device to be wheeled onto force plates and secured. The overall static weight of the system is 37.2kg.

The wheel is placed on the force plate and spun. A VICON motion analysis system captures the positional data of the markers placed around the rim of the wheel. A marker was placed on the eccentric mass at the rim; this marker defines the velocity of the mass and the direction of the centripetal force. Data were processed using Matlab (Fig 2). Force plate and centripetal force data were superimposed, and the RMS error calculated.

RESULTS

For nine trials conducted, the RMS error between the 2 simultaneous measures of force was calculated. The results are displayed in table 1. The difference between the force measurements in the x and y directions were under 1.5N. The difference in the z direction was under 5.5N.

DISCUSSION and CONCLUSIONS

The difference between the two force measurements is approximately 2% in each of the directions. It is difficult to assign the difference to an error in either measurement. The theoretical centripetal force calculation relies on the calibration of the VICON system; the cameras are calibrated to 0.01mm precision. The markers used were 14mm in diameter – 0.07% error. This error is then enhanced in the processing of the data. The force exerted by the mass is approximated by dividing the mass into finite elements and the force exerted by each element is calculated and then summed to calculate the centripetal force. A finer division of the mass may improve the precision of the measurement. However, these sources of error are considered insignificant in comparison to the error induced by the uncontrolled movement in the system

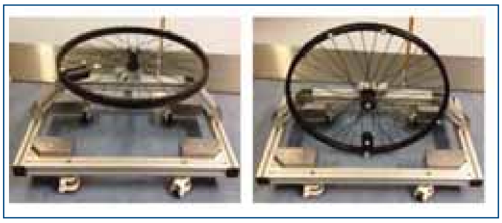

Fig 1: The device - showing both wheel orientations

	X direction RMS (N)	Y direction RMS (N)	Z direction RMS (N)
Mean	1.2925	1.2951	5.4915
s.d.	0.2052	0.1922	0.7341

Table 1: The average difference between the 2 forces measurements over 9 trials

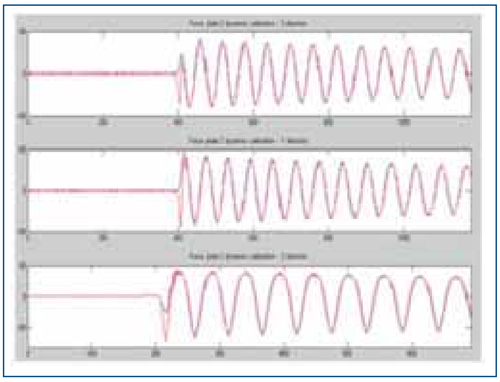

Fig 2: An example figure generated by the Matlab script for each of the x, y and z directions. The red line is the force plate data, the blue is the calculated centripetal force.

KINEMATIC DIFFERENCES EXIST BETWEEN TRANSTIBIAL AMPUTEE FALLERS AND NON-FALLERS DURING DOWNWARDS STEP TRANSITIONING

N. Vanicek (1), S. Strike (2), R.C.J. Polman (3)

(1) Department of Sport, Health & Exercise Science, University of Hull, Hull, United Kingdom
(2) Department of Life Sciences, University of Roehampton, London, United Kingdom
(3) Institute of Sport, Exercise and Active Living, Victoria University, Melbourne, Australia

Main topics: Prosthetics; Analysis of gait and motor disorders

INTRODUCTION and AIM

Falls that occur during stair negotiation are more likely to happen during stair descent than ascent and the consequences are often more severe. Compared to able-bodied individuals, transtibial amputees exhibit altered lower limb mechanics as a result of reduced joint mobility, muscle weakness, postural instability[1] and gait modifications that predispose them to falling[2]. There are few studies that have conducted biomechanical investigations of transtibial amputees transitioning downwards on steps and the mechanical adaptations they make during this complex task are not as well understood. Thus, the aim of this study was to compare the gait kinematics of transtibial amputee fallers and non-fallers transitioning downwards on steps.

PATIENTS/MATERIALS and METHODS

Eleven transtibial amputees were classified as either fallers (n=6; mean [SD] age: 56 [13] years; time since amputation: 3.5 [4.3] years) or non-fallers (n=5; mean [SD] age 57 [21] years; time since amputation: 10.6 [12.3] years). 3D kinematic data were measured while participants took two steps on the top platform and then descended a 3-step staircase and continued level walking. A total of 12 trials involving downwards step transitions at the top and bottom of the staircase were analysed. Nine of 11 participants exhibited an affected limb preference, which was subsequently selected as the lead limb for all participants. Two fallers and 2 non-fallers demonstrated a 'step to' descent strategy, stepping down only one step at a time. Each group was separated into those who used reciprocal vs. step-to descent strategies and group numbers were reduced. Thus, only descriptive statistics were used to compare groups according to falls history and descent strategy.

RESULTS

Of the participants using a reciprocal strategy, the fallers executed the downwards step transition with a mean (SD) velocity of 0.72 (±0.12) $m \cdot s^{-1}$ compared to the non-fallers at 0.50 (±0.06) $m \cdot s^{-1}$. Thus, the fallers walked 44% more quickly compared to the non-fallers. The step-to groups were markedly slower overall; the fallers transitioned downwards on the steps at 0.24 (±0.08) $m \cdot s^{-1}$, with the non-fallers at 0.34 (±0.10) $m \cdot s^{-1}$. The step-to fallers walked 66% more slowly than the fallers who used a reciprocal strategy. Using a reciprocal strategy, the fallers displayed full hip extension (0.7±2.9°), while the non-fallers showed almost 20° of flexion on the affected side when the foot transitioned onto the floor (Figure 1). Using a step-to strategy, the step-to fallers maintained the hip approximately 20° and 17° more flexed on the affected and intact sides, respectively, during stance compared to the reciprocal group. They also had a smaller hip ROM (31.7±3.0°) compared to the fallers with a reciprocal strategy (50.2±9.1°). The step-to group was more reliant on the handrails than the reciprocal group.

DISCUSSION and CONCLUSIONS

The fallers walked more than 0.2 m/s faster than previously reported[3]. Descending more quickly may imply higher functioning. However, in the absence of adequate lower limb musculoskeletal strength and flexibility, an amputee may in fact be placing themselves at risk of a prospective fall. The non-fallers showed a tendency to 'throw' their prosthetic foot down onto the next step compared to the fallers. This was evident with more hip flexion throughout swing, thus lifting the whole leg into the air for stair clearance. Similar observations were reported in transtibial amputees when crossing obstacles with their prosthesis as the lead limb[4]. Incorporating additional safety measures (handrails on the level walkway prior to the staircase) may help to improve dynamic control during downwards step transitions

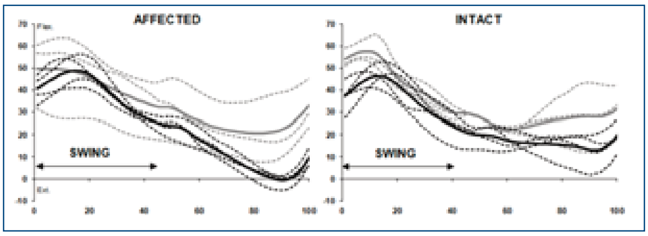

Figure 1 - Average hip joint kinematics (degrees) for the fallers (bold black line) and non-fallers (bold grey line) using a reciprocal stair descent strategy. Individual participant data are included for the fallers (dashed black line) and non-fallers (dashed grey line). The gait cycle is initiated and terminated with toe off.

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CLINICAL VALIDATION OF A NOVEL PROTOCOL FOR DYSTONIA ASSESSMENT USING MIMU SENSORS

A. Pisano (1), E. Palermo (2), L. Cantonetti (1), M. Petrarca (1), S. Rossi (3), S. Gazzellini (1), C.E. Marras (1), P. Cappa (1,2), E. Castelli (1)

Main topics: analysis of gait and motor disorders, movement deviation indexes.

(1) Department of Neuroscience and Neurorehabilitation, "Bambino Gesù" Children's Hospital, Rome, Italy
(2) Department of Mechanical and Aerospace Engineering, "Sapienza" University of Rome, Italy
(3) Department of Economics and Management – Industrial Engineering, University of Tuscia, Viterbo, Italy.

INTRODUCTION

Children with Generalized Dystonia (GD) have atypical muscle movements and abnormal muscle tone, these characteristics can range from mild to severe in children inducing postural control problems [1]. Status Dystonicus (SD) has been classified as "phasic" SD if dystonic movements were rapid and repetitive, "tonic" SD in case of abnormal dystonic posture and sustained contractions [2]. The assessment of the pathology severity is so far performed by means of rating scales that are affected by inter-rater repeatability error: especially for the evaluation of time intervals or joint angular ROMs [3]. We propose a new experimental protocol, based on Magnetic Inertial Measurement Unit sensors -MIMUs- (XBus Master MTx, Xsens Technologies, The Netherlands), for the assessment of dystonia severity in patients with GD. Kinematic data provided by MIMUs were processed to obtain 4 dystonia severity indexes. Therefore, we evaluated the clinical consistency of the proposed indexes, by comparing the results with the scores of the most adopted rating scales for dystonia.

METHODS

The study was conducted using a clinical protocol with the aim of evaluating the clinical and functional outcomes of 17 patients recruited to the trial. The clinical rating scales adopted were: FMRS, UDRS, GRS and BADS. MIMU protocol consisted in 2 sessions (2 trials each), differing for subject position: 1) lying on a table, 2) sitting on a chair. During the first trial we asked the subjects to stay still for 5 minutes. During the second one, we asked the subjects to reach an object with one hand at a time. MIMUs were positioned on 11 body segments, providing the angular velocity of 10 joints. During the static trials, we recorded the movement percentage, the normalized trajectory length of limbs and the sum of angular velocity RMSs for each joint. The moving interval percentage was defined as the total amount of time during which the joint angular velocity of at least one joint (in at least one plane) was higher than 0.1 rad/s. As far as the reaching trials are concerned we introduced the LAF (Limb Activation Focalization) to measure the involuntary activation of the joints not involved in the task.

RESULTS

We found a moderate to high correlation between scales and indexes for movement percentage and the LAF (Table 1). Normalized trajectory length showed lower correlation level, sometimes non-significant ($p>0.05$).

Table 1 – Correlation coefficients between MIMU indexes and rating scales. Significant coefficients are starred

Scale	Index									
	Lying					Sitting				
	MovPer	Traj	RMSTot	RLAF	LLAF	MovPer	Traj	RMSTot	RLAF	LLAF
FMRS	0,793*	0,475*	0,499*	-0,751*	-0,512*	0,802*	0,496	0,549*	-0,780*	-0,509*
UDRS	0,718*	0,479*	0,428	-0,780*	-0,675*	0,775*	0,496	0,476	-0,824*	-0,696*
GRS	0,730*	0,359	0,346	-0,733*	-0,666*	0,719*	0,383	0,388	-0,761*	-0,670*
BARS	0,733*	0,429	0,360	-0,767*	-0,625*	0,786*	0,468	0,437	-0,846*	-0,656*

DISCUSSION and CONCLUSIONS

The results obtained in the study encourage the use of MIMUs in the experimental protocol for dystonia assessment. A lower correlation was observed in Traj and RMSTot indexes, probably due to their intrinsic higher sensitivity to phasic movements with respect to tonic behavior. A future selection of patients features will be expected to elucidate this point. The device can be used in the pre-post pharmacological therapy or Deep Brain Stimulation follow-up. The characteristics of no limitation in workspace and the easy and robust positioning encourage the employment of MIMU sensors for bedridden and/or intensive care patients.

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IMMERSIVE VR PLATFORM FOR REAL TIME GAIT ANALYSIS

L. Piccinini (1), E. Biffi (1), C. Maghini (1) and A.C. Turconi (1)

(1) IRCCS E. Medea, Bosisio Parini (LC), Italy

Main topics: Movement analysis in clinical practice, Analysis of gait and motor disorders, Technical developments in movement science

INTRODUCTION and AIM

New platforms integrating treadmills and motion capture systems have emerged in the treatment of gait impairment. Treadmills have many advantages over typical overground labs such as the continuous collection of data within a small capture volume and the possibility of being integrated with Virtual Reality (VR) to provide visual cues, induce a real life sensation, and offer a safe and ecological environment where gait training can be executed by disabled subjects.

It has been demonstrated that there are differences between overground and treadmill walking [1] even if they can be reduced by adding optic flow by means of immersive VR environments [2,3]. However, in all those studies comparing overground and treadmill walking, too short habituation periods had been allowed, as suggested by [4]. Therefore the present study aims at examining gait parameters during treadmill walking in an immersive virtual environment after an appropriate familiarization period, and comparing them to overground walking data.

PATIENTS/MATERIALS and METHODS

10 healthy subjects performed a standard overground gait assessment (Elite, BTS Bioengineering, Italy) and a treadmill walking test (GRAIL, Gait Real-time Analysis Interactive Lab, Motek Medical BV, the Netherlands) over a split-belt instrumented treadmill in an optical flow matched virtual environment. After at least a six minute familiarization period, data of the two assessments were collected, analyzed and statistically compared. The research protocol was approved by the Ethical Committee of our Institute.

RESULTS

Spatio-temporal parameters, kinematics and kinetics computed during treadmill walking were comparable to data obtained during overground walking for all the subjects. Moreover, data analysis performed on the GRAIL system was time saving and easier than standard analysis.

DISCUSSION and CONCLUSIONS

Treadmill and overground gait must have similar outcomes such that practice on the treadmill can effectively transfer to performance overground. We observed that treadmill gait is similar to overground gait and that the novel GRAIL system has potentiality in reducing time required for data acquisition and elaboration.

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IMPROVEMENTS IN KNEE KINEMATICS DURING WALKING ARE CORRELATED WITH CHANGES IN PHYSICAL ACTIVITY AND USE OF TIME IN FREE LIVING CONDITIONS AFTER TOTAL KNEE ARTHROPLASTY

John Arnold[1], Shylie Mackintosh[2], Timothy Olds[3], Sara Jones[2], Dominic Thewlis[1, 4]

1. Biomechanics and Neuromotor Lab, Exercise for Health and Human Performance, Sansom Institute for Health Research, University of South Australia
2. International Centre for Allied Health Evidence (iCAHE), Sansom Institute for Health Research, University of South Australia, Adelaide, Australia
3. Health and Use of Time (HUT) Group, Sansom Institute for Health Research, University of South Australia, Adelaide, Australia
4. Centre for Orthopaedic and Trauma Research, University of Adelaide, Adelaide, Australia

Main topics: Rehabilitation, Outcomes after Clinical Intervention

INTRODUCTION and AIM

Total knee arthroplasty (TKA) is an effective procedure for improving knee-specific and general physical function [1]. However, there is little information on whether changes in knee biomechanics after surgery measured in the laboratory are related to changes in use of time and physical activity in free-living conditions. The aim of this study was to explore the associations between changes in knee biomechanics during walking, use of time in free-living conditions and symptoms after TKA.

PATIENTS/MATERIALS and METHODS

Fifteen participants with knee osteoarthritis who underwent TKA were tested before and six months after surgery (6M:9F, mean age 67.8 years SD 10.4, height 1.64 m SD 0.1, body mass 85.4 kg SD 15.1, BMI 31.8 SD 5.5). Walking gait kinematics and kinetics were collected at self-selected speed with 12 cameras (VICON MX-F20, Vicon, UK) and two Kistler force platforms (9281B) at 100 Hz and 400 Hz respectively. Data were exported to Visual3D for processing (v 4.0, C-motion Inc., USA). Joint angles were computed using the joint coordinate system method and external joint moments were computed using inverse dynamics (resolved in distal segment coordinate system). Use of time data were collected for each participant using the Multimedia Activity Recall for Children and Adults (MARCA) [2]. The MARCA was administered by telephone interview to record each participant's activities over a 24 hour period on 4 days pre and postoperatively. Each activity in the MARCA is associated with an energy expenditure, so that an overall estimate of daily energy expenditure can be determined, as well as the time spent doing specific activities. Knee symptoms were documented with the Western Ontario & McMaster Universities Osteoarthritis Index (WOMAC). Relationships between changes in sagittal plane knee kinematics and external joint moments, use of time data from the MARCA and the WOMAC subscales were evaluated with Pearson's correlation coefficients.

RESULTS

The change in sagittal plane knee range of motion (ROM) during walking was positively correlated with changes in total daily energy expenditure (r = 0.66, p = 0.008), time spent doing moderate to vigorous physical activity (MVPA) (r = 0.68, p = 0.005), inside chores (r = 0.59, p = 0.022) and time using passive transport (r = 0.66, p = 0.007). The change in peak knee flexion during swing phase was also positively correlated with change in time spent doing MVPA (r = 0.52, p = 0.047), inside chores (r = 0.52, p = 0.025) and time using passive transport (r = 0.53, p = 0.042). Changes in peak knee flexion and sagittal plane knee range of motion during loading response were positively correlated with the changes in the activities of daily living subscale (r = 0.62, p = 0.013 and r = 0.59, p = 0.021) and total WOMAC score (r = 0.61, p = 0.016 and r = 0.58, p = 0.024).

DISCUSSION and CONCLUSIONS

By combining gait analysis with a high resolution use of time instrument, this study demonstrated that improvements in knee ROM during walking measured in the laboratory are related to increases in physical activity and time spent travelling outside the home environment. Improvements in knee ROM were also related to improvements in symptoms. This underscores the importance of achieving a good functional knee ROM after TKA and provides objective evidence to support this common goal of surgery and rehabilitation for increasing post-operative physical activity.

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EVOLUTION OF VAULTING STRATEGY DURING TRANSFEMORAL AMPUTEE LOCOMOTION ON SLOPES AND CROSS-SLOPES COMPARED TO LEVEL WALKING.

C. Villa (1), X. Drevelle (2), X. Bonnet (3), I. Loiret (4), P. Fode (2), F. Lavaste (1,2), H. Pillet (1)

(1) Arts et Métiers ParisTech LBM, Paris, France
(2) INI CERAH, Woippy, France
(3) Proteor, Seurre, France
(4) IRR-UGECAM, Nancy, France

Main topics: Prosthetics, Analysis of clinical movement data, Analysis of gait and motors disorders

INTRODUCTION and AIM

Amputee people are fitted with prosthetic components restoring part of the missing joints functions. Particularly, during swing phase of gait, the prosthetic knee is mobile above the ground. In case of insufficient flexion of the prosthetic knee or inadequate timing of knee extension, the prosthetic foot can touch the ground during swing phase of the prosthetic side. Inclination and uneven surfaces increase the risks to stumble during this critical phase of gait. Vaulting is defined as a “premature midstance plantar flexion by the sound limb” which “assists toe clearance of the prosthetic limb by lifting the body” [1]. Even though potentially harmful, this strategy is often observed among transfemoral amputee people to secure prosthetic swing phase [2]. In clinics, the vaulting strategy is mainly evaluated in a qualitative way using visual assessment. The aim of the study is to provide a quantitative analysis of the evolution of the vaulting strategy in limiting situations of daily living.

PATIENTS/MATERIALS and METHODS

17 transfemoral amputee subjects and 17 control subjects participated in the study. A kinematic and kinetic gait analysis was performed with an optoelectronic system and force platforms for level walking, 10% inclined cross-slope walking, 5% and 12% inclined slope ascending [3]. To study vaulting strategy, the analyses are focused on identifying the presence of a generated power at the sound ankle at mid-stance and quantifying it in the different walking conditions [3]. In particular, values are compared to a vaulting criterion corresponding to a peak of generated power superior to 0.15W/kg. This criterion was defined according to the study [3] that gives a method to quantify vaulting of transfemoral amputee people during level walking.

RESULTS

Table 1 presents the peak of generated power for each patient in each situation. A larger proportion of amputee people overstepped the vaulting criterion during cross-slope walking and slope ascending than during level walking. In addition, magnitude of the peak of generated power increased significantly compared to level walking in these situations.

DISCUSSION and CONCLUSIONS

Identification and quantification of peak of generated power at the sound ankle during prosthetic swing phase showed that vaulting seems to be widely used by transfemoral amputee patients. Number of related patients to vaulting increased with the difficulty of the walking condition. In addition, results suggested that transfemoral amputee patients could dose the amount of vaulting to ensure toe clearance according to the gait environment. Vaulting correction on level surfaces in rehabilitation seems not preventing vaulting on other daily living tasks.

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Table 1 : Peak of generated power for each patient in all situations (grey box = vaulting criterion overstepped, -=missing data).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Vaulting criterion
Flat surface	0.50	0.63	0.43	-0.27	0.00	0.09	-0.05	0.15	-0.09	0.03	0.06	0.27	0.66	0.32	0.93	-0.02	0.26	≥0.15
Cross-slopes (downstream)	-	-	0.52	-0.40	-0.20	-0.03	0.01	0.31	0.26	0.31	0.11	0.68	1.18	0.74	1.29	-0.10	0.60	≥0.15
Ramp 5% (ascent)	0.62	0.90	-	-0.10	0.08	-0.01	0.06	0.33	0.33	0.15	-0.01	0.39	-	0.75	1.36	0.00	0.74	≥0.15
Ramp 12% (ascent)	1.55	1.45	0.49	-	-	0.02	-	0.22	1.43	0.59	0.03	1.37	1.46	0.84	1.79	-	1.13	≥0.15

KINEMATIC GAIT PATTERN IN CHILDREN WITH CEREBRAL PALSY AND LEG LENGTH DISCREPANCY - EFFECT OF AN EXTRA SOLE

MN Eek (1), R Zugner (2), I Stefansdottir (1), R Tranberg (2)

(1) Regional rehabilitation centre, Queen Silvia Children's hospital, Gothenburg, Sweden
(2) Department of Orthopedics, Institute of Clinical Sciences, Sahlgrenska Academy, Gothenburg, Sweden

INTRODUCTION and AIM

Leg length discrepancy is common in children with cerebral palsy (CP), especially where one side is more involved. The aim was to examine the influence on gait pattern and the effect of an extra sole.

PATIENTS/MATERIALS and METHODS

Ten children with spastic CP, 7-14 years old, at GMFCS level I-II, and 10 typically developing (TD) children in the same ages. The children with CP had a leg length discrepancy of 1.7 cm (SD 0.7).
A 3D gait analysis (Oqus ProReflex, Qualisys, Sweden) was performed barefoot, with shoes and with shoes and an extra sole on the short side.
Graphs from hip, knee and ankle were analysed visually and 6 variables were chosen for statistical analysis; hip flexion at loading response (LR), hip abduction at LR, knee extension in stance, knee flexion in swing, ankle at IC and ankle dorsiflexion in stance.

RESULTS

Barefoot the children with CP showed an asymmetric gait pattern with differences between the long and the short leg at all levels ($p<0.05$). The long leg was more flexed in hip, knee and ankle, and the short leg showed a lack of dorsiflexion at IC, the difference varied 5-9º. The gait pattern differed significantly from TD children, also visible in the GDI-score, where values for the children with CP were below normal, more pronounced in the long leg. With shoes+extra sole the gait pattern became more symmetric, the only difference left was at ankle IC.
For TD children the introduction of leg length discrepancy led to an asymmetric gait pattern with differences in hip adduction at LR, knee flexion in swing and ankle dorsiflexion in stance.

DISCUSSION

As the difference in hip and knee flexion for children with CP disappeared with the extra sole, it can be interpreted as compensation for leg length discrepancy.
The pattern of compensation differed between groups, the children with CP flexed the long leg at all levels, while the TD children used abd/add in the hip.

CONCLUSION

An extra sole is an easy way to create a more symmetric kinematic gait pattern in children with CP and leg length discrepancy.

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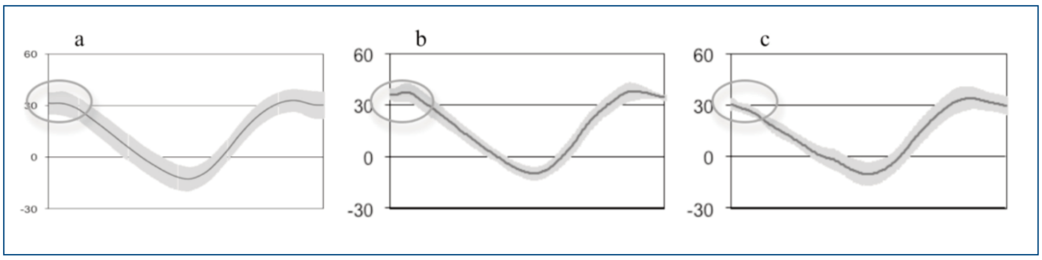

Figure. Hip flex-ext barefoot; a) TD, b) CP long leg, c) CP short leg

ANALYSIS OF THE COEFFICIENT OF FRICTION DURING THE PARKINSON GAIT.

AFR Kleiner (1,2,3), M Galli (3,4), P. Sale (4), F.Stocchi (4), M. Franceschini (4), G. Albertini (4), RML Barros (1)

(1) Laboratory of Instrumentation for Biomechanics, Faculty of Physical Education, University of Campinas, Campinas, Brazil.
(2) CAPES Foundation, Ministry of Education of Brazil, Brasília, Brazil.
(3) "Luigi Divieti" Posture and Movement Analysis Laboratory, Department of Electronics, Information and Bioengineering, Politecnico di Milano, Milano, Italy.
(4) "Motion analysis Lab", IRCCS San Raffaele Pisana, Rome, Italy.

Main topics: Gait, Parkinson, Ground Reaction Forces, Coefficient of Friction.

INTRODUCTION and AIM

Falls are not a new problem in Parkinson's disease. The causes of falling are multifactorial and can be due to individual limitations, environmental conditions and/or the interaction of both effects. The traction that an individual requires from the surface during walking is named Coefficient of Friction (COF). The COF is one of the most critical gait parameters in predicting risk of slipping[1,2]. The probability of a slip raises when either the friction that an individual utilizes increases or the available friction from the floor surface decreases[2]. The relationship between available friction and COF is an effective way of evaluating the interaction between intrinsic and extrinsic factors, giving a reliable estimate of the risk of slipping[1]. So, this study aiming to characterize the COF curves of Parkinson patients during the barefoot gait.

PATIENTS/MATERIALS and METHODS

Forty two volunteers participated in this study, being 21 patients with Parkinson and 21 age-matched healthy subjects as a control group. The participant was oriented to walk barefoot, at him/her self selected speed, along the pathway and over two force platforms, embedded in the data collection room floor. The force plates' ground reaction force data were normalized by the subject body weight and expressed in function of the percent of support phase (SP). Kinetic raw data were filtered using a 2nd order low-pass digital Butterworth filter, with a cut-off frequency of 10 Hz. The COF curve was calculated as the ratio of the shear to normal ground reaction force (GRF) during stance[1,2] - Equation 1. Where FY is the anterior-posterior GRF, FX is the lateral GRF and FZ is the vertical GRF. Comparisons between the Parkinson and Control group were made by applying the two sample T-test ($\alpha \leq 0.05$) applied to every 1% of gait cycle comparing both groups.

$$COF = \frac{\sqrt{(FY)^2+(FX)^2}}{FZ} \qquad (1)$$

RESULTS

The COF curves analysis highlight three phases during the SP where the Parkinson's patients presented alterations compared to the control group: 1st during the loading response (10% to 31% of the SP); 2nd during the midstance (45% to 71% of the SP), and; 3rd during the terminal stance (82% to 95% of the SP).

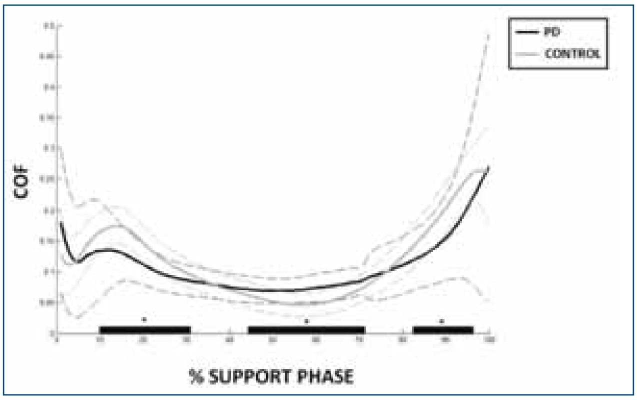

Figure 1. Mean and standard deviation of COF curve of the Parkinson Group (black solid line – mean, and black dashed line - standard deviation) and Control Group (grey line – mean, and grey dashed line - standard deviation. The bars and asterisks on the x-axes indicate the moments of the support phase that presented significant differences ($P \leq 0.05$) between the PD and Control Group curves. Legend: PD = Parkinson Desease; Control = Control Group; %SUPPORT PHASE = normalized by the percentage of the support phase.

DISCUSSION and CONCLUSIONS

Compared to control group, the PD patients presented lower COF at the loading response and terminal stance. This behavior can be explained due to the slow parkinsonian motion pattern and it is probably related to the need of increasing the safety margins. At midstance, PD patients presented higher COF than control group subjects. Considering that the coefficient of rolling resistance is generally much smaller than the coefficient of sliding friction, this result suggests that the parkinsonian gait presents a less efficient rolling mechanism at midstance. In conclusion, the proposed approach of observing the COF during gait revealed a compromise between loss of efficiency in favour of safety in the parkinsonian gait.

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DESIGN AND CONSTRUCTION OF A PATIENT-SPECIFIC 3D-PRINTED WRIST SPLINT WHICH INDUCES MOVEMENT IN THE DART THROWING MOTION PLANE

Sigal Portnoy,[1] Yael Kaufman-Cohen, [1] Andrey Sayapin,[2] Gal Yaacoby,[1] Noa Doron, [1] Yafa Levanon[1]
[1]Department of Occupational Therapy, Tel Aviv University, Tel Aviv, Israel, [2]Afeka College of Engineering, Tel Aviv, Israel

INTRODUCTION and AIMS: Dynamic wrist splinting following distal radius fracture enables extension and flexion exercises that increase passive range of motion, reduce joint stiffness and shorten rehabilitation duration. However, the majority of our daily-life activities involve a combined wrist movement that is basically movement of radial-extension to ulnar-flexion. This movement is termed dart throwing movement (DTM). It has been hypothesized that early activation of the wrist in the DTM plane following distal radius fracture will accelerate the recovery of the patient and enable him or her improved functionality. We therefore aim to characterize the DTM plane in the wrist bilaterally during daily activities and use these data to design patient-specific 3D-printed wrist splint which induces movement in the DTM plane.

METHODS: A telemetric twin-axis electro-goniometer (Myon, Switzerland) was attached to the wrists of 20 healthy subjects (Fig. 1) who were asked to perform 12 activities of daily living, e.g. answer a phone, open and close a jar, and so on. The DTM plane was calculated from the recorded wrist motion data (Fig. 1).
In order to create a patient-specific splint, the arm and hand of the subject was 3D scanned (Fig. 2) and data were imported into SolidWorks 2013. The splint design comprise of a proximal envelope of the arm and a distal envelope of the palm. An axle with two wheels is attached to the proximal part and two wires attach from it to the medial and lateral aspects of the distal part so that when the wrist flexes one wire is released and the other is strained towards the ulna and when the wrist extends, the later wire is released and the former one is strained towards the radius (Fig. 2).

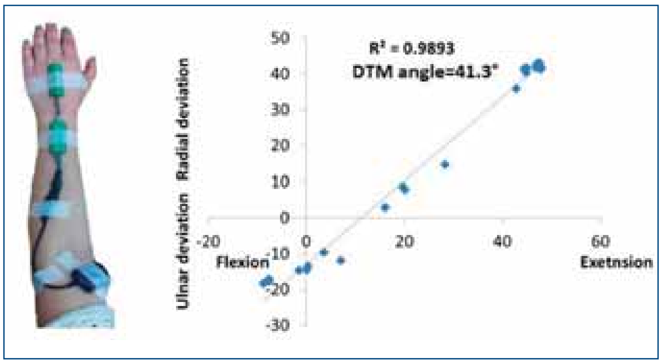

Figure 1: The electro-goniometer placed on the wrist (left frame) and an example of the wrist angles and DTM plane angle which resulted from a trial.

Figure 2: 3D scan of the hand and arm (left) and partial schematics of the DTM splint

RESULTS: The angle of the DTM planes was quantified for the dominant and non-dominant wrist and the DTM splint was 3D printed.

CONCLUSIONS: The design of this splint is the first step towards assessing whether DTM splinting is beneficial to the rehabilitation of persons following distal radius fracture. We are continuing with RCT of these patients to test this hypothesis.

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CHILDREN WITH SPASTIC HEMIPLEGIA AND BILATERAL INVOLVEMENT: DO THEY REQUIRE UNI OR BILATERAL MANAGEMENT?

H. Böhm(1), M. Armbruster(1), M. Hösl(1), L.Döderlein (1),
(1) Orthopaedic Hospital for Children, Aschau im Chiemgau, Germany

INTRODUCTION and AIM

Categorization of cerebral palsy in uni and bilateral involvement has shown good reliability [1]. However the distinction can still be blurred since many children with unilateral CP may also have some degree of motor deficits on the opposite side. Therefore, it is not clear if they have to be classified and treated as uni or bilateral CP [2]. The aim was to describe gait patterns in hemiplegics with bilateral involvement of the lower extremity and compare them to children who exclusively show uni and bilateral involvement.

PATIENTS/MATERIALS and METHODS

In a retrospective study 107 children (6-12 years) with spastic cerebral palsy GMFCS I & II without previous surgeries were included. 43 children had bilateral (BSCP) and 42 children had unilateral (USCP) involvement. 22 children had hemiplegia and mild bilateral involvement (UBSCP). Bilateral involvement was defined by higher muscle tone in the contralateral leg through clinical examination. All patients underwent a 3D gait analysis followed by a clinical exam. The gait pattern of UBSCP and USCP were classified into 4 types according to Winters [3] for unilateral involvement (1. foot drop, 2. equinus, 3. knee and 4. hip involvement). The gait profile score (GPS) [4] was evaluated to answer the main question with an ANOVA of two factors: group (BSCP, UBSCP, USCP) x leg (Involved, less involved or healthy). In addition the movement analysis profile (MAP) over the 9 different joint curves included in the GPS was analyzed to discuss the results.

RESULTS

The classification for unilateral patients showed that 76% of UBSCP were type 3 and 4, whereas in USCP it was only 37%. The number of patients with GMFCS I in each group was 66%, 18% and 77% for BSCP, UBSCP and USCP respectively. The GPS showed significant group and leg differences both $p<0.001$ without interaction effect ($p=0.07$). Post-hoc t-tests revealed significant differences for USCP and BSCP on both legs ($p<0.001$), the difference between UBCP was only significant with respect to USCP on the involved ($p=0.005$) and the uninvolved or less involved side ($p=0.017$). Detailed analysis of joint kinematics in the MAP showed that differences exist in the knee and pelvis flexion-extension angles that were significantly more flexed in BSCP and UBSCP than in USCP.

DISCUSSION and CONCLUSIONS

Summarized UBSCP children had more severe gait deviations including the knee and hip joints that is in accordance with the observed higher GMFCS level in that group. The GPS score in UBSCP showed only significant alterations between unilateral but not between bilateral children. Therefore we suggest that for UBSCP patients the bilateral classification is appropriate, and treatment of pathologies on both sides must be considered. For clinicians presented with patients documented as hemiplegia, it might be helpful to notice that unilateral patients with involvement of the knee and hip are more likely to have involvement of the opposite side. In these patients it is recommended to carefully examine also the presumed uninvolved side.

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CLASSIFICATION OF GAIT PATTERN IN STROKE PATIENTS TO OPTIMISE ORTHOTIC TREATMENT AND INTERDISCIPLINARY COMMUNICATION

D. Sabbagh (1), J. Fior (1), R. Gentz (1)

(1) Fior & Gentz Gesellschaft für Entwicklung und Vertrieb von orthopädietechnischen Systemen mbH, Lüneburg, Germany

Main topics: Analysis of gait and motor disorders, outcomes after clinical intervention, rehabilitation, orthotics.

INTRODUCTION and AIM

The goal of an orthotic treatment of stroke patients is the best possible approach towards physiological gait. In order for the intervention to work in the best way, the orthopaedic technician has to consider the individual biomechanic situation of the patient. With the N.A.P. Gait Classification, patients viewed laterally can be divided into gait types (GTs) with hyperextended and hyperflexed knee [1]. For both GTs, different requirements have to be met by an orthosis (AFO) [2]. The following examination deals with the influence of a dynamic adjustable AFO on the joint kinematics of both GTs.

PATIENTS/MATERIALS and METHODS

8 patients with prior stroke were treated with an adjustable AFO. According to the N.A.P. Gait Classification GT 1a (hyperextension, inversion; n=5) and GT 2a (hyperflexion, inversion; n=3) can be identified. The AFOs for both GTs have a high ventral shell, a long partially flexible foot piece and an adjustable ankle joint with a very strong ventral spring. Additionally, GT 1a has a very strong and GT 2a a medium dorsal spring. Then AFOs are tuned. All patients performed a gait analysis with standardised footwear. Per patient, three gait cycles of the affected side were filmed each with and without AFO. The angle movements of hip (HA), knee (KA), ankle (AA), tibia inclination (TI) and heel contact (HC) were recorded. In mid stance (12 to 31% of the gait cycle), both GTs were tested separately with a Wilcoxon rank-sum test for differences between the conditions “with AFO” and “without AFO”.

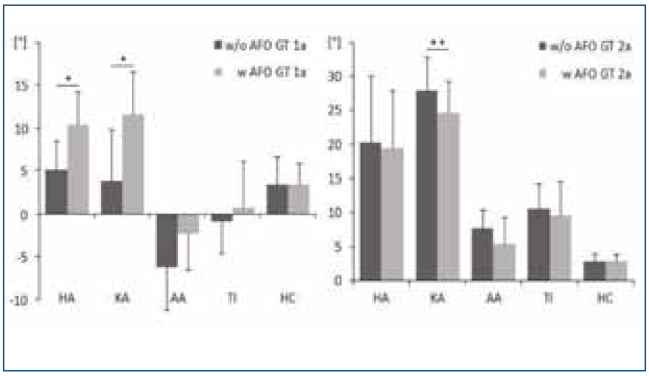

Figure 1: Joint angle [°] in mid stance with AFO and without AFO at a) GT 1a hyperextension and b) GT 2a hyperflexion. Valid is * p=0.05 and ** p=0.01

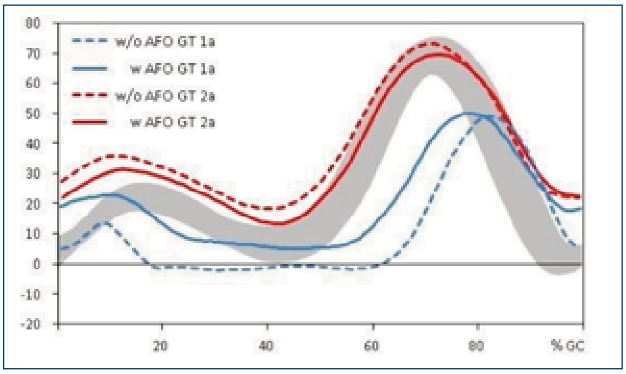

Figure 2: Movements of knee angle [°] at GT 1a hyperextension (blue), GT 2a hyperflexion (red), each with and without AFO as well as physiological gait (gray).

RESULTS

Patients with GT 1a (fig. 1a) show a significantly higher HA (p=0.041) and KA (p=0.039) when walking “with AFO”. In mid stance the KA of GT 2a (fig. 1b) is significantly lower (p=0.002) during gait “with AFO”, than when walking “without AFO”.

DISCUSSION and CONCLUSIONS

The AFOs adjusted to the patient’s individual gait lead to an increase of the KA in mid stance at GT 1a and to a decrease at GT 2a. Therefore, the variable resistance of the used springs has a decisive influence on the gait at lateral level [3]. The KA of both GTs bring the patient closer to a physiological gait (fig. 2). The N.A.P. Gait Classification is the optimal method to identify the gait type fast and unambiguously during the orthotic treatment of stroke patients. With more subjects, differences in the other angle movements could be proved.

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CORRELATION BETWEEN PREOPERATIVE PARASPINAL MUSCLE STATUS AND SEVERITY OF DEGENERATIVE FLAT BLACK AND DEGREE OF IMPROVEMENT AFTER CORRECTIVE FUSION SURGERY

JH Lee(1), SH Lee(2)

(1) Dep. of physical medicine and rehabilitation, Wooridul spine hospital, Seoul, Rep of Korea
(2) Dep. of Neurosurgery, Wooridul spine hospital, Seoul, Rep of Korea

INTRODUCTION and AIM : Degenerative flat back(DFB) is characterized by sagittal imbalance resulting from a loss of lumbar lordosis and, consequently and lead to difficulty in walking with stooped trunk and other daily activity. Although the exact pathophysiology of DFB has not yet been established, extensive degeneration and weakness of lumbar paraspinal muscle are thought to be main cause of DFB. It is assumed to be clinically useful to assess the relationship between paraspinal muscles condition and severity of DFB and its surgical outcomes. The purpose of this study was to evaluate correlation between preoperative paraspinal muscle condition on magnetic resonance image(MRI) and angular severity of DFB and also to evaluate correlation between preoperative paraspinal muscle condition and degree of improvement of DFB obtained by corrective fusion surgery, in terms of static parameters by simple radiography and dynamic parameters by three dimensional motion analysis

PATIENTS/MATERIALS and METHODS : Forty-five patients with DFB were included who took MRI preoperatively and conducted whole spine X-ray and three dimensional motion analysis before and 6 month after corrective surgery. To determine the severity of back muscle atrophy, the cross sectional areas(CSA) of the paraspinal muscle and disc were measured from L1-2 to L4-5 level in MRI and the ratio between CSA of the paraspinal muscle and disc was calculated. The signal intensity of paraspinal muscle was additionally measured to assess the degree of fat infiltration.(Fig.1) As static parameters, thoracic kyphosis (TK), thoracolumbar junction(TLJ), and lumbar lordosis(LL), pelvic incidence (PI), sacral slope(SS), and pelvic tilt(PT) were measured. As dynamic parameters, maximal and minimal angle of posterior pelvic tilt, lower limb joints, and thoracic and lumbar vertebrae column(dynamic TK and LL) in sagittal plane were obtained. The correlation was investigated between preoperative paraspinal measurement and static/dynamic parameters and between preoperative paraspinal measurement and improvement of static/dynamic parameters obtained by corrective surgery

RESULTS : In static parameters, thoracic and thoracolumbar angle were more kyphotic, as atrophy and fat infiltration of paraspinal muscle were more severe,. After surgery, less improvement of thoracic kyphosis was accomplished, as L1-2 and L2-3 paraspinal muscle atrophy were more severe on preoperative MRI. In dynamic parameters, increased thoracic kyphotic angle showed correlation with severe atrophy or fat infiltration of upper lumbar paraspinal muscle, whereas, decreased lumbar lordotic angle had correlation with severe atrophy or fat infiltration of middle to lower lumbar paraspinal muscle. After surgery, thoracic kyphosis was less improved, as atrophy of preoperative upper parapinal muscle were more severe. Less improvement of lumbar lordosis was related to severity of atrophy and fat infiltration of more extensive lumbar paraspinal muscle from L1-2 to L4-5 levels. In lower limb dynamic parameters, increased posterior pelvic tilt angle, hip and knee flexion angle or ankle dorsiflexion angle was sometimes associated with lumbar muscle atrophy and fat infiltration. After surgery, improvement of hip flexion angle was decreased as lumbar paraspinal muscular atrophy was more severe, whereas, no significant correlation was found between other limb joints and paraspinal muscle condition.

DISCUSSION and CONCLUSIONS : The severe atrophy or fat infiltration of lumbar paraspinal muscles was related to severe angular deformity in patients with DFB and to less improvement after corrective surgery in terms of static as well as dynamic parameters.

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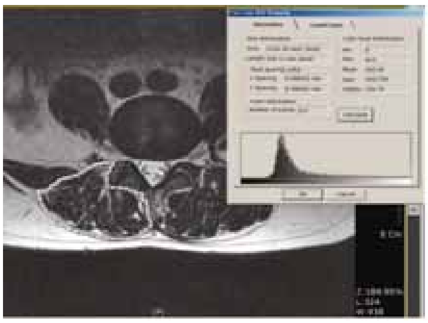

Fig.1.

JOINT LOADING DURING GRADED WALKING WITH DIFFERENT PROSTHESES – A CASE STUDY

N. Alexander, G. Strutzenberger, J. Kroell, J. Christian, T. Wunsch, H. Schwameder

University of Salzburg, Department of Sport Science and Kinesiology, Hallein, Austria

Main topics: prosthetics, analysis of gait and motor disorders, musculoskeletal modelling

INTRODUCTION and AIM

In public areas ramps are built with an inclination up to a maximum of 6% (3.4°) and are a challenge to be met in daily living. For lower limb amputees graded walking imposes even a higher level of motor ability than level walking. This is due to the missing proprioceptive feedback of the limb, as well as the characteristics of the prosthesis forcing the amputee to certain compensation mechanisms [1, 2]. Several studies investigated graded walking in able-bodied participants, however, little is evident about the compensation mechanisms of lower limb amputees during this movement task [1]. In order to facilitate gait a focus in prosthesis research is the advanced development of the prostheses ankle joints from rigid to moveable. First studies showed promising results [3], but the influence of different inclinations was hardly analysed so far [4]. Therefore, the aim of this case study was to analyse the effects of three different prostheses with a rigid and a moveable ankle joint during graded walking of a unilateral amputee on gait parameters, ground reaction forces as well as lower extremity joint angles and moments.

PATIENTS/MATERIALS and METHODS

One male unilateral transfemoral amputee was recruited for this study and a comparison of following three prostheses (endolite, Germany) was performed: Elan (EL): movable ankle joint with flexible resistance, Echelon (EC): movable ankle joint with steady resistance and Esprit (ES): rigid ankle joint. The flexible resistance in the moveable ankle joint of EL is supposed to adapt to different inclinations and therefore facilitate graded walking for amputees. A 6m ramp, which had two force plates (AMTI, MA, 1000 Hz) imbedded in the middle of the walkway, was set to the inclinations of -12°, -4°, 0°, 4° and 12°. Kinematic data was recorded with a twelve-camera, marker based motion capture system (Vicon, UK, 250 Hz). For each inclination 5 trials with self-selected walking speed were recorded. After time normalization over the stance phase the following variables were calculated: gait parameters, ground reaction forces, joint angles and joint moments.

RESULTS

Gait parameters (stance time, step length, step width, stride length and stride frequency) changed with respect to inclination, but were not affected by the different ankle joint designs. In general, higher anterior-posterior forces occurred on the non-affected limb compared to the prosthetic limb. Minor differences between different prosthesis-types were found in ground reaction forces and joint angles. More pronounced effects were demonstrated in the knee and hip joint moments for the rigid ankle joint prosthesis (ES). In the knee of the non-affected limb maximum joint extension moments were 6-78% higher when using ES compared to EL, while maximum joint flexion moments were lower except for one condition. In the hip joint of the prosthetic limb maximum joint extension and flexion moments were higher using ES compared to EL. While only up to 40% higher joint flexion moments occurred, extension moments were up to 10 times higher (Figure 1). In the hip joint of the non-affected limb similar or lower moments were found compared to EL. In most conditions the joint moments when using EC were higher compared to EL and lower than ES.

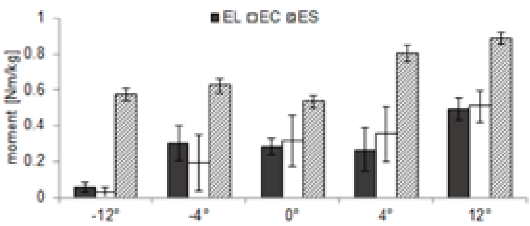

Figure 1: Maximum hip extension moments of the prosthetic limb.

DISCUSSION and CONCLUSIONS

Gait parameters, ground reaction forces and joint angles were marginally influenced by the different prosthetic designs, but major changes occurred on the joint moment level. The use of the rigid ankle prosthesis ES induced up to 10 times higher joint moments compared to the moveable ankle joint prostheses. This case study showed that a moveable ankle joint can reduce the joint moments during graded walking, which might be advantageous to use for transfemoral amputees in graded walking.

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INFLUENCE OF ALTERED GAIT KINEMATICS ON THE RISK OF EDGE LOADING IN THE HIP

Mariska Wesseling (1), Friedl de Groote (1), Christophe Meyer (1,2), Kristoff Corten (3), Jean-Pierre Simon (2), Kaat Desloovere (1,2), Ilse Jonkers (1)

(1) KU Leuven, Belgium
(2) University Hospital Pellenberg, Belgium
(3) Hospital Oost-Limburg, Genk

Main topics: musculoskeletal modelling, musculoskeletal imaging, orthopaedics

INTRODUCTION and AIM

Alterations in gait have been reported in patients before and after hip replacement. They have been linked to changes in magnitude and orientation of hip contact force (HCF) [1]. Furthermore, edge loading has been shown to depend on gait kinematics in patients after hip resurfacing arthroplasty [2]. However, the effect of changing specific kinematics on the risk of edge loading is unknown. Therefore this study investigated the effect of hip kinematics on the orientation of HCFs and the risk of edge loading using muscle driven simulations of gait.

PATIENTS/MATERIALS and METHODS

One gait cycle at self-selected speed was simulated for five subjects (56±3 yrs., BMI 22.3±1.59). 3D marker trajectories were captured using Vicon (Oxford Metrics, UK) and force data was recorded using two AMTI force platforms (Watertown, MA). The musculoskeletal model consisted of 12 segments, 19 degrees of freedom and 92 musculotendon actuators [3]. All analyses were performed in OpenSim 3.1 [3]. The model was first scaled using the marker trajectories of a static pose. An inverse kinematics procedure calculated the kinematics. Using this kinematic solution as a reference, the hip adduction, flexion and rotation as well as the pelvis obliquity were perturbed by ±5°. Also a combination of decreased hip adduction together with increased pelvis obliquity, i.e. a Trendelenburg gait, has been simulated. The point of force application was defined in the local reference frame of the foot to allow it to vary with hip position. Next, for all simulations, a residual reduction algorithm (RRA) was used to improve the dynamic consistency of the simulation. A static optimization procedure was used to calculate muscle forces after which HCFs were calculated. To define edge loading, an acetabular cup with a coverage angle of 170° was assumed to be placed within Liwinnek's safe zone [4]. Four different cup positions were taken into account, coinciding with the extremes of the safe zone (inclination angle of 30° and 50° and anteversion angle of 5° and 25°). To determine the risk of edge loading, the angle between the edge of the cup and the HCF vector (HCF-edge angle) was reported [2] as well as the first and second peak in HCF.

RESULTS

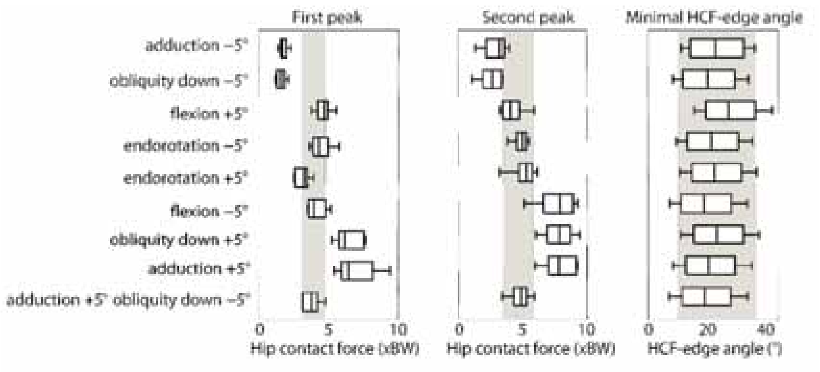

Figure 1. The range of resultant hip contact forces at the first and second peak in contact force (resp. left and middle) and the minimal HCF-edge angle (right) during gait. A decreased HCF-edge angle indicates an increased risk of edge loading. The grey zones indicate the range of nominal values. A Trendelenburg gait is simulated by increasing hip adduction and decreasing pelvis obliquity down (bottom row).

DISCUSSION and CONCLUSIONS

Decreased hip adduction results in decreased HCFs at both peaks (figure 1). With increased pelvis obliquity down, similar results are found, however the risk of edge loading increases as reflected in the decreased HCF-edge angle. For a Trendelenburg gait, HCFs are similar to nominal, but the risk of edge loading increases. With increased hip flexion, risk of edge loading is decreased. These findings suggest that changes in kinematics can have an influence on the risk of edge loading. Rehabilitation exercises focussing on correction of Trendelenburg and hip flexion contractures are found to be key in optimizing hip loading and preventing edge loading.

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USE OF THE OS-STRETCH TO PROVIDE A PROGRESSIVE STRETCH IN STANDING TO THE CALF MUSCLES IN IDEOPATHIC TOE WALKERS AND CHILDREN WITH CEREBRAL PALSY

SE Jarvis (1), C Stewart (1), N Postans (1), A Roberts (1)

(1) ORLAU, RJAH Orthopaedic Hospital, Oswestry, UK

Main topics: Analysis of clinical movement data, Reliability and service development

INTRODUCTION and AIM

ORLAU frequently supplies an angled board for patients to stand on, to help provide a stretch to the calf muscles. A motorised version of this 'Os-Stretch' has been designed to investigate the effects of a slow dynamic stretch to the calf when standing barefoot. The response of subject may help to determine the tilt of the angle board to be supplied. The aim is to achieve an optimal ankle stretch without causing abnormal postures in the trunk, leg or foot that might be detrimental to the patient.

PATIENTS/MATERIALS and METHODS

The Os-Stretch provided a tilting platform for the patient to stand on, hence moving the patient's ankle slowly through a 20 degree range. While each subject stood on the device 3D data and EMG (not reported here) were collected to quantify any changes in posture or muscle activity. A group of 5 normal subjects (aged between 6 and 16), 3 children with cerebral palsy diplegia (CP) and 2 idiopathic toe walkers (ITW) stood on the Os-Stretch as it moved through its range. This was repeated 3 times with a five minute break between movements. Data were collected from a 3D marker set (Plug-in-Gait) including an Oxford Foot Model and additional trunk markers.

RESULTS

Initial results are shown below. The range of motion for joint and segment angles was calculated as the difference between mean of the first 10% and final 10% of the movement.

Table 1: Mean range of motion in degrees for the 3 trials of each subject as the Os-Stretch angle was increased

Range of Motion	*N1*	*N2*	*N3*	*N4*	*N5*	*ITW1*	*ITW2*	*CP1*	*CP2*	*CP3*
Anterior Trunk Lean	12.4	8.2	17.0	8.2	19.7	28.5	19.0	0.8	6.2	24.0
Anterior Pelvic Tilt	4.4	6.8	11.0	-0.1	6.6	13.3	8.3	2.2	2.5	2.8
Hip Flexion	9.9	9.2	15.0	5.8	14.4	15.0	11.6	1.8	4.7	15.9
Knee Flexion	8.1	5.0	1.6	10.4	15.0	-9.3	0.8	-1.6	-7.2	0.2
Ankle Dorsiflexion	26.5	24.3	18.5	22.8	26.8	4.8	18.8	15.3	0.3	0.2
Midfoot Dorsiflexion	5.6	1.6	1.2	2.3	1.8	1.8	4.3	7.9	1.5	-2.0
Hindfoot Varus	5.0	6.1	2.6	1.5	-0.4	0.7	2.2	-0.3	2.0	1.1
Posterior Shank Lean	-2.7	-2.4	2.7	-4.3	-6.9	10.8	2.8	0.8	8.9	12.9

DISCUSSION and CONCLUSIONS

Initial results from this small group show some interesting differences between the normal subjects and the patient groups. It appears that the children with CP have greater difficulty in using pelvic tilt as a means of controlling their posture during the stretch than the normal subjects. Only subject N4 does not increase their anterior pelvic tilt. The ITWs use a combination of anterior tilt and anterior trunk lean to adjust their balance.

The normal subjects tend to use a variable amount of knee flexion during the stretch whereas, in the patient group, the knee either moves into extension (ITW1, CP1, and CP2) or remains still. Increasing extension may not be a detrimental feature of using the Os-Stretch if there is a knee flexion contracture. The patient groups also showed a variable amount of posterior shank lean whereas the normal subjects (except N3) anteriorly inclined the shank.

The ankle dorsiflexion movement is greater than the 20 degree moved by the Os-Stretch in 4 of the 5 normal subjects. Only subject, N1, shows clear movement in the midfoot. In the patient groups the ankle range was less than 20 degrees and in 2 subjects (ITW1 and CP1) there was some evidence of a midfoot break. In the patient groups there was no evidence of an increase in hindfoot valgus as the calf was stretched.

Early results appear to show that CP3 might benefit most from use of an angled board for stretching the calf as the knee is not moving into hyperextension and there is no evidence of a midfoot break during the stretch.

Initial results show that the Os-Stretch is able to discriminate between different responses to a dynamic calf stretch in standing. Further patient testing is planned and the results will hopefully clarify which of the above factors is the most important when considering stretching the calf in standing.

MOTOR CONTROL INDEXES IN REHABILITATION: EFFECT OF THE SAMPLING FREQUENCY

A.Scano (1), **M.Caimmi(1), M.Malosio(1), L.Molinari Tosatti(1)**

(1) Council of National Research (CNR), Institute of Industrial Technologies and Automation (ITIA)

Main topics: Analysis of clinical movement data, Motor control and motor learning, Rehabilitation, Stroke

INTRODUCTION and AIM

Normalized Jerk (NJ) and Coefficient of Periodicity (CP) are motor control, kinematics-based, sampling frequency-dependant performance indexes used to evaluate neuro-motor rehabilitation tasks [1]. In clinics, NJ and CP can be calculated with marker-based systems, that record kinematics at high sampling frequency. With the aim of evaluating motor performances at home with a Kinect sensor, the effect of the change in sampling frequency on NJ and CP was investigated during the execution of reaching movements against gravitary.

MATERIALS and METHODS

Subjects: Five healthy subjects (age 29±5.07, 3 M, 2 F) and one neurological patient (age 70, M, stroke).
Materials: A marker-based system (BTS Smart) and the Microsoft Kinect sensor with SDK release 1.8.
Methods: Subjects performed 12 repetitions of the reaching movement against gravity. A target was put at shoulder height, frontally to the subjects, at a slightly longer distance than the upper limb length, so that subjects' arm could be extended frontally towards it. The repetitions of the movement were recorded simultaneously with the BTS and the Kinect. Wrist, elbow and shoulder articular positions were tracked.
Measures: **Normalized Jerk (NJ)** of the wrist in respect to the target [2]. Jerk is the third derivative of position and is related to motor control, as it is a measure of the smoothness of the movement. Human physiological movements are characterized by high smoothness, while pathological ones are often jerky.
Coefficient of Periodicity (CP) of the acceleration calculated on the distance between wrist and target. The repeatability among individual repetitions of reaching was evaluated by means of singular value decomposition pattern analysis (SVDPA) [3]. The result of the processing is a number between 0 and 1, indicating the repeatability of the movement.
Both NJ and CP were computed at the following frequencies: 140Hz (BTS native frequencies), 100Hz, 50Hz, and Kinect frequency (between 20Hz and 30Hz, depending on the trial), obtained down-sampling the BTS signal. Frequencies others than BTS native and Kinect were considered to capture the possible presence of threshold frequencies and trends in the computation of NJ and CP.

RESULTS

Table 1: Normalized Jerk / Table 2: Coefficient of Periodicity

Kinect <30Hz	BTS <30Hz	BTS 50Hz	BTS 100Hz	BTS 140Hz	**Sj**	Kinect <30Hz	BTS <30Hz	BTS 50Hz	BTS 100Hz	BTS 140Hz
9.8	9.4	9.6	12.3	11.3	**H1**	0.97	0.94	0.94	0.94	0.96
10.4	11.7	12.4	16.1	25.2	**H2**	0.96	0.94	0.93	0.94	0.94
9.1	10.4	13.7	14.9	17.2	**H3**	0.99	0.95	0.94	0.95	0.96
8.8	12.0	9.8	11.6	15.1	**H4**	0.98	0.96	0.95	0.96	0.96
8.4	15.5	15.7	20.3	18.0	**H5**	0.92	0.91	0.94	0.95	0.94
19.8	22.5	28.3	49.8	59.8	**Pt**	0.84	0.81	0.84	0.83	0.85
11.0±4.4	13.6±4.8	14.9±7.0	20.8±14.5	24.4±17.9	**M**	0.94±0.06	0.92±0.06	0.92±0.04	0.93±0.05	0.93±0.04

DISCUSSION and CONCLUSIONS

The NJ index is affected by the sampling frequency. The higher the sampling frequency, the higher the NJ. The NJ is more sensible to the frequency rise in the neurological patient. Despite the loss of sensibility due to the lower acquisition frequencies, in our trial the Kinect distinguishes between healthy subjects and the patient, even if it slightly underestimates the NJ in respect to the BTS when compared at the same frequency. As expected, the neurological patient presents a significantly higher NJ, even if, with the Kinect, the difference with healthy subjects decreases. The CP index is not significantly affected by the sampling frequency. For subjects 1 to 4 the Kinect slightly overestimates the CP in respect to BTS. All the healthy subjects show high periodicity, while the neurological patient, as expected, has lower CP.
We conclude that motor control indexes are in general sensible to the sampling frequency, but despite the partial loss of sensibility, proper motor control evaluations are allowed even at lower frequencies. Further investigations will be conducted especially on neurological patients.

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MORE PROFOUND BALANCE IMPAIRMENT AT FAST PLATFORM SHIFT OCCURS IN LATERAL THAN ANTERIOR-POSTERIOR DIRECTION

Z. Kováčiková (1), E. Zemková (2), M. Jeleň (2), T.Vilman (2)

(1) Faculty of Physical Culture, Palacký University in Olomouc, Czech Republic
(2) Faculty of Physical Education and Sports, Comenius University in Bratislava, Slovak Republic

Main topics: Analysis of clinical movement data, Experimental studies in human movement science

INTRODUCTION and AIM

It is known that perturbation velocity influences automatic postural responses [1]. However, this has been found predominantly in anterior-posterior direction [2, 3]. On the other hand, there is a lack of information on postural sway perturbation to other directions. Therefore the study evaluates the effect of different platform perturbation directions at slow and fast velocity on centre of pressure (CoP).

MATERIALS and METHODS

Twelve healthy fit participants (9 male, age 23.2 ± 3.3 y; height 180.1 ± 7.3 cm; weight 79.2 ± 7.2 kg and 3 female, age 26.3 ± 3.1 y; height 170.3 ± 5.7 cm; weight 61.0 ± 6.9 kg) underwent in random order two trials of postural perturbations in four directions (anterior, posterior, lateral-left, lateral-right, respectively) at slow and fast velocity (0.10 cm/s and 0.20 cm/s, respectively). Basic stabilographic parameter- total CoP excursion (peak displacement (Peak1) to peak to peak displacement (Peak2) (Figure1)) was registered using by FiTRO Dynamic Posturography System (FiTRONIC, Slovakia).

RESULTS

Table 1: Total CoP excursion (mean ± SD) in different directions at slow and fast velocity

Perturbation direction	Perturbation velocity 0.10 cm/s	0.20 cm/s	P value (Cohen's d)	
Anterior (cm)	15.66 ± 2.45	20.06 ± 4.12	0.004** (1.3)	0.01* (0.6)
Posterior (cm)	14.00 ± 3.93	19.15 ± 4.06	0.013* (1.3)	
Lateral-Left (cm)	18.03 ± 5.44	28.45 ± 6.53	0.005** (1.8)	
Lateral-Right (cm)	19.25 ± 7.13	26.14 ± 5.14	0.005** (1.1)	

Note: * P<0.05; **P<0.01

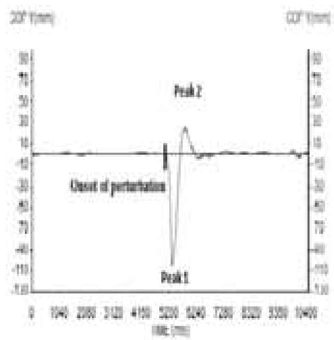

Figure1: Total CoP displacement

DISCUSSION and CONCLUSIONS

It has been found that there was a significant difference in CoP excursion in each direction between slow and fast velocity and between anterior-posterior and lateral left-lateral right direction. Cohen's coefficient of substantive significance in each direction between slow and fast velocity has reached values indicating large effect and medium effect between anterior-posterior and lateral left-lateral right direction. Based on our results, we can conclude more profound balance impairment at fast platform shift in lateral than anterior-posterior direction.

Acknowledgement

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GROUND REACTION FORCE COMPUTATION USING ZERO MOMENT POINT

Erik J. Dijkstra (1,2), Elena M. Gutierrez-Farewik (1,2,3),

(1) KTH Engineering Sciences, Mechanics, Royal Institute of Technology, Stockholm, Sweden
(2) KTH BioMEx Center, Stockholm, Sweden
(3) Dept. of Women's & Children's Health, Karolinska Institutet, Stockholm, Sweden

Main topics: Technical developments in movement science, Mathematical simulation in human movement science.

INTRODUCTION and AIM

Obtaining accurate kinetic data in motion analysis studies can be challenging; clean strikes on at least three force plates are required to capture a full gait cycle. Modelling techniques can therefore be used to estimate the ground reaction loads from known kinematics of the body. Several methods have earlier been developed and used to predict ground reaction forces (GRFs). One method is to use detailed contact models. However such models are difficult to tune and tend to be computationally expensive [1]. Another method uses optimization to estimate the GRFs; the external loads are treated as unknowns and computed in an optimization problem together with the joint torques or muscle forces [2]. An alternative is the Zero Moment Point (ZMP) method [3] that uses inverse dynamics and a distribution function to solve the underdetermined double stance loads [4]. The ZMP is the point where horizontal moments due to the external loads are zero. To our knowledge, none of these methods has been applied to gait analysis. The objective of this study was therefore to use the ZMP to compute GRFs during gait for given kinematics.

PATIENTS/MATERIALS and METHODS

Experimental motion analysis data was collected in a motion laboratory (8-camera Vicon MX40 + 2 Kistler force plates) on ten subjects. The subjects were asked to perform several motions along with normal walking. A modified Inverse Dynamics Tool was written as a plugin for OpenSim [5]. The ZMP method as defined by Xiang et al [4] was implemented in the plug-in to compute the GRFs [4]. Single and double stance phases were detected by studying the positions and velocities of the heel and forefoot. In single stance the computed GRFs can directly be applied to the stance leg. A linear function [4] was applied to obtain the load distribution in double stance. The computed GRF were compared to those measured directly by the force plates.

RESULTS

Results from only one subject are shown in this abstract (female, 26 years, height: 175 cm, weight: 79.3 kg). The computed GRFs matched the experimental data very well in the vertical direction, and relatively well in the horizontal plane, with a slight tendency to underestimate horizontal forces, which varied among subjects.

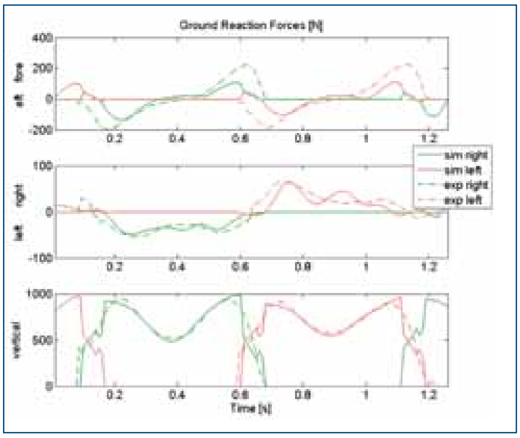

Figure 1: Simulated and experimental GRFs during a gait cycle in one subject

DISCUSSION and CONCLUSIONS

A reliable method to compute ground reaction forces from only kinematic data would be extremely valuable for all motion analysis situations where force plates are not possible or practical, and would render many new predictive simulation methods possible. The use of the ZMP to compute GRFs shows large promise in this direction.

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CATCH EVENT IDENTIFICATION BASED ON MUSCULOSKELETAL ANALYSIS: PILOT STUDY

M. Cognolato(1), D. Conte(2), L. Modenese(3), E. Carraro(2), C. de Conti(2), E. Trevisi(2), N. Petrone(1)

(1) Department of Industrial Engineering, University of Padova, Padova, IT
(2) “F. Fabbri” Posture and Motion Analysis Laboratory, “E. Medea” Scientific Institute, Conegliano, IT
(3) Griffith Health Institute, Centre for Musculoskeletal Research, Griffith University, Griffith, AUS

Main topics: Analysis of clinical movement data, Musculoskeletal modeling.

INTRODUCTION and AIM

Spasticity is defined as a velocity-dependent increase in tonic stretch reflexes as component of the upper motoneuron syndrome. Increased activity of a spastic muscle during passive muscle stretch results in sudden resistance or stop to the movement imposed, happening at a joint position identified as the *Angle Of Catch* (AOC). Definitions of AOC are based on different parameters as: joint angular velocity/acceleration and applied force/torque [1, 2]. However, all these measures are evaluated at the joint level, while the origin of the Catch Event (CE) is at muscle level. Our aim is therefore to assess if the use of a Musculoskeletal Model (MM) driven by data recorded by Inertial Motion Unit (IMUs) can provide further insights on catch event origin and its relation to AOC measured with the Maximum Angular Deceleration (MAD) method.

PATIENTS/MATERIALS and METHODS

A 10 years old child with spastic cerebral palsy (CP) able to walk independently volunteered in this pilot study. Analysis focused on the knee joint. Surface EMG signals from medial hamstring (MH), rectus femoris (RF) and gastrocnemius medialis (GAS) muscles were recorded via wireless sensors (Cometa Wave, Italy). Muscles were tested by performing passive stretch by an experienced examiner at 3 different speeds: slow (used to set the joint ROM), medium and high. Four IMUs (XSens, theNetherlands) were synchronized with the EMG device and placed on foot, shank, thigh and pelvis segments to estimate sagittal plane joint kinematics. Subject’s anthropometric parameters and joint angles were used to scale and drive a lower limb OpenSim MM to obtain muscle fibres contraction velocity. The instant of maximum MH fiber-tendon lengthening velocity (CEM) was compared with CE identified with the MAD method.

RESULTS

Fig.1 shows angle and angular velocity of the knee joint, EMG signal and fiber-tendon lengthening velocity of MH muscle during MH passive stretch at high velocity. CEM (in grey, Fig. 1) identified by the MM based method is associated to an AOC of 36° with maximum fibers velocity of the (extending) MH muscle equal to 23.06 cm/s, while MAD-based CE (in red, Fig. 1) is associated to an AOC of 25°.

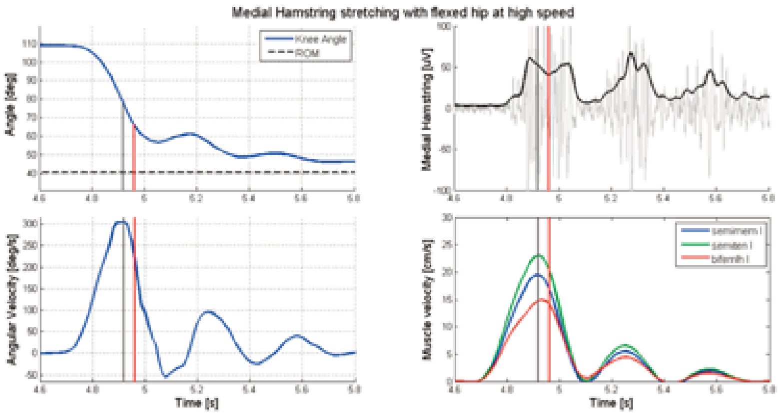

Fig. 1 Medial Hamstring high speed stretching passive test. Vertical red line is the catch event identified by MAD method and the grey line corresponds to the maximum velocity of semitendinosus contraction

DISCUSSION and CONCLUSIONS

CEM obtained through MM differs from MAD-based CE: this observation supports a more systematic application of the MM and the comparison of CEM with the CE identified by different criteria introduced so far in order to recognize the most correspondent to the maximum lengthening velocity. Considering that results are referred to a single pediatric patient further investigation are needed involving a large number of subjects.

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Py3DFreeHandUS: A PURE PYTHON LIBRARY FOR 3D VOXEL-ARRAY RECONSTRUCTION BY USING 3D FREEHAND ULTRASOUND

D. Monari (1,2), F. Cenni (1,2), E. Aertbeliën (1), K. Desloovere (2,3)

(1) KULeuven, Department of Mechanical Engineering, Leuven, Belgium
(2) Clinical Motion Analysis Laboratory, University Hospital Pellenberg, Belgium
(3) KULeuven, Department of Rehabilitation Sciences, Leuven, Belgium

Main topics: musculoskeletal imaging, technical developments in movement science.

INTRODUCTION and AIM

3D Freehand ultrasound (3DUS) is a technique that combines ultrasound images and position + orientation sensors (POS) with the aim to reconstruct large 3D anatomical parts. However, the few existing applications for applying this technique have at least one of the following disadvantages: i) not open-source; ii) only supporting data streams from a limited number of ultrasound or POS devices; iii) they are written in low-level languages such as C++, making rapid development and prototyping more difficult.
We developed a pure Python library called Py3DFreeHandUS that solves all the above issues.

PATIENTS/MATERIALS and METHODS

Py3DFreeHandUS is written in Python 2.7 which has the same level of abstraction as MATLAB® but it is open-source and also suitable for scientific applications since there are available similar libraries. The *pure* Python implementation ensures the cross-platform aspect of the code without any compilation effort and achieves reasonable computation speed due, despite the heavy vectorization. Its inputs are independent to ultrasound systems and POS devices. The library is able to process data acquired simultaneously by US and POS devices, being input as DICOM and C3D files, respectively. In particular, it allows to perform the following operations:

- Estimation of the pose of an US image with respect to POS (*calibration* as in Figure 1, [1]);
- Estimation of the calibration quality by calculating Distance Accuracy and Reconstruction Precision [2];
- Creation of the 3D voxel-array (Figure 2) containing the US images repositioned in 3D space. It is possible to set the voxel-array axes aligned with global reference frame ones or rotate them to "follow" the swapping silhouette and so minimize the voxel-array dimensions.
- Filling of empty voxels among slices by using Voxel Nearest Neighbour or Weighted Distance algorithm.
- Exportation of grey values and US images scan silhouette voxel array to VTI file (VTK) for later visualization (e.g. Paraview, MeVisLab)

RESULTS

The present library is downloadable (https://github.com/u0078867/Py3DFreeHandUS). The calibration quality assessments were 1.9 mm and 3.9 mm for the distance accuracy and reconstruction precision, respectively. In Figure 2, a 3D reconstruction is showed. The average data processing time for each reconstruction was 5.9 min.

DISCUSSION and CONCLUSIONS

Py3DFreeHandUS implements state-of-the-art procedures for voxel-array reconstruction by using an open-source, rapid-development and high-level language such as Python. This reconstruction provides large 3D data sets which are useful to extract clinical features such as muscle morphology. Calibration quality assessment revealed satisfactory results, and the applied heavy vectorization allows users to speed-up computation.

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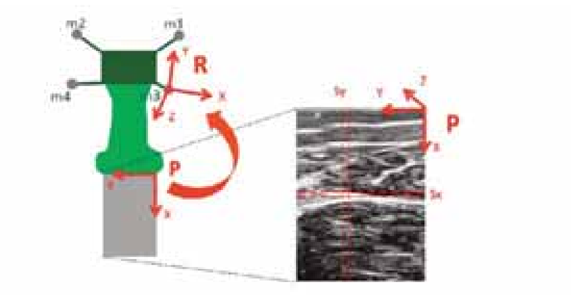

Figure 1: marker-based cluster reference frame R and US image reference frame P. The relative pose estimation is called calibration.

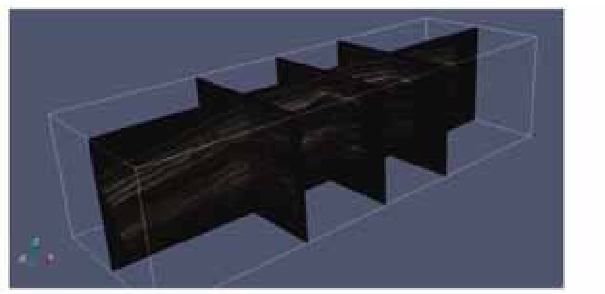

Figure 2: Three transversal and one longitudinal section of a reconstructed 3D voxel-array (e.g. calf muscle scanning, ~90 voxels, 10mm^3 each).

ANALYSIS OF THE SIT TO STAND TASK IN TRANSTIBIAL AMPUTEES USING MAGNETO-INERTIAL SENSORS

E. Di Stanislao (1,2), G. Vannozzi (2), A. Summa (2), F. Paradisi (2,3), M. Traballesi (3) and A. Cappozzo (2)
(1) ITOP SpA Officine Ortopediche, Palestrina (Roma), Italy
(2) Interuniversity Centre BOHNES - University of Rome "Foro Italico", Roma, Italy
(3) I.R.C.C.S. Fondazione Santa Lucia, Roma, Italy

Main topics: Movement analysis in clinical practice, Central and peripheral resources for the movement

INTRODUCTION and AIM

Transtibial amputees are unable to adopt the same movement strategies during the sit-to-stand (STS) task as healthy subjects typically do [1]. STS was studied in transtibial subjects using force plates and/or optoelectronic systems [1], generally expensive and complex to use in non-laboratory environments such as hospitals and/or orthopaedic companies. Experimental protocols and analyzed parameters mainly involved lower limb joint kinematics. Magneto-inertial measurement units (MIMUs) allow a proper definition of the determinants of the STS task [2,3] and are increasingly considered adequate for applications in real clinical settings. Current studies are often limited to a single MIMU. Aim of this study was to verify the feasibility of using multiple MIMUs in identifying differences in upper body and pelvis kinematics in transtibial amputees as compared with healthy subjects performing STS and in detecting the presence of the mentioned different strategies.

MATERIALS and METHODS

A sample (TT) made of 20 persons (19 males, 1 female, age 51 ± 12 years, height 1.73 ± 0.06 m), with unilateral transtibial amputation (7 right and 13 left), users of modular prostheses and able to ambulate without aids, and a control sample (CG) made of 20 healthy subject (19 males, 1 female, age 48 ± 13 years, height 1.78 ± 0.17 m) participated in the study. Three MIMUs (Opal APDM) were placed at the level of sacrum, sternum and head, through appropriate elastic belts. Each subject performed three STS repetitions at self-selected speed, using a seat without arm rests. Each trial was video-recorded to facilitate clinical interpretation of the data. According to the literature, each STS subphase duration [3] and kinematic variables [3,4] (peak-to-peak linear acceleration, angular velocity, jerk, and range of motion (ROM) along an around each axis) were estimated. Unpaired Student's t-tests were carried out on normal-distributed variables to analyze between-group differences ($p<0.05$). Spearman correlation between all the parameters was for performed for each group.

RESULTS

Data confirmed a significant higher STS duration ($p<0.05$) and trunk flexion duration prior seat-off ($p<0.01$) [5], and a higher value of trunk angular velocity during the flexion-extension movement that precedes and follows the seat-off, in TT than in CG ($p<0.05$). Trunk angular velocity in flexion-extension (peak, mean and standard deviation) were also higher as well ($p<0.05$). TT presented also head pitch and roll angles ($p<0.05$) and greater sternum and pelvis ROM in the three planes of the space ($p<0.05$) in TT. Different correlations between temporal and kinematic data were also found in each groups ($R>0.8$, $p<0.05$), for example higher trunk flexion duration prior seat-off in TT is related ($R>0.8$) with an increase of all STS subphase durations.

DISCUSSION

Higher STS duration and angular velocity recorded in TT could be related to TT lower limb muscle weakness that is compensated with the need of higher trunk flexion-extension inertia to pass from sitting to standing position, also revealed by the increased sagittal trunk and pelvis ROMs. The higher medio-lateral head, sternum and pelvis ROMs could also identify the presence of weight bearing asymmetry [1,5]. All the identified differences and correlations could be linked to a different TT strategy in STS task execution. The proposed MIMUs protocol could support clinical evaluation and/or optimization of the prosthetic device fitting.

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COMPARISON OF JOINT TORQUE DURING ISOMETRIC MUSCLE CONTRACTION TO JOINT TORQUE DURING WALKING AT DIFFERENT VELOCITIES

[1]Marije Goudriaan, [2]Chris Bruyninckx, [1]Angela Nieuwenhuys, [2]Karlien Delanghe, [2]Julie Casie, [3]Davide Monari, [1,2]Kaat Desloovere.

(1) KU Leuven, Dept of Rehabilitation Sciences
(2) Clinical Motion Analysis Laboratory, CERM, University Hospital Leuven
(3) KU Leuven, Dept. of Mechanical Engineering, Leuven, Belgium

Main topics: Analysis of clinical movement data, analysis of gait and movement disorders & rehabilitation.

INTRODUCTION and AIM

A number of studies have tried to determine the effect of weakness on gait kinetics in children with cerebral palsy (CP) by trying to find a relationship between muscle torque during maximal voluntary isometric contraction (MVIC) and peak joint moments measured during gait [1-3]. However, the results vary and one way to explain these differences might be the choice of test positions during MVIC. Additionally, the MVIC is often compared to kinetics collected during self-selected walking velocity, which can be considered as a submaximal effort, rather than a high demand functional test. We compared the maximal knee and ankle moments generated while walking at two walking velocities (self-selected (v1) and as fast as possible without running (v2)) with the maximal muscle torques generated during MVIC.

PATIENTS/MATERIALS and METHODS

10 Typical developing children (TD; M ± SD: age 10.3 ± 3.3) and 9 children with spastic CP (CP; M ± SD: age 8.89 ± 2.88; GMFCS I-II) participated in the study. MIVC torques were measured in a custom made chair that assured a standardized fixed lower limb position that represents the averaged hip, knee and angle observed during gait. Joint moments generated during gait were measured with 3D motion analysis equipment. Differences between CP and TD children were determined with a Mann-Whitney U test and differences between MVIC and the two walking speeds were determined with Wilcoxon signed rank test.

RESULTS

Overall the TD children showed significant higher torques for all MVICs. Additionally they had higher plantar flexion (PF) and knee extension (KE) joint moments during gait (table 1). For the TD children, MVIC torques of the PF were significantly lower than the joint moments seen during both walking velocities ($p<0.05$). DF MVIC torques were higher than the joint moments at v2 ($p<0.05$). KE MVIC torques were significantly higher than the KE joint moments during gait ($p<0.05$) and the same was seen for KF MVIC torque compared to v1. For the CP children, PF MVIC torque was significantly lower than the PF joint moments during both velocities ($p<0.05$).
In TD children, joint moments for KE and KF increased significantly when walking velocity increased. In the CP children, PF and KF joint moments increased significantly with increasing walking velocity.

Table 1. Mean (M), standard deviations (σ) and the p-values from the Mann-Whitney U test of the maximal torques.

	Plantar flexion			Dorsiflexion			Knee extension			Knee flexion		
	v1	v2	mvic	v1	v2	mvic	v1	v2	mvic	v1	v2	mvic
M td	1.46	1.37	0.67	0.11	0.17	0.26	0.58	0.94	1.23	0.41	0.70	0.83
σ td	0.16	0.26	0.29	0.04	0.05	0.06	0.22	0.32	0.45	0.10	0.12	0.22
M cp	1.12	1.29	0.31	0.16	0.13	0.08	0.49	0.55	0.56	0.43	0.78	0.48
σ cp	0.18	0.28	0.04	0.18	0.07	0.03	0.11	0.14	0.21	0.25	0.32	0.13
p	.001	.20	.000	.18	.091	.000	.16	.003	.002	.27	.36	.011

DISCUSSION and CONCLUSIONS

The CP children showed significantly lower MVIC values than the TD children, which might be explained by a decrease in selective muscle control. Power generation needed for increasing walking velocity is usually derived from an increment in PF, KE and hip flexion (HF) moments. In the CP children, joint moments in PF and KF increased significantly, despite their low MVIC values. The gastrocnemius and hamstrings are muscles prone to spasticity and it seems that CP children use this spasticity to increase their walking velocity. In the TD children, there was no increase in PF moments, but we observed a significant increase in KE extension moment. Measure of HF MVIC muscle torque and HF joint moments during walking in future studies might give more insight.

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A TRACTABLE CLOUD-BASED FRAMEWORK FOR HUMAN MOVEMENT ANALYSIS AND CLASSIFICATION

R, Matias (1,2,3), J, Rosa (1), H, Silva (3), A, Fred (3), A.P, Veloso (2)

(1) School of Health Care of the Polytechnic Institute of Setúbal, Setúbal, Portugal
(2) Neuromechanics of Human Movement Research Group, University of Lisbon, Lisbon, Portugal
(3) Pattern and Image Analysis Research Group, University of Lisbon, Lisbon, Portugal

Main topics: Analysis of clinical movement data, Analysis of gait and motor disorders..

INTRODUCTION and AIM

Current clinical practice still lacks accurate and tractable tools that are able to merge patient clinical information and human movement analysis data, and deliver relevant clinical information that can help clinicians communicate and enables consistent rehabilitation assessment, building evidence for effectiveness.. The aim of this work was to develop a tractable cloud-based open-source framework for human movement analysis and classification that benefits from the complementary information of biomechanical modeling, patient clinical information, high quality normative kinematic gait and shoulder data sets, with algorithms for multi-dimensional data classification.

PATIENTS/MATERIALS and METHODS

This framework combines the convenience of HTML5/CSS3 for multiplatform rich graphical user interface design, with a high performance cloud computing backend where 2 validated musculoskeletal models [1,2] and pattern recognition algorithms can be run. A user-defined report of gait or shoulder movement analysis and impairment classification is achieved by having as input patient clinical information and 3D motion files to perform scaling and inverse kinematics using OpenSim dynamic-link libraries [3], and by comparing the results with embedded normative data consisting of patient clinical information, skin-mounted sensors, and bone-pin sensors kinematic collected from a variety of daily activities of subjects with and without gait or shoulder related impairments. A sample of 30 subjects including researchers, clinicians and students was used to conduct a usability and learnibility analysis using the System Usability Scale [4].

RESULTS

After a 4 minutes explanation on the framework features and use, subjects reported that the interface was extremely easy-to-use - usability and learnability scores of 77 and 70, respectively - and are likely to recommend the framework to others - total score 75. These results and subjects valuable feedback were used to develop the final version of a user-friendly interface that enables an effective interaction during patient and motion data upload, models scaling and inverse kinematics setups, and report customization. In this version users can upload patient clinical information (e.g. gender, age, pain and disability information, and others) different 3D motion file formats (e.g. c3d, emf, trc, xls, and others), determine how the selected musculoskeletal model anthropometry should be modified so it best matches patients characteristics, to what degree each model's segment (markers) should match the collected motion data during the inverse kinematics process. Finally, the user is able to define: the report variables; if the report should encapsulate results of one given trial, an inter-trials analysis or compare the reconstructed motion with the match normative data set; if an impairment classification result and its accuracy should be included; annotations to each plotted information; and if the report should be directly sent to a specific email address in a portable document format.

DISCUSSION and CONCLUSIONS

Clinical decision making is constrained by the accuracy and relevance of the information on which they are based. The proposed cloud-based framework offers clinicians the opportunity to freely gain access to accurate patient movement information, and while merging the latter with patient clinical data, pattern recognition algorithms benefits from embedded normative data set to deliver relevant information, such as movement impairment classification.

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A QUANTITATIVE PERFORMANCE EVALUATION DURING ROBOTIC REHABILITATION TREATMENT

E. Biffi (1), E. Peri (2), C. Maghini (1), F. Servodio Iammarrone (1), C. Gagliardi (1), C. Germiniasi (1), A. Pedrocchi (2), A.C. Turconi (1) and G. Reni (1)

(1) IRCCS E. Medea, Bosisio Parini (LC), Italy
(2) Politecnico di Milano, DEIB, NearLab, Milan, Italy

Main topics: Robotic devices in human movement science and rehabilitation, Functional outcome measures in mobility

INTRODUCTION and AIM

In clinical practice, it is substantial to identify with quantifiable, valid, and sensitive tools which variables involved in rehabilitation treatments might have a larger impact on outcome measurements [1]. In this context, measures derived from robots, used to assist rehabilitation treatments, can be helpful. During the past few years, few groups have developed some ad-hoc assessment tools to extract outcome measures of patients' performance [2,3]. However, these methods require the development of dedicated technologies and often additional time both for patients and clinicians to perform the rehabilitation assessments. In this work we describe a simple parameter that can be easily derived from data saved by the robot and that gives an indication of subjects' performance.

PATIENTS/MATERIALS and METHODS

Fourteen inpatients (8-16 years old) affected by cerebral palsy performed a training with Armeo® Spring Pediatric (Hocoma, AG) for 4 weeks. A novel performance parameter P was computed for each training session taking into account the time needed to finish an exercise, the score obtained during the exercise and the level of difficulty. These data were automatically recorded by the system, with no additional effort for the physiotherapists. Moreover, it was also evaluated the Melbourne Assessment of Unilateral Upper Limb Function before and after the robotic-aided training. The research protocol was approved by the Ethics Committee of IRCCS Medea.

RESULTS

The values of P increased during the training and significant improvements in P were observed before and after the whole rehabilitation treatment ($p=0.002$). Moreover, the increase of P corresponded to a functional improvement in terms of Melbourne scale (root mean square error between data and linear fitting curve equal to 0.04) for all the subjects, clinically validating our results (see Figure 1).

DISCUSSION and CONCLUSION

Here we propose a performance parameter which is computed in a simple and quick way from data automatically acquired by the robot during the training. It can be used to follow the trend of a robot-aided treatment, to describe changes in performance before and after a rehabilitation and thus to investigate the effects of variations in the therapy on patients' motor and functional recovery.

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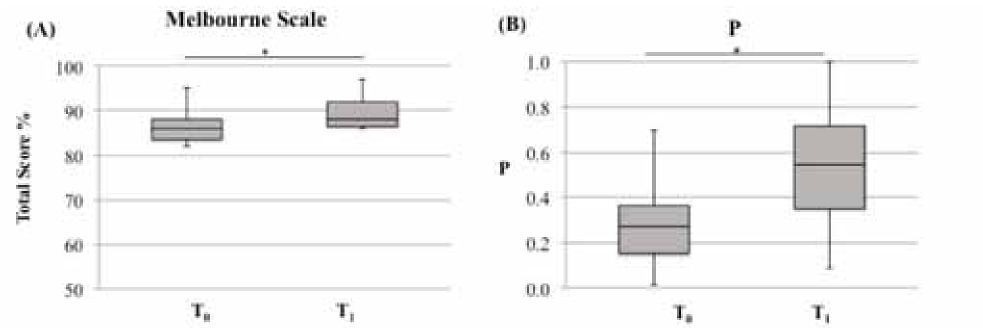

Figure 1. Comparison between P and Melbourne scale. **A:** results of the Melbourne scale for the group before (T0) and after (T1) the training. **B:** P during the first week (T0) and the last week (T1) of training. Median, I quartile and III quartile are represented as box. The maximum and minimum values are also shown as bars. * represents $p<0.05$ in the Wilcoxon statistical test.

DANCE THERAPY ITS EFFECT ON QUALITY OF LIFE AND FUNCTIONAL CAPACTIY

L. Allet[1,2], S. Müller[c]; I. Punt[1,2], Z. Pataky[3], A. Golay[3]

[1] University of Applied Sciences of Western Switzerland, Dpt. of Physical Therapy, Geneva, Switzerland
[2] University Hospitals and University of Geneva, Health Care Directorate, Geneva, Switzerland
[3] University Hospitals and University of Geneva, WHO Collaborating Centre, Department of Community Medicine, Geneva, Switzerland

INTRODUCTION and AIM

The associations between obesity and functional capacities are multifaceted and complex. In order to develop effective and subject-centered prevention and treatment strategies, a more systematic and more comprehensive approach, which could provide an overview of obese patients' functional deficits and functional decline in daily life activities, is needed. Therefore the aim of this study was to assess the relationships between BMI and walking speed, balance control, sit-to-stand performance (a measure of mass specific lower limb power), and endurance.

PATIENTS/MATERIALS and METHODS

Thirty-six women with a BMI ≥ 30 kg/m^2 and 10 women with normal body weight (BMI between 18 kg/m^2 and 25 kg/m^2) were enrolled in this observational study. The obese group comprised 12 persons with a BMI ≥ 30 and < 35 (obese), 14 subjects with a BMI ≥ 35 and < 40 (severe obesity) and 10 people with a BMI ≥ 40 kg/m2 (morbid obesity). All subjects underwent a clinical examination, a gait test, an endurance test (6 minutes walking test), a mass specific lower limb power test (five times sit-to-stand) and a balance test.

RESULTS

Obese women exhibited slower fast gait speeds ($P < 0.05$) with correspondingly shorter stride length (Table 1), poorer sit-to-stand performance ($P < 0.05$), and endurance ($P < 0.05$) (Figure). However, once the state of severe obesity was reached, additional weight gain (morbid obesity) does not seem to decrease these functional capacities any further.

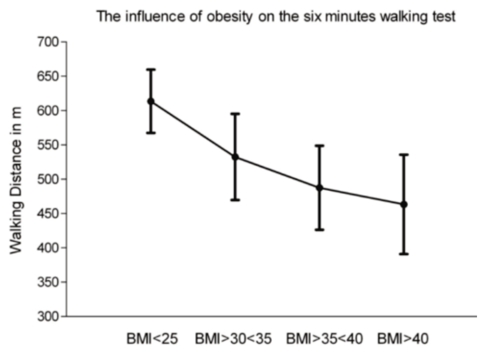

Table 1. Description of spatiotemporal gait parameters per subject group

	Normal Walking			Fast Walking		
BMI	Speed (m/s)	Cadence (Steps/min)	Stride length (m)	Speed (m/s)	Cadence (Steps/min)	Stride length (m)
<25	1.53 (0.22)	122 (11.51)	1.50 (0.10)	2.11 (0.20)	147 (12.71)	1.73 (0.10)
>30<35	1.34 (0.20)	120 (11.47)	1.34 (0.13)	1.82 (0.25)	144 (14.29)	1.52 (0.17)
>35<40	1.15 (0.15)	109 (7.31)	1.26 (0.12)	1.73 (0.21)	136 (6.70)	1.53 (0.14)
>40	1.18 (0.15)	109 (4.39)	1.29 (0.17)	1.63 (0.19)	130 (7.37)	1.51 (0.19)

DISCUSSION and CONCLUSIONS

This study underlines the importance of assessing obese patients' related physical problems in an early stage of obesity in order to focus exercise regimens and promote appropriate health behaviors.

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HOW DO NEWLY WALIKING TODDLERS COMBINE DIFFERENT GAIT STRATEGIES WHEN DEVELOPING PENDULUM MECHANISM? A QUANTITIATIVE LONGITUDINAL STUDY

M.C. Bisi (1), R. Stagni (1,2)

(1) DEI, University of Bologna, Bologna, Italy
(2) HST – ICIR, University of Bologna, Bologna, Italy

Main topics: Motor control and motor learning, Experimental studies in human movement science.

INTRODUCTION and AIM

Toddlers use different gait strategies during the first months of independent walking and then converge to more similar walking forms, developing manifestation of the pendulum mechanism. The extreme modes of walking usually used by toddlers are three: the Twister, who uses trunk twist, the Faller, who uses gravity and the Stepper, who remains balanced as much as possible [1]. The aim of this work was to analyze quantitatively how toddlers explore those strategies and combine them when developing the pendulum mechanism.

PATIENTS/MATERIALS and METHODS

Twenty healthy infants participated in the study. Each infants performed 5 tests in 6 months after the onset of walking. Two tri-axial wireless inertial sensors (OPALS, Apdm, USA) were mounted respectively on the lower back and on the right leg. The participants were asked to freely walk in the room. For all the participants 10 consecutive strides were analyzed. The following characteristics have been searched for in the data:

- Twister: high angular velocity around L5 vertical axis;
- Faller: high peak to peak L5 acceleration range along the AP axis;
- Stepper: low peak to peak range at L5 acceleration and angular velocities in all directions and high accelerations of the legs happening in a small percentage of the stride.

A typical parameterized waveform was designed for each gait strategies. Each waveform was fitted into toddlers data and then subtracted from the signals. Percentage of signal power left was calculated as an indication of how much the gait deviated from the intended strategy.

RESULTS

The identified waveforms for each gait strategies were:

- Twister: a sinusoidal function on the angular velocity around the vertical axis of L5;
- Faller: an inverted saw-tooth waveform on the antero-posterior acceleration of L5;
- Stepper: a sinusoidal function on the vertical acceleration of the foot for 20% of the stride and then a constant value.

Preliminary results of signal power analysis are based on three toddlers, each one showing at the first week of independent walking a different gait strategy (Fig.1). Assuming that the percentage of signal residual power indicates of how much the gait deviated from the intended strategy, each toddler explored and combined mostly two of the three strategy presented when developing the pendulum mechanism (twister and faller or stepper and twister).

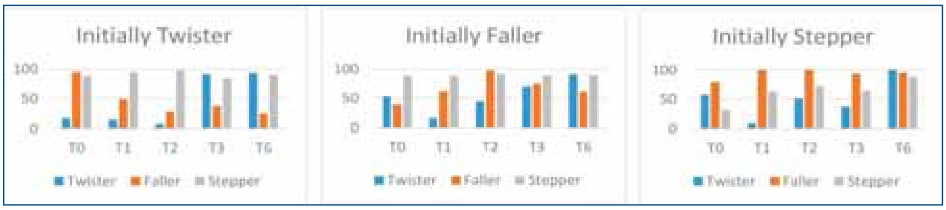

Fig. 1 Percentage of signal power left after removing the estimated trend of each gait strategies (twister in blue, faller in orange and stepper in grey) at different stage of gait development. The three figures show results of three toddlers who manifested during the first week a twister (a), faller (b), stepper (c) strategy.

DISCUSSION and CONCLUSIONS

Preliminary results showed that each toddler explored and combined mostly two of the three strategy presented when developing the pendulum mechanism. The two combinations found were twister and faller or stepper and twister: faller and stepper strategies appeared to be alternative in the development of mature gait. The analysis of more data will confirm this first conclusion. Further work is needed to understand how the different strategies combine in order to create the pendulum mechanism.

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MEDIO-LATERAL GAIT STABILITY IN CHILDREN WITH HEMIPLEGIC & DIPLEGIC CEREBRAL PALSY

P. Meyns (1), J. Duysens (1), K. Desloovere (2,3), S.M. Bruijn (4), M. Pijnappels (4), J.H. van Dieën (4)

(1) Department of Kinesiology, Faculty of Kinesiology and Rehabilitation Sciences, KU Leuven, Belgium; (2) Department of Rehabilitation Sciences, Faculty of Kinesiology and Rehabilitation Sciences, KU Leuven, Belgium; (3) Clinical Motion Analysis Laboratory, University Hospital Pellenberg, Belgium; (4) MOVE Research Institute Amsterdam, Faculty of Human Movement Sciences, VU University Amsterdam, Amsterdam, The Netherlands.

Main topics: Analysis of gait and motor disorders.

INTRODUCTION and AIM

Poor balance control is a major deficit in children with Cerebral Palsy (CPc)[1]. Strikingly, little effort has been made to quantify gait stability in CPc. These studies usually did not include the comparison between different types of CPc (hemiplegia and diplegia)[2,3]. We investigated medio-lateral gait stability in children with spastic hemiplegic (HEc) and diplegic CP (DIc), and typically developing children (TDc).

PATIENTS/MATERIALS and METHODS

Total-body (PlugInGait) kinematics during overground walking were recorded in 11 HEc, 15 DIc, and 24 TDc (all 4-12yr) using an 8-camera Vicon-system. Three walking trials were assessed (with full visible left and right stride). The most affected side in CPc was determined as the side with the highest median lower limb spasticity score (i.e. non-dominant side in TDc). Total body centre of mass (CoM) kinematics were calculated from a 15-segment 3D-model. Medio-lateral CoM amplitude (CoMampl), CoM velocity at foot-strike (vCoM), and Margins of Stability (MoS) were calculated[4]. Step width was determined as the medio-lateral distance between the ankle markers during double support. A general linear model was used with group as factor, side of the body as repeated measures factor (if applicable), and walking speed as co-variate. Tukey's post-hoc comparisons were applied (α=0.05).

RESULTS

CoMampl was increased in CPc (especially in DIc; TDc:0.15±0.02m; DIc:0.21±0.04m; HEc:0.17±0.03m; p=0.002), and DIc had larger step widths than TDc (TDc:0.04±0.01m; DIc:0.06±0.02m; HEc:0.06±0.02m; p=0.013). DIc showed significantly larger MoS (on both sides; fig1A).

At foot-strike of the least affected leg, vCoM (toward the least affected leg) was higher in CPc than TDc (fig1B).

DISCUSSION and CONCLUSIONS

Motor impairments on the most affected side in CPc most likely caused the increase in vCoM toward the least affected leg (DIc>HEc). This may account for the increased CoMampl in CPc, and could have caused the increased (compensatory) step width. The larger MoS, however, indicated that DIc increased their step width more than strictly required. Further research should focus on the different balance control strategies used in different types of CP.

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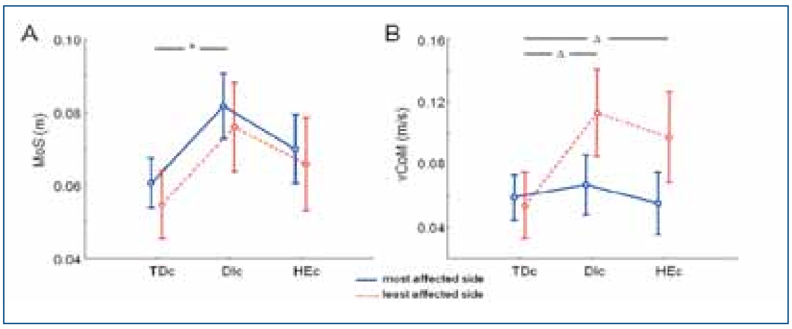

Figure 1. Between-group differences in (A) medio-lateral Margins of Stability (MoS), and (B) velocity of the center of mass at foot-strike (vCoM).
* significant between-group difference (Main effect of Group: F=5.65, p=0.006; Tukey's post hoc TDc vs. DIc: p<0.001).
∆ significant between-group difference (Group*Side interaction effect: F=3.76, p=0.031; Tukey's post hoc TDc vs. DIc: p<0.001; Tukey's post hoc TDc vs. HEc: p=0.030).

GAIT ANALYSIS AFTER MEDIAL PATELLOFEMORAL LIGAMENT RECONSTRUCTION

<u>Makoto. Asaeda (1)</u>, Masataka. Deie (2), Chiaki. Terai (1), Yoshifumi. Kono (1), Noboru. Shimada (3), Naoya. Orita (3), Daisuke. Iwaki (3), Mitsuo. Ochi (4)

(1) Health Sciences Major, Graduate School of Biomedical & Health Sciences, Hiroshima University, Hiroshima, Japan
(2) Department of Musculoskeletal Functional research and regeneration, Integrated health sciences, Institute of Biomedical & Health Sciences, Hiroshima University, Hiroshima, Japan
(3) Department of rehabilitation, Division of clinical support, Hiroshima university hospital, Hiroshima, Japan
(4) Department of orthopaedic surgery, Integrated health sciences, Institute of biomedical & health sciences, Hiroshima University, Hiroshima, Japan

Main topics: •Analysis of clinical movement data, •Orthopaedics

INTRODUCTION and AIM

Medial patellofemoral ligament (MPFL) reconstruction has become a mainstay of surgical treatment of recurrent patella dislocation and obtains satisfactory results such as reducing re-dislocation and patellar instability[1]. However operative treatment including MPFL reconstruction is higher incidence of patellofemoral osteoarthritis than conservative treatment[2]. We investigated gait kinematics to examine mechanical stress of the knee after MPFL reconstruction.

PATIENTS/MATERIALS and METHODS

Eight recurrent patella dislocation patients were underwent gait analysis before MPFL reconstruction (Patella group). Six patients were underwent gait analysis again after 3 and 6 months from the surgery (Preope, Post3m, Post6m group). Seventeen healthy people with no history of lower limbs were recruited as the Control group. Kinematic and kinetic data were acquired using a three-dimensional motion analysis system (VICON NEXUS, Vicon Motion Systems, Oxford, UK). Knee joint kinematics was measured using the point cluster technique which was advocated by Andriacchi[3]. Subjects were tested at a self-selected normal gait speed. Kinematic date was examined using non-paired t test between the Control group and the Patella group, and following changes of kinematics was examined using one factor repeated measures ANOVA, and Bonferroni correction.

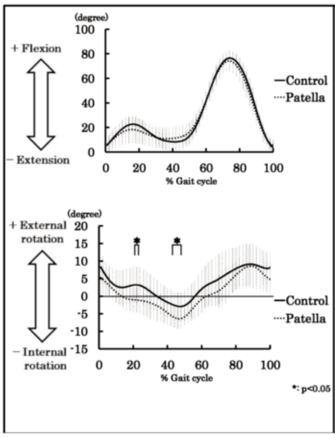

Figure 1: Knee kinematics in gait cycle before the surgery.

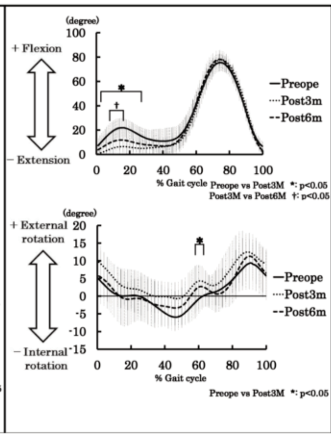

Figure 2: Following changes of knee kinematics in gait cycle after the surgery.

RESULTS

Before MPFL reconstruction, internal tibial rotation significantly increased in stance phase (Gait cycle 21~23%, 43~48%) than the Control group. Three months later, the patients who were underwent MPFL reconstruction showed the increasing external tibial rotation and the decreasing knee flexion angle (Gait cycle 2~27%). After six months from the surgery, the patients showed the reappearance of internal tibial rotation.

DISCUSSION and CONCLUSIONS

Before MPFL reconstruction, recurrent patella dislocation patients showed the internal tibial rotation at stance phase of the gait cycle, and we found the similar tibial motion after 6 months. On the other hands, the internal tibial rotation significantly decreased after 3 months. In this study, we found that the patients who were underwent MPFL reconstruction had the different tibial rotational motions at gait which may cause post-operative osteoarthritis, and this motion differed about depending on post-operative time. We have to consider the rehabilitation after MPFL reconstruction differentiated by time.

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USE OF ‘GAIT PROFILE SCORE’ TO REVEAL PRE-POST GAIT IMPROVEMENTS AFTER SURGERY IN DIPLEGIC CEREBRAL PALSY

R. Neviani (1), D. Pandarese (1), Al. Ferrari (2), F. Grassi (2), Ad Ferrari (1)

(1) Motion Analysis Laboratory LAMBDA, IRCCS Santa Maria Nuova Hospital, Reggio Emilia, Italy
(2) Department of Electrical, Electronic, and Information Engineering, University of Bologna, Italy

Main topics: Movement deviation indices, outcomes after clinical intervention, rehabilitation.

INTRODUCTION and AIM

Bone and soft-tissue surgery at lower limbs is a common treatment in the management of gait impairments in cerebral palsied children. Surgical treatments are aimed at improving gait and overall locomotor function, decreasing discomfort, and moderating disabling structural deformities [1]. The goal of this study was to assess changes of gait performance pre-post orthopedic surgery by means of gait analysis. In order to compare results obtained from different patients minimizing inter-subject variability, patients were divided into four groups corresponding to the four forms as proposed by Ferrari et al. classification [2]. This classification, addressing the main top-down features of motor organization i) is able to differentiate children on the base of success and efficacy in achieving and maintaining walking and ii) does not expect children to shift clinical form after treatments. Furthermore, the classification divides the diplegic sample into four groups ranging from most skilled of form IV, decreasingly, to less skilled of form I.

PATIENTS/MATERIALS and METHODS

This is a retrospective, consecutive cohort study. 36 children (mean age 12, range 6-20 years) with spastic diplegia who had lower extremity multilevel surgery were enrolled. Aim of the surgery was to improve motor performance and autonomy level in walking. All children had a kinematic analysis of gait pre- and post- surgery at six months after surgical intervention. In particular, subjects were asked to walk barefoot at a self-selected speed along a 12m walkway equipped with an 8 cameras optoelectronic system (Vicon Motion System, UK). The Gait Profile Score (GPS), being a global index which summarizes the overall deviation of gait kinematics with respect to normative data [4], was then computed as outcome measure of treatment efficacy.

RESULTS

Overall median and inter-quartile range of GPS was 16.65° (4.54°) preoperatively and 13.47° (3.22°) postoperatively (see table 1). The 3.18° pre-post difference was statistically significant with a Wilcoxon signed- rank ($p < 0,01$).

DISCUSSION and CONCLUSIONS

In our sample, GPS demonstrated statistically significant improvements in the overall gait pattern following lower limb surgery. This finding is in agreement with the literature [5]. All 4 diplegic forms showed improvements in GPS values. In particular, 67% of children belonging to form I shifted to the “moderate” level of gait deviation; as well, in forms II and III we found a reduction of children ranked in “very severe” level and an increase of those included in “moderate” level. Finally, all children of form IV shifted from “very severe” to other levels. In conclusion results show overall a good efficacy of surgery treatment as revealed by GPS values. Despite small sample size, these results suggest that, from a prognostic standpoint, surgical treatment on children belonging to form IV may lead to higher possibilities on pattern improvements. Indeed, according to Ferrari et al. classification, children of form IV present more motor, perceptual and intentional abilities than those of other forms; therefore they are more able to benefit from musculoskeletal system changes induced by surgery.

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		v. severe	severe	moderate			v. severe	severe	moderate
I form	Pre	0	100	0	**II form**	Pre	46	27	27
(n= 3)	Post	0	33	67	(n= 11)	Post	13	33	54
III form	Pre	62	23	15	**IV form**	Pre	31	46	23
(n= 9)	Post	13	38	49	(n= 13)	Post	0	23	77

Table 1: distribution (%) of 4 forms of diplegia in three levels of gait deviation as proposed by Rutz et al. [5] : “very severe” (GPS> 18°), “severe” (14°<GPS< 18°); “moderate” (GPS< 14°).

QUANTIFYING LEVEL WALKING USING SMARTPHONES: A VALIDATION STUDY

S. Schmid (1), M. Furrer (1), L. Bichsel (2), M. Niederer (3), H. Baur (1)
(1) Bern University of Applied Sciences, Health Division, Discipline of Physiotherapy, Bern, Switzerland
(2) Bern University of Applied Sciences, Institute for Rehabilitation and Performance Tech., Bern, Switzerland
(3) Zurich University of Applied Sciences, Institute for Physiotherapy, Zurich, Switzerland

Main topics: 1) Analysis of gait and motor disorders, 2) Technical developments in movement science

INTRODUCTION and AIM

The ability of quantifying gait is crucial in order to evaluate the severity of impairment or the effects of a treatment intervention. This is commonly achieved using sophisticated measurement tools such as marker-based motion analysis systems. However, these systems are usually dependent on a motion analysis laboratory and associated with high costs, restricting their use for most clinical practitioners. Recently, researchers have suggested to use the acceleration sensors incorporated into nowadays' smartphones (SMP) as a possible alternative to the expensive and time consuming laboratory-based tools [1,2].
The aim of this study was therefore to validate a previously developed smartphone application for the measurement of center of mass (CoM) displacement during gait by comparing it to a reference standard.

MATERIALS and METHODS

A total of 22 healthy young volunteers (male/female: 10/12; age: 27.4±3.9 years; height: 1.74±0.1 m; mass: 65.5±10.2 kg) participated in this study. A previously developed Android-based smartphone application was used to sample the corrected (using magnetic field sensor) and uncorrected vertical acceleration of the device (Desire HD, HTC Corp., Taoyuan City, Taiwan) that was attached over the region of the third lumbar vertebra using a custom-built non-elastic Velcro® belt. Acceleration signals were filtered and converted into displacement data using a custom-built LabVIEW program (National Instruments Corp., Austin TX, USA).
As a reference standard, a marker-based three-dimensional motion analysis system (Vicon UK, Oxford, UK) was used. Markers were placed according to the Plug-in Gait fullbody model and vertical displacement of the CoM was calculated using the software Nexus (Vicon UK, Oxford, UK). Participants were asked to walk barefoot along a 10-meter walkway at a self-selected speed. Both displacement curves were then normalized and expressed as a percentage of body height and parameterized as follows: minimum to minimum and minimum to maximum CoM displacement for the left and right steps (Mimi_Disp_L/R [%] and Mima_Disp_L/R [%]) as well as the respective durations (Mimi_Time_L/R [ms] and Mima_Time_L/R [ms]). Reliability was calculated using the intraclass correlation coefficient (ICC(2,1)) and the standard error of measurement (SEM). Concurrent validity was determined using Pearson correlation coefficients (r) and Bland-Altman limits of agreement.

RESULTS

Overall, parameters based on the uncorrected accelerometer signal revealed higher reliability values than the corrected signal and therefore, only those results are presented. Table 1 displays the results for the variables indicating ICC-values of ≥0.75 for both left and right steps. Moderate to high correlations (all statistically significant at $p<0.01$) were found between the SMP- and the Vicon-derived parameters.

Table 1: Reliability and validity values for the variables minimum to minimum center of mass displacement for the left and right steps (Mimi_Disp_L/R [%]) as well as their durations (Mimi_Time_L/R [ms]).

Variable	Reliability						Validity			
	SMP-derived			Vicon-derived			Corr. (r)	Mean diff.	Limits of agreement	
	Mean (SD)	ICC	SEM	Mean (SD)	ICC	SEM			Lower	Upper
Mimi_Disp_L	3.3 (0.7)	0.781	0.3	3.4 (0.4)	0.817	0.2	0.679	-0.04	-1.05	0.97
Mimi_Disp_R	3.5 (0.5)	0.801	0.2	3.3 (0.4)	0.842	0.2	0.674	0.19	-0.58	0.96
Mimi_Time_L	568 (30)	0.772	14	562 (39)	0.850	15	0.829	6	-38	50
Mimi_Time_R	557 (37)	0.860	14	558 (36)	0.820	15	0.916	-1	-31	29

DISCUSSION and CONCLUSIONS

The current results revealed a great potential for the smartphone application to be a practicable, reliable and valid tool for the quantification of level walking in a clinical setting. Further studies should investigate whether the application can be used for the assessment of pathological gait and whether the application is sensitive enough to detect changes in order to evaluate therapeutic interventions.

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DEVIATION OF SELECTED MOVEMENT INDICATORS IN THE SHOT PUT

A. Mastalerz (1), L. Gwarek (1), J. Sadowski (2)

(1) University of Physical Education in Warsaw, Poland,
(2) University of Physical Education (Warsaw, Poland), Department of Physical Education and Sport, (Biała Podlaska, Poland

Main topics: Experimental studies in human movement science, Movement deviation indexes.

INTRODUCTION and AIM

Good performance in throwing events has been mainly determined by the athlete's movement technique than the tactics. The aim of the study was to compare the deviation of selected movement indicators of the athlete body and the put estimated by the average relative error (AV).

PATIENTS/MATERIALS and METHODS

Fourteen world-class (right-handed) competitors took place in that analysis. Eight of them (5 competitors used spin technique and 3 used glide technique) performed trials during international competition on the stadium (group A) and six of them (3 used spin technique and three used glide technique) performed trials during national championship in the athletics hall (group B). Two high speed digital cameras (JVC, model GR DVL-9800) were placed perpendicular to each other near the shot put throwing circle. Following movement indicators of the athlete (CG – athlete's center of gravity in case of velocities) and the put (P – the center of the put) during release (RLS - the last contact of the athlete's) were taken into account during analysis including only measured trials: release angle, height of release, the height of the center of the put above the surface of the circle at release, height of the center of the body during release, distance of the throw, shoulder-hip separation during RLS (it is the orientation of the hips relative to the shoulders), rear (right) and front (left) knee angle, relative angle between thigh and leg segments, shoulder and elbow angle of the right arm, right and left hip angle. Two-factor analysis of variance (ANOVA) was used to analyze significant differences depending on the two factors: the Group and/or the Technique.

RESULTS

The ANOVA analysis revealed a significant effect of Group factor for: the angle of the right elbow ($F(1,57)=35{,}432$, $p\leq0{,}0001$), angle of the right hip ($F(1,57)=14{,}890$, $p\leq0{,}001$) angle of the right shoulder ($F(1,57)=16{,}306$, $p=0002$), shoulder-hip separation ($F(1,57)=9{,}545$, $p=0{,}003$), horizontal velocity of the athlete's center of gravity ($F(1,57)=7{,}547$, $p=0{,}008$), the horizontal, vertical and resultant velocity of the put (respectively $F(1,57)=10{,}657$, $p=0{,}002$, $F(1,57)=16{,}897$, $p\leq0{,}001$, $F(1,57)=28{,}846$, $p\leq0{,}001$), height of the put ($F(1,57)=13{,}0$, $p\leq0{,}001$), angle of release ($F(1,57)=9{,}552$, $p=0{,}003$). Significant effect of Technique factor was obtained for: the angle of the right shoulder ($F(1,57)=5{,}461$, $p=0{,}002$), shoulder-hip separation ($F(1,57)=10{,}462$, $p=0{,}002$), horizontal velocity of the put ($F(1,57)=6{,}052$, $p=0{,}017$) and for the angle of release ($F(1,57)=6{,}950$, $p=0{,}011$). The ANOVA revealed a significant effect of Group x Technique interaction for: the angle of the right shoulder ($F(1,57)=18{,}377$, $p\leq0{,}001$), angle of the right elbow ($F(1,57)=4{,}574$, $p=0{,}037$), vertical velocity of the put ($F(1,57)=4{,}766$, $p=0{,}332$), angle of release ($F(1,57)=4{,}887$, $p=0{,}031$) and distance of the throw ($F(1,57)=14{,}417$, $p\leq0{,}001$).

DISCUSSION and CONCLUSIONS

The comparison of selected release indicators for two different groups of athletes during indoor competition and comparative group from the study of Gutiérrez-Davila [1] has also confirmed that the height of the put at the moment of release had relatively constant and low deviation (AV). Generally, release indicators and the indicators of the path of athletes' center of gravity and the center of the put were observed to be very comparable (low AV) indicators in the shot put. The variability of release indicators was found to be the low variable ones (below 10% according to the AV), especially in group A (stadium) compared to group B (hall). On one hand it could be because of the genetic related factors (on which we have very small influence during training session, like the height of the put and the center of the athlete's center of gravity), on the other hand the higher sport level has caused more stable technique.

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A NOVEL APPROACH TO ASSESS THE POSTURAL CONTROL OF UNSUPPORTED SITTING IN PATIENTS WITH SPINAL CORD INJURY: A FEASIBILITY STUDY

Philippe Terrier (1,2), Anne-Gabrielle Mittaz Hager (3)

(1) Institute for Research in Rehabilitation, Sion, Switzerland
(2) Clinique Romande de Réadaptation, Sion, Switzerland
(3) University of Applied Sciences Western Switzerland, Health and Social Work, Leukerbad, Switzerland

Main topics: Rehabilitation, Functional outcome measures in mobility

INTRODUCTION and AIM

Patients with injuries to spinal cord often exhibit a limited ability to sit unsupported, due to sensory loss and paralysis of trunk muscles. Because unsupported sitting is of utmost importance in daily life activities, it is a privileged target during rehabilitation. However, in order to improve the follow-up of patients, there is still a need for better methods to objectify the capacity to control posture while sitting. Therefore, we designed a standardized test to evaluate smoothness and dynamic stability of trunk movements by measuring accelerations and angular velocities with a wearable inertial sensor. The objective was to explore the feasibility of the method and to present preliminary results obtained in a small sample of patients and healthy individuals.

PATIENTS/MATERIALS and METHODS

Twelve spinal-cord injured males (mean(SD): age 52(12) yr.; time since lesion: 13(13) yr.) and four age-matched healthy controls participated in this feasibility study. The ASIA score of the included patients were: A: N=3; B: N=3; C: N=2; D: N=1; N/A N=2. While sat on an exam table, with the trunk in upright position and feet on the floor, the subject had to perform rhythmically (25 cycles per minute, metronome paced) back-and-forth anteroposterior trunk movements. He had to alternatively touch, with chest and upper-back, two targets (to the front and behind) at the mid-sternum level. The targets were placed to set the amplitude of the movement between -20 and +20 degree, zero being the upright position. Fifteen back-and-forth movements were measured, repeated twice. The inertial sensor (3D accelerometers and gyroscopes) was attached to the lower sternum. The smoothness of the movement was defined as the relative power in the 2Hz-10Hz band: it was hypothesized that impaired motor control would produce substantial noise that would affect the frequency pattern. The local dynamic stability (LDS) of the movement was based on computation of divergence exponents (Lyapunov exponents), a method that has been already proposed to analyse postural control and trunk stability [1,2]. Preliminary statistical analyses were performed to evaluate the repeatability of the measures (intraclass correlation coefficient, ICC) and the difference between the patients and the controls (standardized mean difference, i.e. effect size, ES).

RESULTS

One patient (ASIA A) was not able to complete the test (high risk of fall). In the patients, the repeatability (ICC(A-1), i.e. the absolute agreement among 2 repetitions, N=11) of smoothness index measured from the angular velocity was 0.72 (95% confidence interval (CI): 0.23-0.93). LDS exhibited a repeatability of 0.44 (CI: 0-0.82). Smoothness index was significantly lower in the patients as compared to the controls (ES 0.75, CI: 0.21-1.24). LDS was also lower in the patients (ES 0.94, CI: 0.31-1.98).

DISCUSSION and CONCLUSIONS

With one exception, the patients were able to perform the test without difficulties, even those with a low ASIA score. The investigators and the patients reported a good feasibility of the procedure. Due to the small sample size, no firm conclusion can be drawn from the results (large confidence intervals). A low repeatability of LDS is likely, which indicates that more movement repetitions should be included in the test. We observed that most patients had difficulties to finely tune trunk movements in order to softly touch the targets. They often exhibited a higher power in the 2Hz-10Hz bandwidth, which reflects substantial noise in the motor control. They also likely had lower dynamic stability as compared to the healthy controls. The proposed test seems feasible to evaluate the capabilities of postural control in unsupported sitting. A study will be conducted to compare the scores obtained from this novel approach with other validated scores of postural control.

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GROUND REACTION FORCES DURING LINEAR AND CURVED WALKING TRAJECTORIES

M. Godi (1), A.M. Turcato (1), A. Giordano (1) F. Comazzi (1), M. Schieppati (3,4) A. Nardone (1,2)

(1) Fondazione Salvatore Maugeri (IRCCS), Veruno (NO), Italy
(2) University of Eastern Piedmont, Novara, Italy
(3) Fondazione Salvatore Maugeri (IRCCS), Pavia, Italy
(4) University of Pavia, Pavia, Italy

Main topics: Motor control and motor learning, Analysis of gait and motor disorders.

INTRODUCTION and AIM

During activities of daily living, linear walking is frequently intermingled with turns while moving within the environment [1]. Turning involves complex reorientation of head, trunk, pelvis and feet [2,3,4] and is accompanied by postural adjustments aimed to counteract the centrifugal acceleration acting on the body, in addition to asymmetric motion of the lower limbs, whereby the leg inside the trajectory travels a shorter pathway than the leg outside [2,5]. Knowledge of the pattern of distribution of pressures when walking along curved pathways gives insight into the ground reaction forces (GRF) during turning, and helps understand the way subjects accomplish the task. The present investigation addresses the distribution of the GRF of the two feet, and their relation with the trajectory features and body medio-lateral displacement during curved walking.

MATERIALS and METHODS

Twenty-six healthy young participants, mean age 25.1 ± 4.3 SD were recruited. Subjects walked under three different randomized conditions: linear (Lin) and curved along a circle path (1.2 m radius), clockwise (CW) and counter clockwise (CCW) at self-selected speed. Subjects executed two 20 m trials for each trajectory, making a total of 6 trials. Both feet were instrumented with insoles Pedar-X (Novel, Germany). An accelerometer was fixed to the trunk to detect medial-lateral inclination of the body. We analysed walking speed, stance duration in percent of gait cycle (%GC), GRF of both feet during the entire stance, and trunk inclination.

RESULTS

Spatio-temporal variables. Gait speed was 1.54 ± 0.16 m/s, 1.24 ± 0.17 m/s, 1.24 ± 0.15 m/s during Lin, CCW, CW, respectively. Speed during Lin was faster than during curved walking, and was not affected by the direction of curved trajectory. Stance duration was 62.8 ± 3.1 %GC (average of right and left foot during Lin, Foot-Lin), 62.6 ± 2.3 %GC (average of both feet when inside curved trajectory, Foot-In), and 61.1 ± 2.6 %GC (average of both feet when outside curved trajectory, Foot-Out). Stance duration of Lin foot and Foot-In was longer than that of Foot-Out.

GRF. At heel strike, the peak of GRF was larger in Foot-Lin than Foot-Out, in turn being larger than in Foot-In. During mid-stance, GRF of both Foot-In and Foot-Out was higher than that of Foot-Lin; the Foot-In showed higher GRF values than the Foot-Out. At toe off, the peak of GRF of both Foot-In and Foot-Out was lower than that of Foot-Lin; in addition, Foot-In had lower GRF values than Foot-Out.

Medial-lateral trunk inclination. During Lin, trunk inclination was negligible. On the contrary, curved trajectories were accompanied by an inclination of the trunk toward the centre of the path.

DISCUSSION and CONCLUSIONS

Gait speed during curved trajectory is lower than during Lin due to the need of controlling stability and producing an asymmetric pattern of cyclic activation of the limbs, as suggested by the longer stance duration of the Foot-In with respect to the Foot-Out. During curved trajectory, Foot-Out seems to play a predominant role in steering the body, as shown by the higher value of the GRF during both heel strike and foot off. During mid-stance, Foot-In shows a higher GRF connected with the body inclination towards the centre of the path as if the body pivoted onto it.

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MAXILLO-TEMPORAL JOINTS MOVEMENTS IN SPASTIC PATIENTS

M.Syczewska (1), K.Graff (1), A.Dąbrowska (2), D.Olczyk-Kowalczyk (2), E.Szczerbik (1), M.Kalinowska (1), E.Jelonek (1)

(1) Dept. Neurology, Epileptology, and Paeditaric Rehabilitation, The Children's Memorial Health Institute, Warsaw, Poland
(2) Faculty of Stomatology, Warsaw Medical University

Main topics: please, select at least two topics from the long list of the topics of the conference.

INTRODUCTION and AIM

Patients with spasticity suffer not only from neurological problems but also from stomatological ones, Although their problems are known among dentists there are no studies dealing with these problems. The presence and degree of spasticity is assessed in the upper and lower limbs, but it is known that it could also be present in the muscles of other parts of the body. If spasticity is present in the jaw muscles it could influence its function. Clinically the spasticity is assessed with tests, but also a Wartenberg test, from which several indices are calculated could be used. These indices reflect the damping of the limb movement, and together with maximal velocity are the measure of the degree of spasticity. The assessment of the proper function of maxillo-temporal joints is usually done clinically by the dentists. A new Zebris device is dedicated to measurements of the functions of these joints. The aim of this study was to find out if information about the degree of spasticity in the lower legs taken from the Wartenberg test could be used to predict the degree of spasticity in the jaw muscles, and to see if maxillo-temporal joints movement in spastic patients differ from healthy subjects.

PATIENTS/MATERIALS and METHODS

Two groups of subjects participated in the study: 25 healthy subjects with no history of neurological problems, and 25 spastic patients with Cerebral Palsy. The study was approved by the Ethical Committee of CMHI.
All measurements were done using ultrasound Zebris device dedicated for the maxillo-temporal joints measurements. All subjects had to repeat a series of jaw movements: opening of the jaw (as wide as possible), retrusion movements, left and right, and laterotrusion, left and right. Spastic subjects underwent also instrumented Wartenberg test of lower limbs [1], using VICON MX system.
The collected data were later analysed using Statistica 10.0 software.

RESULTS

At the opening movement the range of left and right joint are correlated: in healthy subjects the correlation is strong: R=0.739, and in spastic subjects moderate: R=0.598. At two other movements there was no correlation between range of left and right joint in healthy subjects, while in spastic patients the statistically significant correlations were found: during retrusion movement R=0.752, during laterotrusion R=0.642. While comparing the results between healthy and spastic subjects we found statistically significant differences in laterotrusion and opening. The Wartenberg indices and maximal velocity were correlated (rang Spearman correlation coefficient) with opening, retrusion, and laterotrusion movements measured with Zebris device. Nearly all correlation were not statistically significant, apart from the correlation between the maximal velocity of the lower limb and laterotrusion movement: R=0.439.

DISCUSSION and CONCLUSIONS

The joint ranges are correlated in healthy subjects only during opening movement, while in spastic subjects during the performance of all three movements. These results suggest that in Cerebral Palsy subjects spasticity is present also in the muscles spanning the jaw, and they negatively influence the ability of the patients to perform the jaw movements. Jaw movements could be restricted by the spasticity of the jaw muscles, but there are no clinical or instrumented methods, which could allow for the assessment of their spasticity. The medium correlation between the maximal velocity of lower limb during the Wartenberg test and laterotrusion movement of the jaw suggest that in patients with Cerebral Palsy the degree of spasticity measured in one body segment reflects its degree is other segments. The positive sign of the correlation shows that higher velocity (i.e. less spasticity) is connected with higher range of lateotrusion jaw movement.

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LIGHTarm: A HIGHLY ADAPTABLE GRAVITY-COMPENSATED EXOSKELETON FOR UPPER-LIMB REHABILITATION AND ADL ASSISTANCE.

G. Spagnuolo (1), M. Malosio (1), J. C. Dalberto (1), M. Caimmi (1), L. Molinari Tosatti (1)
(1) Inst. of Industrial Technologies and Automation, National Research Council of Italy, Milan, Italy

Main topics: Orthotics, Rehabilitation.

INTRODUCTION and AIM

A systematic review of rehabilitation robotics suggests that such devices are well suited for improving proximal upper extremity strength, promoting motor recovery to a greater extent than traditional therapy. Nevertheless, it is still unclear whether the ability to apply programmable forces to the patients' limb is important to improve movement recovery [1]. Indeed, it has not yet been demonstrated the importance of inducing positive effects associated with robotic therapy [2], [3]. In fact, helping a patient to move with robotic actuators may actually decrease the effort and the attention of the patient, especially if the robot can perform the desired movement without contribution by the patient, which in turn may have a negative effect on motor plasticity [4]. Technology that allows patients to perform therapy without robotic actuation may also be effective in improving recovery [5], [6]. In contrast to actuated devices, unactuated and gravity-compensated orthoses are potentially less costly, safer and appropriate for semi-autonomous training at home.

MATERIALS and METHODS

The Institute of Industrial Technologies and Automation of the Italian National Research Council (ITIA-CNR) is involved in the development of *LIGHTarm*, a highly ergonomic passively gravity-compensated exoskeleton for the human upper-limb rehabilitation and ADLs assistance, characterized by a peculiar kinematic structure expressly conceived to face shoulder rhythm and elbow singularity issues, achieving high backdrivability throughout a large exploitable range of motion. Moreover, an optimized spring-based gravity compensation mechanism guarantees a good limb support for impaired people, facilitating upper-limb spatial movements in rehabilitation therapies and activities of daily living assistance.

RESULTS

Multibody simulation results confirm that the upper limb is not affected by its own weight during its necessary movements for rehabilitative tasks, and the reachable ROM results increased in respect to the passive devices at the state of the art.

DISCUSSION and CONCLUSIONS

LIGHTarm is a passive gravity-compensated exoskeleton for upper-limb rehabilitation and ADLs assistance at home. Specific benefits derive from its peculiar kinematic structure (a European patent application is pending). In the next weeks, it will be experimentally assessed by healthy subjects. The first prototype will be presented during the 1st Clinical Movement Analysis World Conference.

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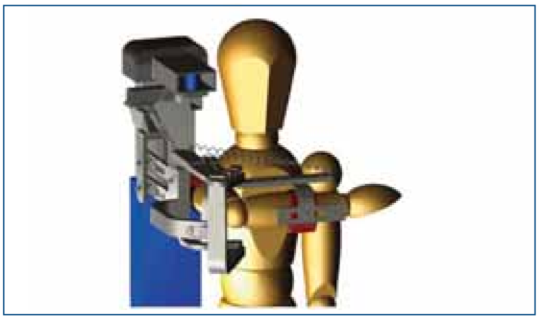

Figure1. CAD model of the LIGHTarm device.

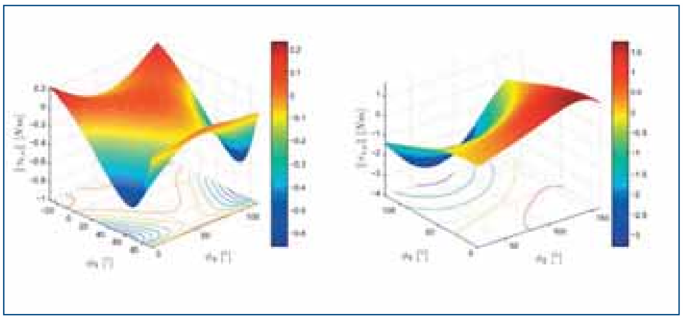

Figure2. Optimized torques loading the shoulder (left) and elbow (right) spring suspension.

TIBIALIS ANTERIOR AND SOLEUS ACTIVITIES DURING PRESWING AND SWING PHASES AND PATHOPHYSIOLOGY OF EQUINUS GAIT IN CHILDREN WITH CEREBRAL PALSY

C. Beyaert [a,b], S. Caudron [b,c], H. Ceyte [b,c], C. Billon [a,b], J. Paysant [a,b]

[a] Motion Analysis Laboratory, Pierquin Rehabilitation Center, Institut Regional de Readaptation, Nancy, France
[b] EA3450 - Development, Adaption and Disadvantage. Université de Lorraine
[c] UFR STAPS Villers-les-Nancy, Université de Lorraine

Main topics: Cerebral palsy, Motor control, Gait, Equinus, Spasticity

INTRODUCTION and AIM

The spastic origin of equinus at initial contact (IC) in children with cerebral palsy (CP) is highly questioned [1]. Last year, we reported in CP children an adaptive ankle dorsiflexion at IC only when wearing negative heel shoes of 10° (NHS) compared to positive heel shoes of 4° (PHS) or walking barefoot while maintaining high early braking of ankle dorsiflexion [2]. We suggested that foot equinus at IC resulted from motor adaptation starting during the swing phase to allow early contribution of the triceps to decelerate ankle dorsiflexion when walking barefoot or walking with SS. The Tibialis anterior (TA) and Soleus (Sol) patterns of activity during pre-swing and swing phase were analyzed and confronted to this hypothesis.

PATIENTS/MATERIALS and METHODS

TA and Sol activities were recorded in 6 (10 affected limbs) out of the 11 studied CP children with spastic triceps walking without assistive device barefoot, with NHS or PHS and compared to controls walking barefoot (n=12). EMG activity was normalized to peak activity across all conditions and to stance or swing phase and averaged on 5 gait cycles.

RESULTS

In CP children walking barefoot or with PHS, at mid- and terminal- swing, TA activity was very low compared to controls whereas Sol activity was similar. With NHS, TA activity increased at pre-, initial- and terminal- swing compared to barefoot condition.

Table 1: Walking speed, ankle kinematics and TA and Sol activity in children with TD and children with CP in all conditions

	TD Barefoot	CP Barefoot	CP NHS (5 first steps)	CP NHS (After 2 min)	CP PHS
Walking speed (dimensionless)	0.44 (0.07)	0.42 (0.07)	0.23 (0.11)*§	0.39 (0.14)	0.37 (0.14)
Peak ankle dorsiflexion at MidSwing (°)	4.7 (3.7)	-1.3 (10.0)§	8.1 (7.0)*	6.1 (6.6)*	7.0 (11.2)*
Ankle dorsiflexion at IC (°)	3.8 (3.7)	-5.2 (5.0)§	5.9 (5.8)*	5.7 (5.5)*	-2.8 (5.8)§
TA at PreSwing (%peak.%stance)	79 (69)	86 (58)	416 (164)*§	157 (121)	28 (33)*
TA at InitialSwing (%peak.%swing)	663 (285)	583 (235)	993 (178)*§	760 (235)*	382 (300)*§
TA at MidSwing (%peak.%swing)	415 (331)	218 (224)	546 (210)§	368 (242)	130 (151)
TA at TerminalSwing (%peak.%swing)	1015 (219)	110 (74)§	417 (242)*§	168 (155)*§	27 (52)*§
Sol at PreSwing (%peak.%stance)	77 (72)	62 (56)	56 (59)	66 (64)	131 (91)§
Sol at InitialSwing (%peak.%swing)	103 (186)	0 (0)	19 (45)	6 (18)	4 (13)
Sol at MidSwing (%peak.%swing)	22 (40)	3 (9)	9 (16)	6 (17)	0 (0)
Sol at TerminalSwing (%peak.%swing)	157 (210)	133 (119)	225 (141)§	121 (77)	95 (128)

NHS, negative heel shoes; PHS, positive heel shoes; IC, initial contact; TA, Tibialis anterior integrated activity; Sol, Soleus integrated activity; * $p<0.05$ compared to CP walking barefoot; § $p<0.05$ compared to TD walking barefoot

DISCUSSION and CONCLUSIONS

The foot equinus appears mainly related to strong reduction in TA activity at mid- and terminal- swing in barefoot and PHS conditions and can be reduced by TA alteration in NHS condition. Early braking of ankle dorsiflexion might play a functional role and be farorized by an equinus pattern when barefoot or with PHS.

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EFFECT OF LEVODOPA AND SUBTHALAMIC DEEP BRAIN STIMULATION ON DUAL TASKING GAIT IN PARKINSON'S DISEASE

Danielli Souza. Speciali (1), Natália Mariana. Luna (2), Rachael. Brant (2), Erich Talamoni. Fonoff (2), Manoel Jacobsen. Teixeira (2), Julia Maria D'Andrea. Greve (2), Wagner. Godoy (1), Silvio. Garbelotti (1), Richard. Baker (3), Paulo Roberto Garcia. Lucareli (4)

(1) Hospital Israelita Albert Einstein, São Paulo, Brazil
(2) Universidade de São Paulo, São Paulo, Brazil
(3) University of Salford, United Kingdom
(4) Universidade Nove de Julho, São Paulo, Brazil

INTRODUCTION and AIM

The effects of bilateral subthalamic nucleus (STN) deep brain stimulation (DBS) and levodopa on gait and cognitive in advanced Parkinson's disease (PD) are not established. Less is known about the effect of stimulation on cognitive function and the capacity to walk while dual tasking [1]. The Gait Profile Score (GPS) and the Movement Analysis Profile (MAP) were developed in order to summarize the data of kinematics and facilitate understanding of the results of gait analysis. The GPS can be broken down to furnish the Gait Variable Score (GVS), based on nine values related to kinematics, and establish a MAP, which describes the magnitude of the deviation of nine individuals variables related to the gait cycle [2]. The aim of this study was to analyze, using GPS/MAP, the effects of levodopa and STN deep brain stimulation on dual task walking in patients with advanced Parkinson's disease.

PATIENTS/MATERIALS and METHODS

Sixteen patients with PD (11 male and 5 female) who were submitted to bilateral high frequency DBS of the STN participated in the study. The gait assessment was conducted using three-dimensional kinematics (SMART-D® BTS) in ON medication and ON DBS condition. All subjects performed single (walking free) and dual walking tasks (arithmetic subtraction regressive test). The label of the markers and the processing of the biomechanical model to obtain kinematic data were performed using Vicon Nexus® software and the Plug in Gait® model. The kinematic data were imported into a spreadsheet, where a mathematical routine was used to calculate the GPS/MAP in different tasks. The data were analyzed using the variance for repeated measures test (ANOVA), with the level of statistical significance set at $p < 0.05$.

RESULTS

Differences were found between tasks (single vs dual walking task) regarding the GPS (left, right and overall) and GVS (knee flexion-extension, ankle dorsiflexion-plantar flexion, pelvic obliquity, pelvic rotation, hip internal-external and foot internal-external rotation). In the comparison of sides, differences were found in the GPS (left and right) and GVS (hip flexion-extension, ankle dorsiflexion-plantar flexion, pelvic obliquity, hip adduction-abduction, pelvic rotation, hip internal-external and foot internal-external rotation).

DISCUSSION and CONCLUSIONS

Everyday walking takes place in complex environments that often require multi-tasking. Hence, dual tasking gait performance reflects everyday ambulation as well as gait automaticity [3]. The changes in GPS/MAP in patients with STN stimulation and levodopa during dual task indicates interference on the gait pattern and suggests that PD patients may be unable to adequately cope with dual tasks.

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INFLUENCE OF MARKER MISPLACEMENT ON THE CALCULATION OF A MULTI-SEGMENT FOOT MODEL – A SIMULATION STUDY

E. Graf (1), S. Schelldorfer, F. Rast, D. Stamm, C. Bauer

(1) Institute of Physiotherapy, Zurich University of Applied Sciences, Winterthur

INTRODUCTION and AIM

Consistency in marker placement is crucial for good repeatability of the Oxford Foot Model (OFM) [1,2]; however, the effect of marker misplacement on the repeatability of the OFM in children has not been studied. Therefore, this study aimed to simulate marker misplacement on the hindfoot and to examine the influence on hindfoot-tibia angle (HFTBA) and forefoot-hindfoot angle (FFHFA).

PATIENTS/MATERIALS and METHODS

One healthy child had markers placed on his left foot and shank and recorded during walking using a Vicon System. Segment coordinate systems (CS) were defined and HFTBA and FFHFA calculated according to the OFM [1].

Misplacement was simulated for three markers: posterior calcaneus (HEE), lateral calcaneus (LCA), sustentaculum tali (STL). For each markers, 100 shifted marker positions were simulated during the static trial using Matlab. The shifted markers were normally distributed on the surface of a hemisphere with a radius of 5 mm and the original marker as pole. During the walking trial with the shifted markers, joint angles were calculated and compared to the original angles. For statistical analysis, root mean square error (RMSE) and coefficient of determination (R^2) were calculated.

RESULTS

For LCA and STL markers, the error was low while the displacement of the HEE marker resulted in higher RMSEs (Table 1). R^2 was close to 1.0 for most conditions but reduced for FFHFA in the frontal plane (HEE: 0.9; LCA: 0.7; STL: 0.8).

DISCUSSION and CONCLUSIONS

Displacements of the HEE marker resulted in larger RMSE than other markers. It defines the origin as well as all axes of the hindfoot-CS. Shifted positions of the HEE marker caused altered angles in all three directions. The STL and LCA markers affect the definition of the CS; but, the effect is reduced as the midpoint between the two markers defines the x-axis.

R^2 displayed small influence of marker misplacement on curve characteristics. Lower R^2 values of FFHFA in the frontal plane could be explained by the smaller range of motion in this segment. This study may help with the interpretation of foot motion measured with the OFM.

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Table 1: Root-mean square error [degree] for hindfoot-tibia (HFTBA) and forefoot-hindfoot (FFHFA) angles due to misplacement of heel (HEE), lateral calcaneus (LCA), and sustentaculum tali (STL) marker

	Sagittal plane		Frontal plane		Transversal plane	
	HFTBA	FFHFA	HFTBA	FFHFA	HFTBA	FFHFA
HEE	1.4 (0.1)	1.4 (0.0)	2.4 (0.1)	1.9 (0.2)	3.3 (0.1)	3.6 (0.1)
LCA	0.2 (0.1)	0.2 (0.0)	0.3 (0.2)	0.4 (0.1)	1.2 (0.1)	1.1 (0.1)
STL	0.3 (0.1)	0.4 (0.1)	0.4 (0.2)	0.5 (0.2)	1.1 (0.1)	1.1 (0.1)

SPASTIC CO-CONTRACTION OF GASTROCNEMIUS MEDIALIS AND PERONEUS LONGUS DURING THE SWING PHASE OF GAIT IN VERY YOUNG HEMIPLEGIC CHILDREN

M. Vinti (1,2), J.M. Gracies (1,2), A. Merlo (3), N. Bayle (1,2), E. Viehweger (4,6), G. Authier (4,6), B. Chabrol (5), C. Boulay (4,5,6)

[1] Université Paris Est Créteil (UPEC), France
[2] AP-HP, Service de Rééducation Neurolocomotrice, Hôpitaux Universitaires Henri Mondor, Créteil, France
[3] Movement Analysis Laboratory, Rehabilitation Department, Reggio Emilia Local Health Unit Correggio, Italy
[4] Gait Lab, Pediatric Orthopaedic Surgery Department, CHU Timone Enfants, F-13385 Marseille, France
[5] Pediatric Neurology Department, CHU Timone Enfants, F-13385 Marseille, France
[6] Institut des Sciences du mouvement, Aix Marseille Université, UMR CNRS 6233, F-13385 Marseille, France

INTRODUCTION and AIM

Spastic cocontraction [1] is a form of muscle overactivity that may alter gait in infant hemiparesis. We quantified EMG activity in Gastrocnemius Medialis (GM) and Peroneus Longus (PL) during the swing phase (SW) of gait in very young hemiparetic children with an equino-valgus pattern [3], comparing the paretic and non-paretic side .

PATIENTS/MATERIALS and METHODS

Ten hemiparetic children (age 3±1, mean±SD) were monitored for GM and PL EMG during gait. The SW was divided into three thirds (initial–T1, middle–T2 and end–T3). In each period, a Cocontraction Index (CCI) , ratio of the Root Mean Square (RMS) EMG from each muscle during that period to the peak 500-ms RMS obtained from voluntary plantar flexion during a selected submaximal state (standing on tiptoes) was measured.

RESULTS

GM and PL CCIs during SW were higher on the paretic than on the non-paretic side (Wilcoxon: CCI_{GM}, p<0.01; CCI_{PL}, p<0.01). When subdividing the SW, there was a cocontraction increase on the paretic side during mid and late SW for GM (Wilcoxon: CCI_{GMT2}, p<0.01; CCI_{GMT3}, p<0.001), and during early, mid and late SW for PL (Wilcoxon: CCI_{PLT1}, p=0.03; CCI_{PLT2}, p=0.014 and CCI_{PLT3}, p<0.001).

DISCUSSION and CONCLUSIONS

GM and PL cocontraction increases may contribute to the equinus on the paretic side. Specifically, PL cocontraction increase might cause the hind-foot valgus at late swing, moving the first metatarsal downwards and pronating the forefoot. Quantification of cocontraction could provide a better understanding of the adverse muscle actions and contribute to better target the therapeutic actions, especially botulinum toxin injection in PL, to improve gait in very young hemiparetic children before orthopaedic deformation.

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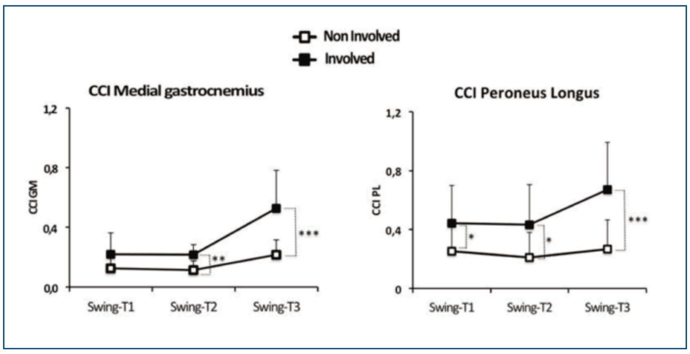
Figure 1: Co-contraction Index (CCI) of Gastrocnemius medialis and Peroneus longus during the swing phase (initial–T1, middle–T2 and end–T3)



THE POTENTIAL OF USING NARMAX FOR MODELLING HUMAN GAIT: CREATING A POLYNOMIAL FIT OF KNEE FLEXION FROM JOINT MOMENTS

C. Stewart (1,2), T. Kyriacou (2), E. Chadwick (2), N. Postans (1), S. Jarvis (1), A. Roberts (1)

(1) ORLAU, RJAH Orthopaedic Hospital, Oswestry, UK
(2) Keele University, Staffordshire, UK

Main topics: Mathematical simulation in human movement science, Analysis of gait and motor disorders

INTRODUCTION and AIM

NARMAX (Nonlinear Auto-Regressive Moving Average model with eXogenous inputs) [1,2] is a polynomial function representing the relationship between the inputs u and the output y of a non-linear system. The importance of each term is given by a measure called the Error Reduction Ratio (ERR). The aim of the NARMAX model methodology is to determine the structure (polynomial terms) and parameters (term coefficients) of the polynomial linking inputs and outputs in order to characterise a system and make predictions.
This study aims to use NARMAX techniques to investigate the feasibility of characterising the relationship between inputs (joint moments) and outputs (knee flexion), exploring the link between cause (kinetics) and effect (kinematics). This first step paves the way towards the ultimate aim of generating predictions.

PATIENTS/MATERIALS and METHODS

3D motion analysis data were collected for one unimpaired subject. Inverse dynamic modelling was performed using Plug-in-Gait (VICON). The subject completed a number of different movements including standing, swaying, jumping, hopping and walking. The resulting trials were trimmed to exclude any data where foot contacts were not on a force plate and resampled to 25Hz. NARMAX modelling techniques were used to construct a polynomial for right knee flexion. 18 input moments were used. A second degree model was used with no input lag (ie no previous values) but an output lag of 2 (allowing 2 previous predicted values to be used). The model was used to fit the knee flexion 10 steps ahead of any known point (ie 400ms). Inspection of the ERR values was performed to gauge the relative importance of the terms in the polynomial.

RESULTS

The form of the polynomial for the right knee is given below, along with detail of the model and its performance.

$y(n) = k - 0.0023\, u1(n) + 0.0017\, u2(n) \ldots - 0.0000013\, u1(n)^2 \ldots + 0.79\, y(n-1) \ldots - 0.000034\, u1(n)\, y(n-1) \ldots$

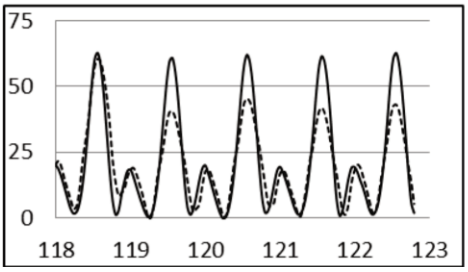


Figure 1: Illustration of true (solid) v fitted (dotted) right knee flexion for gait. Angles are plotted in degrees v time in seconds

	ERR value	Term	Definition
1	27.3	y(n-1)	Previous value of output
2	21.3	u7	Left knee flexion moment
3	11.4	u1	Left ankle flexion moment
4	5.6	u13	Left hip flexion moment
5	5.4	u16	Right hip flexion moment
6	5.0	u3	Left ankle rotation moment
7	5.0	u10	Right knee flexion moment
8	4.8	u6	Right ankle rotation moment
9	3.4	u4	Right ankle flexion moment
10	1.9	u17	Right hip adduction moment

Table 1: Highest ERR values for right knee model

The model gave a good fit across the whole range of movements (Spearman's correlation coefficient of 0.87). Only the gait cycle data is illustrated above (Figure 1). The terms with the highest ERR values were all linear.

DISCUSSION and CONCLUSIONS

A single NARMAX polynomial has succeeded in capturing most of the features of the very diverse movements. Inspection of the gait data alone (Figure 1) shows a good prediction of the two peaked knee flexion profile, with the second peak being somewhat truncated. The terms with the highest ERR values are all linear, and predominantly sagittal plane. Both limbs make significant contributions to the model.

Future work will focus on creating predictive models ie modelling based on input data not used in the creation of the polynomial, with the aim of gaining insights into the dynamics of normal and pathological gait.

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THE EFFECTS OF REHABILITATIVE TREATMENT OF THE TRUNK ON SIT TO STAND MOVEMENT IN ADULTS WITH HEMIPLEGIA

L. Pianta (1), A Scirè (1), E. Tacchini (1), M. Bigoni (1), V. Cimolin (1, 2, 4), M. Galli (2, 3), N. Cau (1, 2, 4), S. Baudo (1), P. Capodaglio (4), A. Mauro (1, 5)

(1) Department of Neurology and NeuroRehabilitation, Ospedale San Giuseppe, Istituto Auxologico Italiano, IRCCS, Piancavallo (Verbania), Italy
(2) Department of Electronics, Information and Bioengineering, Politecnico di Milano, Milano, Italy
(3) IRCCS "San Raffaele Pisana", Tosinvest Sanità, Roma, Italy
(4) Orthopaedic Rehabilitation Unit and Clinical Lab for Gait Analysis and Posture, Ospedale San Giuseppe, Istituto Auxologico Italiano, IRCCS, Piancavallo (Verbania), Italy
(5) Department of Neuroscience "Rita Levi Montalcini", University of Torino, Torino, Italy

INTRODUCTION

Rising from a chair, or Sit To Stand movement (STS), is a significant movement often considered in order to evaluate motor control and the stability in patients with functional limitations; also into clinical evaluation scales. The selective activity of trunk function is a prerequisite for optimal performance of the locomotor system. Also limb movements are allowed by the activation of the stabilizers of the trunk by the anticipatory postural system. Hemiplegic patients often have an impairment or lack of postural symmetry and rapid movements of postural adjustment which are essential for a dynamic and stable STS. This compromises the performance in STS and increases the risk of falls. Training of a symmetrical distribution of the body weight is able to improve the performance in the STS and consequently decrease the incidence of falls. In literature [1,2] some studies were conducted as for STS movement analysis, but to our knowledge no studies quantified the effects of rehabilitative treatment of the trunk. The objective of this study is to quantify the effect of a rehabilitative treatment of the trunk on STS performance in patients with hemiplegia with an optoelectronic system.

METHODS

10 healthy subjects (CG; range: 27-40 years) and 5 hemiplegic patients (PG; range: 34-55 years) were evaluated clinically and instrumentally before (PRE) and after (POST) the treatment. The patient group was subjected to a conventional treatment lasting 60 minutes, plus 30 minutes of specific treatment for the trunk for a total of 10 sessions. Clinical evaluations were conducted using Time Up and Go (TUG) test and Berg Balance Scale. Instrumental evaluation was done using 6-camera optoelectronic system with passive markers (VICON, UK), 2 force platforms (Kistler, CH) and a video system recording. The experimental set up was defined according to literature [3], in terms of markers' position, subject starting position and movement execution. Three STS trials were considered for each subject in each session. In order to quantify the motor strategy during STS execution, some kinematic (shoulder, hip, knee and ankle 3D angles) and kinetic (forces, moments and powers) parameters were identified and calculated.

RESULTS

As concerns clinical evaluation we obtained significant improvements in terms of TUG test (PRE: 38.4 s vs. POST:2 3.8 s) and Berg Balance Scale (PRE: 40.4 vs. POST: 44). Instrumental evaluation of STS displayed improvements in most of patients in terms of movement duration (80% of patients) and trunk range of motion on the sagittal plane (60% of the patients). No other significant changes were found.

DISCUSSION

Our results, although derived from a small sample, seem to confirm that a targeted treatment of the trunk in subjects with paresis / plegia post-stroke can produce significant changes in the performance of the STS and to decrease the risk of falls. Moreover the use of instrumental tools of evaluation such as optoelectronic system can give additional useful informations to evidence treatment efficacy and patient clinical improvements.

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RELIABILITY OF GAIT DEVIATION INDEX IN CHILDREN WITH SPASTIC CEREBRAL PALSY

H.M. Rasmussen (1,2), D.B. Nielsen (1,2), N.W. Pedersen (1,2), S. Overgaard (1,2), A. Holsgaard-Larsen (1,2).
Department of Orthopaedic Surgery and Traumatology Odense University Hospital, Odense, Denmark and Institute of Clinical Research University of Southern Denmark, Odense, Denmark

Main topics: Movement deviation indexes, Reliability and service development.

INTRODUCTION and AIM

Children with cerebral palsy (CP) whom walk independently, corresponding to Gross Motor Function Classifications System (GMFCS) level I and II, often exhibits an altered gait pattern. Instrumented gait analysis (IGA) is used to describe specific gait pattern and impairments. Gait Deviation Index (GDI) is based upon kinematic data from the IGA, and is an overall quantitative index that summarizes the overall gait function into a single score for right and left side of the body for each patient [1]. A GDI value of 100 represents the absence of gait pathology, and each 10-point decrement below 100 indicates 1 standard deviation (SD) from normal gait kinematics. Satisfactory concurrent validity and construct validity of the GDI have been shown in children with CP [1-3]. However, test-retest intra-assessor reliability of GDI in children with CP has not previously been investigated. The aim of this study is to investigate intra-assessor reliability of Gait Deviation Index in children with spastic CP across two repeated sessions.

PATIENTS/MATERIALS and METHODS

18 children (mean age 7.98 years, SD 2.11) with spastic CP (10 unilateral and 8 bilateral), at GMFCS level I and II (9 children at each level). For intra-assessor reliability IGA was completed by one out of three assessor teams on two different days, separated by 0-9 days. The children walked at a self-selected walking speed. The IGA was performed using a 6-camera Vicon MX system, Oxford, UK movement analysis system (100 Hz) with the Plug-in-Gait marker set. The GDI score of five successfully trials, with a consistent velocity (± 15%), were obtained and the median GDI score for each child on the left and right side (a total of 72 GDI scores) were used for further analysis.

Intra-assessor reliability was investigated with calculation of a paired Intraclass correlation coefficient (ICC), Standard error of measure (SEM), and smallest detectable change (SDC) based on 95% confidence intervals.

RESULTS

The reliability for GDI for children with CP was found to be moderate to good. The smallest detectable change with 95% confidence interval was found to be 12.7 to 17.4 points (Table 1). No significant learning effect and/or systematic bias were observed between test and retest since the SEM 95% confidence interval included zero.

Table 1: Results of intra-assessor reliability

Assessor	Patients	Sides *N*	Mean 1 (SD)	Mean 2 (SD)	Mean Diff (SD)	ICC [95% CI]	SEM [95% CI]	SDC
Laboratory	18	36	79.1 (11.9)	79.4 (12.4)	-0.3 (7.4)	0.81 [0.73-0.88]	5.3 [-5.1-15.8]	14,7
Team A	5	10	78.6 (15.3)	81.2 (12.7)	-2.6 (8.6)	0.80 [0.64-0.96]	6.3 [-6.0-18.6]	17.4
Team B	7	14	75.8 (9.9)	74.0 (10.2)	1.8 (7.3)	0.74 [0.57-0.91]	5.2 [-5.0-15.3]	14.3
Team C	6	12	83.4 (11.3)	84.3 (12.8)	-0.9 (6.5)	0.84 [0.84-0.96]	4.6 [-4.4-13.6]	12.7

DISCUSSION and CONCLUSIONS

The present observed moderate to good reliability holds promise for the use of GDI as an outcome in clinical research. However, on an individually level the smallest detectable change was found to be larger than the reported 5-10 points differences in mean GDI between GMFCS level II/III and I/II [3]. Thus, GDI is only applicable as outcome measure for an individual child, if the treatment is expected to change minimum one GMFCS level.

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VALIDATION OF A REMOTE EYE-TRACKER: APPLICATIONS TO GAIT ANALYSIS

V. Serchi (1, 2), A. Peruzzi (1, 2), A. Cereatti (1, 2), U. Della Croce (1, 2)
(1) Information Engineering Unit, POLCOMING Department, University of Sassari, Sassari, Italy
(2) Interuniversity Centre of Bioengineering of the Human Neuromusculoskeletal System, Sassari, Italy

Main topics: Experimental studies in human movement science, technical developments in movement science.

INTRODUCTION AND AIM

Inaccurate visual sampling and foot placement may lead to unsafe walking [1]. The combined use of virtual environments and treadmill allows providing different visual stimuli while walking in a laboratory setting. To analyze the visual strategy, remote gaze eye-trackers (ET) may be used. However, their performance is affected by several sources of inaccuracy, which may compromise the quality of the acquired data [2]. The present study aims at assessing the ET performance under different experimental conditions to determine its limits of usability, precision and accuracy. In particular, we evaluated: a) the range of motion of the head within which the ET can track the eyes gaze (range of trackability, RoT); b) the effect of the subject-ET distance and c) the influence of the visual stimulus location. The ET was tested through static and walking tasks. The selected visual stimuli consisted in dot targets and in static and moving geometrical shapes.

MATERIALS AND METHODS

A remote ET (Tobii, TX300, 300Hz) was used to estimate the point of gaze (PoG) of a healthy adult (h: 1.80m). A LCD monitor (47-inch) was used to display visual stimuli; both the monitor and the ET were centered to a treadmill. Eight markers were attached on the participant's head and on the ET. An optoelectronic system (Vicon, T20, 300Hz) was used to track the head motion. An initial subject-specific gaze calibration was performed with the participant at 650mm from the ET (according to the manufacturer guidelines). To assess the RoT, the subject was asked to look at a dot target while oscillating along the anterior-posterior (tAP), medio-lateral (tML) and the vertical (tV) directions and rotating the head around the vertical direction (rV). To assess the influence of the stimulus location and the effect of the subject-ET distance, the subject was asked to look at 13 dots-grid on the screen while standing at 550mm (st550), 650mm (st650) and 750mm (st750) from the ET. Finally, to test the performance of the ET during gait, the subject was asked to look at 1) 13 dots-grid (walk1) and 2) a static rectangle and a moving T-shaped object (walk2) while walking at 1.1m/s. The subject-ET distance was, on average, of 650mm. For each acquisition, the head range of motion (RoM) was computed from the markers. For each dot target location, bias (b), standard deviation (sd) and maximum error (eMAX) values of the PoG were computed. The b and sd values were averaged over the 13 dot target locations in order to obtain a global description of accuracy and precision. The percentage of the gaze fixations [3], falling in a neighborhood of the static and moving geometrical shapes, was computed.

RESULTS

The RoT and eMAX values during tAP, tML, tV and rV are reported in Table 1. Average b and sd values over the 13 dot target locations were13±4mm for the st550, 8±4mm for st650 and 20±6mm for st750. The variability of b values associated to the dot target locations ranged between 4 and 8mm at the distances analyzed. In walk1, the RoM was always within the device RoTs and b and sd values were similar to those of the static tasks. In walk2 the percentage of gaze fixations was always higher than 90%.

DISCUSSION AND CONCLUSIONS

The RoT along ML and V directions was consistent with the ET specifications (±100mm), while along the AP direction (70mm) was lower than indicated (-150mm). Stimulus locations seemed to not influence the ET accuracy and precision. The mean accuracy decreased when moving away from the optimal distance (650mm): the largest error (20mm) was observed at 750mm distance. In gait, the ET performance was adequate since no gaze loss occurred and accuracy and precision were similar to those of the static tasks. The high fixation percentage during walking suggest that the proposed experimental setup may be used for tracking gaze while watching virtual reality objects during gait.

Table 1: The device range of trackability (RoT) and the maximum error (eMAX) during tAP, tML, tV and rV

Task	*RoT*		e_{MAX}
	min	max	
tAP [mm]	580	790	30[b]
tML [mm]	-150	120	29[b]
tV [mm]	-90	-[a]	28[b]
rV [deg]	-50	50	23[b]

[a] No gaze tracking interruption; [b] [mm].

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NEURO-MECHANICAL ASSESSMENT OF POSTURAL RESPONSES ON A 3D ROBOTIC PERTURBED PLATFORM IN CHILDREN WITH HEMIPLEGIA

C.De Marchis(1), F.Patané(2,3), M.Petrarca(3), S.Carniel(3), M.Schmid(1), S.Conforto(1), E.Castelli (3), P. Cappa(2,3), T.D'Alessio(1)
(1) Biolab3, Department of Engineering, University Roma TRE, Rome, Italy
(2) Department of Mechanical and Aerospace Engineering, "Sapienza" University of Rome, Italy
(3) Pediatric Neuro-Rehabilitation Division, Children's Hospital "Bambino Gesù" IRCCS, (Rome), Italy

Main topics: Robotic devices in human movement science and rehabilitation, Functional outcome measures in mobility, Analysis of gait and motor disorders

INTRODUCTION and AIM
The control of standing posture is an extremely complex task for the Central Nervous System (CNS). Balance impairments are present in a variety of neurological diseases and musculo-skeletal disorders, and dynamic posturography, consisting in the active manipulation of posture and balance, has been recently proposed as a valuable tool to assess the degree of impairment, in particular when it is combined with electrophysiological and kinematic measurements. The aim of the present study is the assessment of differences in the postural responses in a population of children with hemiplegia with respect to control subjects. EMG-related and kinematic indexes are used to characterize the responses of the two studied population samples.

PATIENTS/MATERIALS and METHODS
Five normally developed (ND, age 6-14) and six children with hemiplegia (CH, age 6-12) participated in the study. The exercise consisted of maintaining an upright posture while a perturbation was applied by means of a robotic platform (Rotobit3D [1]). Two different perturbations conditions (FW forward 24° plantar-flexion perturbation and BW 24° dorsi-flexion perturbation) were applied with three different perturbation velocities (30°/s, 48°/s and 80°/s). Every trial was repeated four times for each pair condition/velocity. Surface EMG was recorded bilaterally from hamstrings (HS), quadriceps (QD), triceps surae (TS) and tibialis (TA). EMG amplitude envelopes, together with the bilateral hip, knee and ankle angles within each perturbation, were time normalized on 100 data points to compare different perturbation velocities. Symmetries in the muscular and kinematic postural responses were evaluated in terms of correlation coefficient as a Shape Symmetry Index (SSI). Muscle symmetric response was also evaluated by using the Area Symmetry Index (ASI) as in [2].

RESULTS
Symmetry in muscle and kinematic responses was found significantly different between the two population samples ($p<0.001$). A globally asymmetric postural response is present in CH. Different kinds of perturbation are able to highlight asymmetries in different muscle groups and in different joints (Fig. 1). Hip flexion response and TA muscle are the only to exhibit significant differences in symmetry indexes between populations for all the perturbation conditions. This holds for different kinds of indicators (i.e. ASI and SSI) at the muscular level.

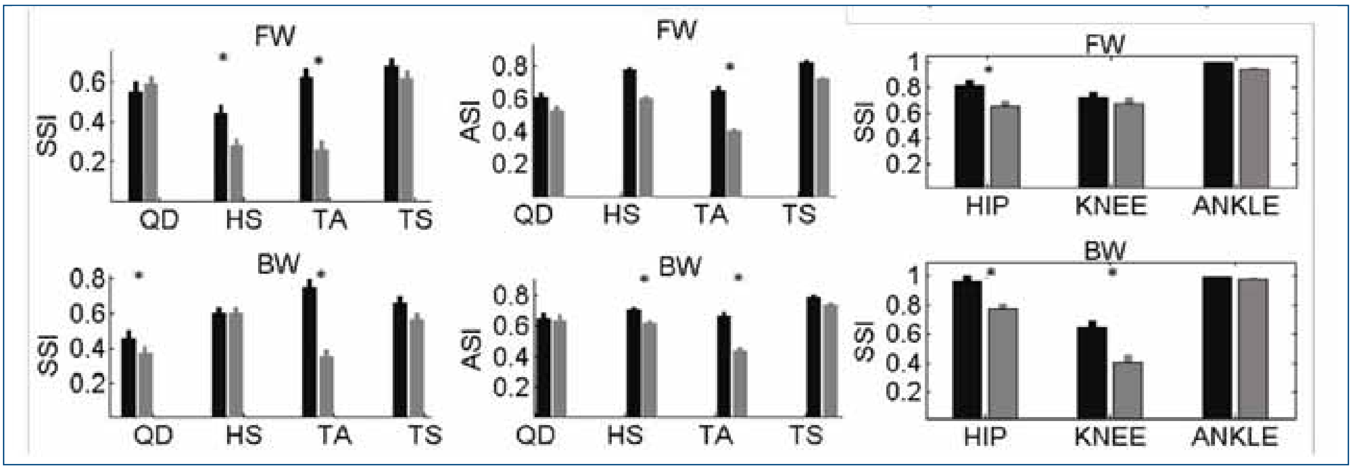

Figure 1: Symmetry indexes for muscle responses (ASI and SSI) and for kinematic responses (SSI) in ND (black) and CH (grey). (*) indicates statistical significance

DISCUSSION and CONCLUSIONS
The use of dynamic posturography protocols with rotational paradigms, combining electrophysiological and kinematic symmetry indexes, significantly highlights differences in the motor control strategies between ND and CH populations. Although specific effect of perturbation condition and duration on different muscle and kinematic symmetric response can be identified, a general and consistent difference in symmetry between ND and CH is present in the muscular response for the TA muscle and for the hip joint.

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A DESCRIPTIVE ANALYSIS OF THE UPPER LIMB MOVEMENT DURING GAIT IN INDIVIDUALS WITH CEREBRAL PALSY

A. Bonnefoy-Mazure (1), Y. Sagawa Jr (2), G. De Coulon (1), P. Lascombes (1), S. Armand (1).
(1) Geneva University Hospitals and Geneva University, Geneva, Switzerland.
(2) CHRU de Besançon, France.

INTRODUCTION and AIM

Patients with cerebral palsy (CP) are characterised by a large diversity of gait deviations; thus, lower limb movements during gait have been well-analysed in the literature [1]. However, the question of upper limb movements and, more particularly, arm movements during gait has received less attention for CP patients [2]. Thus, the aim of this study was to investigate upper limb movements for a large group of CP patients.

PATIENTS/MATERIALS and METHODS

A retrospective search was used, including upper limb kinematic parameters and 92 CP patients (42 females and 50 males, mean ± standard deviation (SD); age: 15.2 ± 6.7 years). The diagnoses consisted of 48 Hemiplegic (HE) and 44 Diplegic (DI). A control group (CG) of 15 subjects was included in the study to provide normal gait data (7 females and 8 males, age: 18.4 ± 8.4 years). For the DI patients and control group, 88 arms and 30 arms were analysed, respectively. For the HE patients, 48 affected arms (HE-A) and 48 non-affected arms (HE-NA) were analysed. The kinematic parameters selected and analysed were shoulder elevation angles; elbow flexion angles; thorax tilt and obliquity angles; hand vertical and anterior-posterior movements; and arm angles [3, 4]. Statistical analyses were performed to compare CG with the affected and non-affected upper limbs of HE patients and with the two upper limbs of DI patients.

RESULTS

The results showed that HE and DI patients have altered upper limb movements. Moreover, DI patients have greater arm angle (Figure 1), shoulder and elbow movements (Figures 2 and 3) compared with HE patients. HE patients adopt different shoulder movements between their affected (HE-A) and non-affected arms (HE-NA). Their non-affected arms have no differences with the arms movements of the CG excepted for the range of motion of their arms.

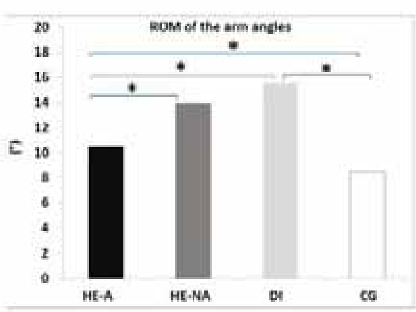

Figure 1: Range of motion of the arms (°) for HE-A, HE-NA, DI and CG during gait.

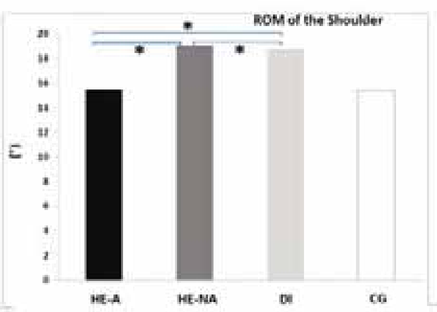

Figure 2: Range of motion of the shoulder (°) for HE-A, HE-NA, DI and CG during gait.

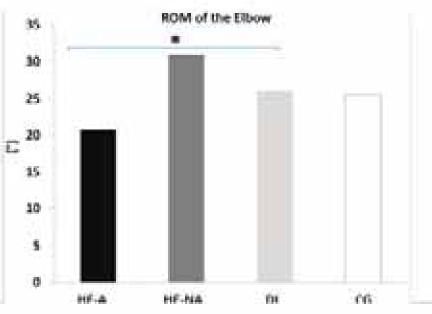

Figure 3: Range of motion of the elbow (°) for HE-A, HE-NA, DI and CG during gait.

DISCUSSION and CONCLUSIONS

Arm movements have an important biomechanical role during CP gait for stabilisation, compensation and to develop strategies that optimise the gait despite the lower limb level impairments and poor balance control. Thus, the patients move their upper limbs especially as gait deviations are important. These observations confirm that the upper limbs must be integrated into rehabilitation programs to improve inter-limb coordination, to decrease energy expenditure and also to improve gait speed and gait patterns [5].

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TRUNK KINEMATICS IN NON-SPECIFIC LOW BACK PAIN PATIENTS FOLLOWING SUDDEN UNLOADING

B Sommer (1,2), B Hinterberger (1,2) FM Rast (1), S Oetiker (1), MJ Ernst (1), RP Kuster (3), SR Lorenzetti (2), CM Bauer (1,4)
(1) ZHAW, Department of Health Sciences, Winterthur, Switzerland
(2) Institute for Biomechanics, ETH, Zurich, Switzerland
(3) ZHAW, Department of Engineering, Winterthur, Switzerland
(4) University of Tampere, School of Medicine, Tampere, Finland

Main topics:
Experimental studies in human movement science, Analysis of clinical movement data

INTRODUCTION and AIM
In recent years, considerable evidence has emerged regarding the importance of altered motor-control and movement patterns in non-specific low back pain (NSLBP) supporting the assumption that motor-control impairments may be a significant factor in NSLBP (1). Deficits in responding to sudden unloading (SU) of the trunk may be associated with NSLBP and were previously assessed using centre of pressure (CoP) measures (2). This study examined if motor-control deficits in responses to SU exist in hip and trunk kinematics of NSLBP-patients.

PATIENTS/MATERIALS and METHODS
23 NSLBP-patients were matched (age, gender) to 22 pain-free participants. The participants sat upright on a bench with their thighs fixated and 10% of body weight attached to their trunk (horizontal force-line) from anterior and posterior, respectively. Participants were asked to maintain upright posture after SU of the weight. Trunk and hip kinematics were measured with inertial measurement units attached to the spinal processes on the height of vertebra T1, L1, S2. Motor control of the spine and hip was evaluated by measuring range of motion (ROM), stabilization time, onset of movement and peak angular velocity. A Kruskal-Wallis-test compared differences between the groups. Percentage of NSLBP-patients out of the norm range (5-95% of pain-free participants range) and corresponding Odds-ratios (OR) were calculated to investigate existence of subgroups.

RESULTS
ROM in the hip joint, after SU from posterior, was significantly increased in the patient group (p=.042). There were no significant differences between groups in movement of thoracic and lumbar spine. NSLBP-patients had an OR of 5.8/3.2 for an increased lumbar/thoracic ROM and an OR of 4.2 for shorter stabilization time in lumbar spine.

DISCUSSION and CONCLUSIONS
The results demonstrated that motor control is compromised in NSLBP-patients. NSLBP patients displayed greater variability, but contrary to previous research on CoP measures (2) did not show deficits in all parameters. In order to determine the factors causing the observed increased ROM of NSLPB-patients further studies are required. Clinicians should consider stability of the trunk of NSLBP-patients during the course of rehabilitation.

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CHANGE OF LATERAL STABILITY DURING THE FIRST YEARS OF INDEPENDENT WALKING

T. Robert (1), A. Van Hamme(1,2), W. Samson(1,2), B. Dohin(3), R. Dumas(1), L. Cheze(1)
(1) Université de Lyon, IFSTTAR, UMR_T9406, LBMC, Université Lyon 1, Lyon, France
(2) Comité Professionnel de Développement Cuir Chaussure Maroquinerie, Lyon, France
(3) Université de Lyon, Laboratoire Inserm U864, Lyon, France

Main topics: Analysis of clinical movement data, Functional outcome measures in mobility.

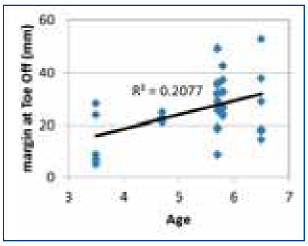
INTRODUCTION and AIM

During the first years of independent walking, gait changes from the toddler's style first gaits to young adult mature and efficient walking. This maturation has been already described for the main kinematic and dynamic parameters such as joint angles, moments and power [5]. However, change in gait stability with age or walking experience has been less documented, even though control of lateral balance while walking is a major challenge [1]. Hof et al. [2] proposed an interesting framework to analyse the control of balance for activities, such as gait, that cannot be considered as quasi-static. It consists of comparing the relative position of the centre of pressure (CoP) to a particular point named "extrapolated centre of mass" (XCoM). At toe off, the CoP must lie more laterally than the XCoM in order to accelerate the CoM toward the contralateral side. Analysis of the distance the frontal plane between these points at toe off events has already produced interesting results for healthy and pathological adult gait [3]. The aim of this study is: 1/ to apply this analysis on children's data; 2/ to provide a first preliminary description of the change of lateral stability with the age for young children.

PATIENTS/MATERIALS and METHODS

For this preliminary study, data from 5 typically developed children, aged between 3.5 and 6.5 years old were processed. Children walked several times at self-selected speed in straight line. Three force platforms, embedded in the walkway, recorded the ground reaction forces, from which the CoP was estimated. Eight Motion Analysis® cameras recorded the trajectories of 18 skin markers located on the lower limbs and trunk. The CoM was extracted from these trajectories using regression equations from Jensen [4]. XCoM was estimated as $XCoM = CoM + V_{CoM}/\omega_0$ [2], with $\omega_0=(g/h)^{1/2}$, h the altitude of the CoM, g the gravity ($9.81\ m.s^{-2}$) and V_{CoM} the CoM velocity, obtained by differentiating and filtering (zero-lag filter, cut off at 5 Hz) the CoM positions. Margins between CoP and XCoM were estimated at toe-off (b), and normalized by leg length ($b_{\%}$). Between 4 and 10 toe off events per children could be processed, resulting in a total of 33 values b and $b_{\%}$.

RESULTS



CoP-XCoM margin at toe-off vs. age

Averaged per subjects, margin b and $b_{\%}$ ranged between 14 and 30 mm and 3 and 6% of the leg length, respectively. Both increase with age (cf. Figure), although this relation is only close to be significant for $b_{\%}$ ($R^2=0.21$, $p<0.05$ and $R^2=0.11$, $p=0.06$, respectively).

As a comparison, b and $b_{\%}$ values reported [3] for healthy adults were about 16 mm, while those for the prosthetic side of above knee adult amputees were about 27 mm (comparable to the results of 6 years old children from this study).

DISCUSSION and CONCLUSIONS

Margin between CoP and XCoM tend to increase between 3 to 6 years old, even if they are normalized by the leg length. It indicates that older children could tolerate larger lateral perturbation (external perturbation or misplacement of the supporting foot) than younger walkers. However, these margins at 6 years old are still larger than those observed for healthy adults, and comparable to those observed for above knee amputees. We can interpret this as the fact that 6 years old gait is still not fully mature and that some control mechanisms, such as the active control of the CoP during the stance phase, are not yet fully developed. These mechanisms allow reducing the CoP-XCoM margin, leading to a more efficient gait [3]. Nonetheless, further data should be processed in order to overcome the relatively large variability and to confirm these results.

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EFFECTS OF OBESITY ON FUNCTIONAL CAPACITY

Zoltan Pataky[1], Stephane Armand[2], Solange M€uller-Pinget[1], Alain Golay[1] and Lara Allet[3,4]
[1]Service of Therapeutic Education for Chronic Diseases, WHO Collaborating Centre, Department of Community Medicine, University Hospitals of Geneva, Geneva, Switzerland
[2] University Hospitals and University of Geneva, Willy Taillard Laboratory of Kinesiology, Geneva, Switzerland
[3] University of Applied Sciences of Western Switzerland, Physiotherapy, Geneva, Switzerland.
[4] University Hospitals and University of Geneva, Health Care Directorate, Geneva, Switzerland.

INTRODUCTION and AIM

The associations between obesity and functional capacities are multifaceted and complex. In order to develop effective and subject-centered prevention and treatment strategies, a more systematic and more comprehensive approach, which could provide an overview of obese patients' functional deficits and functional decline in daily life activities, is needed. Therefore the aim of this study was to assess the relationships between BMI and walking speed, balance control, sit-to-stand performance (a measure of mass specific lower limb power), and endurance.

PATIENTS/MATERIALS and METHODS

Thirty-six women with a BMI ≥ 30 kg/m^2 and 10 women with normal body weight (BMI between 18 kg/m^2 and 25 kg/m^2) were enrolled in this observational study. The obese group comprised 12 persons with a BMI ≥ 30 and < 35 (obese), 14 subjects with a BMI ≥ 35 and < 40 (severe obesity) and 10 people with a BMI ≥ 40 kg/m2 (morbid obesity). All subjects underwent a clinical examination, a gait test, an endurance test (6 minutes walking test), a mass specific lower limb power test (five times sit-to-stand) and a balance test.

RESULTS

Obese women exhibited slower fast gait speeds ($P < 0.05$) with correspondingly shorter stride length (Table 1), poorer sit-to-stand performance ($P < 0.05$), and endurance ($P < 0.05$) (Figure). However, once the state of severe obesity was reached, additional weight gain (morbid obesity) does not seem to decrease these functional capacities any further.

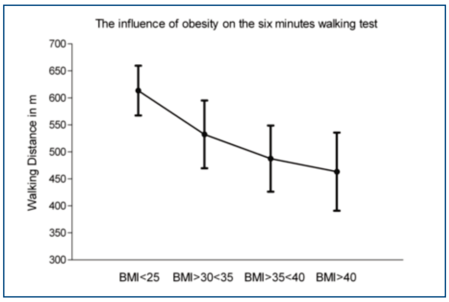

Table 1. Description of spatiotemporal gait parameters per subject group

	Normal Walking			Fast Walking		
MI	Speed (m/s)	Cadence (Steps/min)	Stride length (m)	Speed (m/s)	Cadence (Steps/min)	Stride length (m)
25	1.53 (0.22)	122 (11.51)	1.50 (0.10)	2.11 (0.20)	147 (12.71)	1.73 (0.10)
30<35	1.34 (0.20)	120 (11.47)	1.34 (0.13)	1.82 (0.25)	144 (14.29)	1.52 (0.17)
35<40	1.15 (0.15)	109 (7.31)	1.26 (0.12)	1.73 (0.21)	136 (6.70)	1.53 (0.14)
40	1.18 (0.15)	109 (4.39)	1.29 (0.17)	1.63 (0.19)	130 (7.37)	1.51 (0.19)

DISCUSSION and CONCLUSIONS

This study underlines the importance of assessing obese patients' related physical problems in an early stage of obesity in order to focus exercise regimens and promote appropriate health behaviors.

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VALIDATING THE NEURAL TORQUE COMPONENT WITH EMG DURING MANUALLY CONTROLLED SPASTICITY ASSESMENT OF CHILDREN WITH CEREBRAL PALSY

IM de Jong (1), K Desloovere (2), E Aertbeliën (3), G Molenaers (2), SH Schless (2), L Bar-On (2)
(1) Delft University of Technology Department of Biomechanical Engineering, The Netherlands
(2) KU Leuven Department of Rehabilitation Sciences, Belgium
(3) KU Leuven Department of Mechanical Engineering, Belgium

INTRODUCTION and AIM

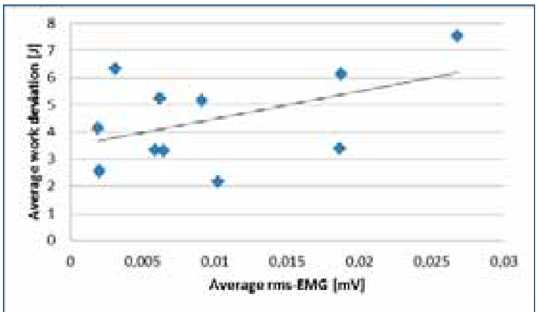
To optimize the treatment of patients with spasticity, it is important that the neural and non-neural components of joint resistance can be distinguished. In a previous study, we adapted a model [1] that represents the properties of muscle stiffness and viscosity of healthy muscle. This model was applied to the torque data collected during passive stretches of the gastroc-soleus at different velocities in children with cerebral palsy (CP). A biomechanical parameter (*work deviation*) that captured those properties that could not be explained by the healthy model was found to be sensitive to the effect of anti-spasticity medication [2]. Work-deviation was therefore attributed to the pathologically increased neural component of joint resistance. In the current study, further validation of this parameter is sought by exploring its relationship to simultaneously acquired electromyography (EMG).

PATIENTS/MATERIALS and METHODS

Ten children with CP (11.5±3.3yrs; bilateral/unilateral involvement=6/4; GMFCS I-II) were assessed using a manually controlled, instrumented spasticity assessment [3]. With the child supine, passive ankle rotations were manually applied at low, medium and high velocity. Joint torque, kinematics, and EMG were simultaneously recorded. EMG was collected from the soleus (Sol) and from the lateral and medial gastrocnemius (LaGa, MeGa, respectively). All tests were performed by the same assessor. The most affected leg was always assessed, except in one child with diplegia who was assessed bilaterally. A model to describe healthy muscle stiffness and viscosity,
, approximated from [1], was applied to the data from the time corresponding to maximum angular velocity to 90% of the range of motion (ROM) and only for the stretches without an EMG onset. The parameters from this estimation (b, k, T_0 and θ_0) were applied to estimate the torque for the stretches with an EMG onset. For the resulting torque-joint angle graph, the average work deviation (E_W) between measured and modeled data was calculated according to: E_W, and normalized per child to their estimated lower leg weight. The average root mean square EMG (rms-EMG) was calculated per muscle from 200ms before till 90% ROM, for only the high velocity stretches. The rms-EMG values of the 3 muscles were summed with the following weighing factors: 3% for LaGa, 6% for MeGa and 91% for Sol [1]. The relation between the summed rms-EMG and work deviation parameter was sought using Spearman rank correlation coefficient ($p<0.05$ indicating significance).

RESULTS

Average work deviation ranged from 2.18-7.53J. Rms-EMG values for LaGa, MeGa, and Sol ranged from 2.55-29.2μV, 2.45-31.5μV, 3.37-17.7μV, respectively. A moderate positive (r= 0.38), but insignificant correlation between the summed rms-EMG and the average work deviation was found (**Fig. 1**).



DISCUSSION and CONCLUSIONS

This small pilot study reports a positive correlation between E_W and the rms-EMG of the plantarflexors during passive muscle stretch. However, the correlation value was low and insignificant indicating that this finding should be supported by larger studies before E_W can be used to represent the neural components of ankle joint resistance in children with CP. Alternatively, more effort can be made to improve the current models by including EMG based parameters.

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THE ZOOSYSTEM: AN OPEN-SOURCE MOVEMENT ANALYSIS MATLAB TOOLBOX

PC. Dixon (1), JJ. Loh (2), Y. Michaud-Paquette (3), DJ. Pearsall (3),
(1) University of Oxford, Oxford, United Kingdom
(2) Medicus Corda, Montreal, Canada
(3) McGill University, Montreal, Canada

INTRODUCTION and AIM

Movement analysis datasets contain numerous variables recorded over time, often, for many subjects, groups, and conditions. Standard sorting, processing, and statistical operations are performed in order to answer research questions. Visualization of the data is also crucial. The zoosystem provides customizable tools and graphical user interfaces to achieve these goals. The aim of this abstract is to demonstrate the key features of the system.

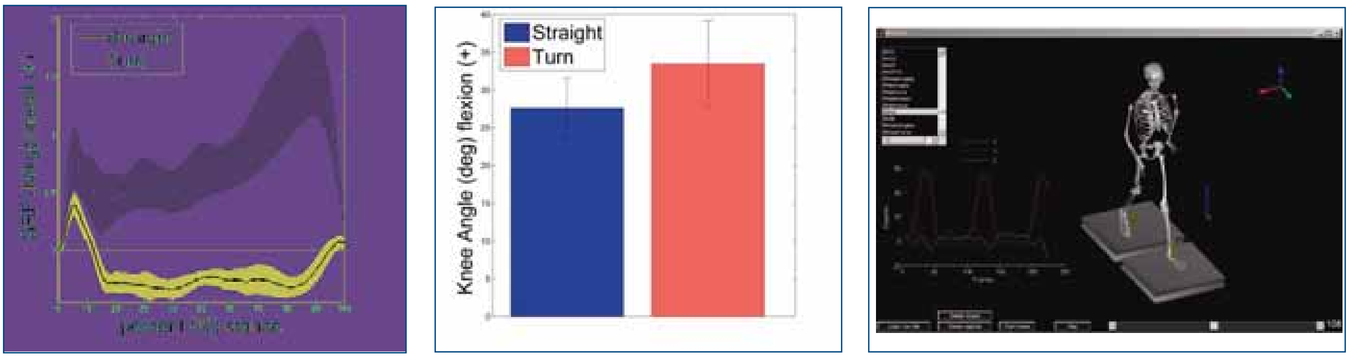
PATIENTS/MATERIALS and METHODS

Gait data from typically developing children (n = 11) performing two walking conditions (straight and turning) were extracted from a laboratory database. For demonstration purposes, we wished to determine if there were differences in maximum medio-lateral ground reaction force (GRF), maximum hip adduction in stance, and knee flexion angle at foot-off between conditions. Thus, GRFs, joint kinematics, and gait events were obtained (Vicon Nexus v.1.7, Vicon, Oxford, UK). Data files (.c3d) were exported for zoosystem processing in Matlab (v2011b, The Mathworks Inc., Natick, USA) running on a windows platform (version 7, Microsoft Inc. Redmont, USA).

A batch processing script containing analysis steps was created. First, data were converted to zoosystem format (.zoo) using the *c3d2zoo* function. Zoosystem files are structured arrays containing a branch for each physical channel of data, each further subdivided into line and event fields. An additional channel stores meta-information. Next, data were partitioned over a single gait cycle (*bmech_partition*). Channels were split by dimension into three sub-channels to ease analysis and visualization (*bmech_explode*). Maximum medio-lateral GRF, maximum hip adduction angle in stance, and knee flexion at foot-off were identified and added to the appropriate event branch (*bmech_addevent*). Data were normalized to 100% of stance (*bmech_normalize*), sorted by condition and graphed (*ensembler),* and visualised in a three-dimensional virtual environment (*director*). Final event data were exported to a spreadsheet (.xls) (*eventval*). Differences between groups were assessed outside of the zoo system using paired t-tests (SPSS v20. IBM corp, Armonk, NY, USA).

RESULTS

All data and m-files are available on-line [1]. Differences were found across conditions for GRFs (Fig.1a), knee flexion angles (Fig. 1b), and hip adduction angles ($p < 0.02$). Data visualization tool identified outliers (Fig.1c).



(a) (b) (c)

Fig.1: a) Medio-lateral GRF curves, b) bar graphs for knee flexion event, and c) director environment.

DISCUSSION and CONCLUSIONS

The zoosystem toolbox represents the work of several years and multiple contributors to provide a generic yet flexible interface to examine large time series datasets. It can be fully integrated into existing frameworks [2]and code is provided in open-source format. Users are encouraged to modify or add modules to meet specific goals. The zoosystem may be of great use to novice programmers and students.

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IMMEDIATE EFFECTS OF A UNILATERAL ANKLE FOOT ORTHOSIS ON GAIT KINEMATICS IN HEALTHY SUBJECTS

Jacqueline Romkes, Katrin Schweizer, Reinald Brunner
Laboratory for Movement Analysis, Children's University Hospital Basle, Basle, Switzerland
University of Basle, Basle, Switzerland

Main topics: Orthotics, Analysis of gait and motor disorders, Outcomes after clinical intervention

INTRODUCTION and AIM

Unilateral ankle foot orthoses (AFOs) are utilized by patients with a pathological initial toe-contact (e.g. drop foot, stroke, hemiplegic cerebral palsy) to restore the first ankle rocker [1]. AFOs block plantarflexion during swing phase of gait enabling certain groups of patients to convert the initial pathological toe-contact into a heel-contact. This exploratory study investigated the influence of a unilateral AFO on lower body gait kinematics in asymptomatic normative adult subjects. Evaluation of the immediate changes of an AFO on healthy gait can help to differentiate between gait deviations/adaptations as a direct effect of the AFO and those caused by the restored first ankle rocker in patients.

PATIENTS/MATERIALS and METHODS

Fifteen healthy subjects (age 24.7±5.0 years) participated in the study. An AFO with the best fit was chosen from three sizes of AFOs with fixed neutral ankle position. The subjects walked barefoot and with an AFO on the right leg, without shoes or socks, along a 10 m walkway at a self-selected speed. The Plug-in-Gait model for the lower body was used to acquire the gait kinematics by motion capture (Vicon, Oxford, UK). All reflective markers, except for the heel marker with AFO, were placed directly on the skin and were not replaced between conditions. Excel and MATLAB software were used for data analysis. The movement curves were normalised to 100% gait cycle. Specific parameters (e.g. peak values) of clinical relevance were compared between the conditions by paired t-tests ($p<0.01$). Furthermore, the 95% confidence intervals (CI) were calculated.

RESULTS

With blocked plantarflexion, the subjects compensated mainly in the sagittal knee and hip angles on the AFO-side (figure 1). Peak hip flexion in terminal swing increased significantly by 5.9±2.9° ($p<0.000$) and peak hip extension in mid-stance reduced significantly by 2.8±1.9° ($p<0.000$) with AFO compared to without AFO. Peak knee flexion in mid-swing increased significantly by 9.2±4.9° ($p<0.000$) whereas peak knee extension in mid-stance was unaffected by the AFO ($p=0.320$). Accept for the latter parameter, all 95% CIs did not overlap.

DISCUSSION and CONCLUSIONS

In contrary to studies investigating the effects of AFOs in patients, this study explored the kinematic adaptations to unilateral blocked plantarflexion in healthy subjects. Blocked plantarflexion by an AFO resulted in compensatory movements in the sagittal knee and hip flexion angle. While the CIs do not overlap, the differences can be regarded as clinically relevant. These kinematic changes can be interpreted as the direct result of the AFO and are not caused by the restored first ankle rocker. The results provide a more complete understanding of the effect of AFOs and the secondary gait adaptations.

ACKNOWLEDGEMENT

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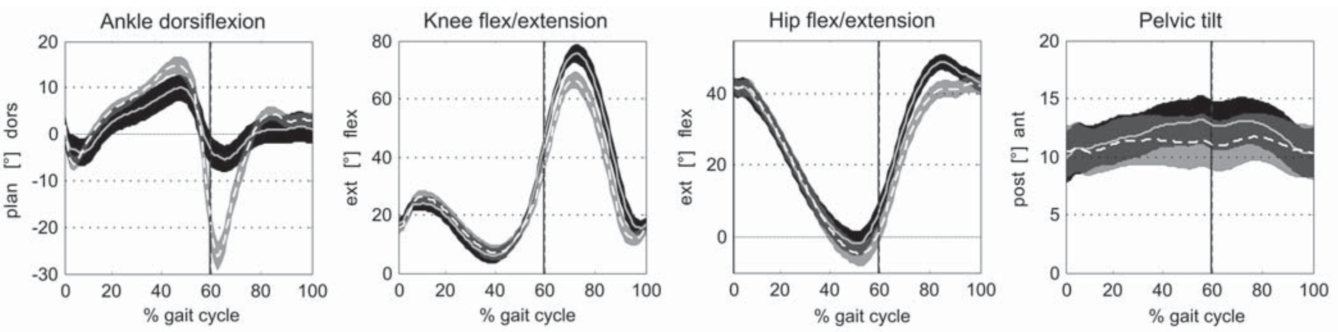

Figure 1: Sagittal plane joint angles for the right leg (goup mean with 95% confidence interval)

PREDICTION OF CEREBRAL PALSY GAIT PATTERNS FROM CLINICAL PARAMETERS WITH STANDARD MACHINE LEARNING TECHNICS

Pablo. Strasser (1,2), Alice Bonnefoy-Mazure (3), Stéphane Armand (3), Alexandros Kalousis (1,2)
(1) Department of Business Informatics, University of Applied Sciences, Western Switzerland
(2) Computer Science Department, University of Geneva, Switzerland
(3) Geneva University Hospitals and Geneva University, Geneva, Switzerland.

Main topics: Cerebral palsy gait, gait prediction, Machine Learning

INTRODUCTION and AIM

Human locomotion involves complex spatiotemporal patterns that are governed by biomechanical, neurological and functional constraints. In pathological gait, many clinical constraints influence gait patterns [1]. The question of how cerebral palsy (CP) gait patterns are encoded in clinical data and how this information can be retrieved is complex and pose a real challenge. Thus, the aim of this study was to evaluate whether clinical measurements are sufficient to reproduce the sagittal plane angles of CP gait. For this, four different standard Machine Learning models were used to predict the lower limb angles and then were compared.

PATIENTS/MATERIALS and METHODS

145 CP patients were included in this study. Thirty-six clinical parameters (range of motion, muscle strength and spasticity of the lower limb) were used as a 36-dimensional vector input data. From the clinical gait analysis, hip, knee and ankle angles of the sagittal plane were selected (101 point time series for each joint angle).
From the experimental data, four standard algorithms were tested: Median, Linear Regression [2], SVM [3], Neural Network (NeuralNet) [4]. Linear Regression was done by Ridge Regression (MOR). SVM was done by rbf nu-SVM using implementation [5]. Neural Network was done by one layer back propagation learning with l_2 regularizer. All angles were treated separately for model learning. The complete data was separated in 10 folds. For every fold, 9 remaining folds were used for training and to predict the joint angle curves of one patient.

RESULTS

The results presented were on the 10 folds cross validation (table 1). All methods were compared against others using two different calculations. The first calculation was separated in two different values concerning the number of time where methods were better and the number of time where methods were worse (compared with a binomial test, *p*<5%). This first calculation only scored how many times algorithms made a worse score without looking of how much. For this, a second calculation (in italic and bold in the table 1) was done to evaluate, on all the instances, the total contribution of the error (compared with a t-test, *p*<5%), in parenthesis is the opposite t-test. The error was calculated with the root mean square error (RMS). In grey are the methods that were significant at least for one measure.

LEFT HIP	RMS	Median	MOR	SVM	NeuralNet
Median	9.2±3.2		79\66(16%) ***5(95%)***	60\85(88%) ***95.5(4.5%)***	57\88(99%) ***100(0%)***
MOR	8.9±3.2	66\79(88%) ***95 (5%)***		53\92(100%) ***100(0%)***	61\94(99.7%) ***100(0%)***
SVM	8.8±4.8	85\60(2%) ***4.5(95.5%)***	92\53(0%) ***0(100%)***		64\81(93%) ***74(26%)***
Neural Net	8.7±4.5	88\57(0.6%) ***0(100%)***	94\61(0.5%) ***0(100%)***	81\64(9%) ***26(74%)***	
LEFT KNEE	**RMS**	**Median**	**MOR**	**SVM**	**NeuralNet**
Median	9.5±3.8		84\61(3%) ***0.2(100%)***	86\59(99%) ***100(0%)***	60\85(98%) ***99.5(0.5%)***
MOR	10±3.7	61\84(98%) ***100 (0.2%)***		49\96(100%) ***100(0%)***	58\87(99%) ***100(0%)***
SVM	9.4±5.2	86\59(1.5%) ***0(100%)***	96\49(0%) ***0(100%)***		77\68(25%) ***18(81%)***
Neural Net	9.6±5.2	85\60(2.3%) ***0.5(99.5%)***	87\58(1%) ***0(100%)***	68\77(80%) ***81(18%)***	
LEFT ANKLE	**RMS**	**Median**	**MOR**	**SVM**	**NeuralNet**
Median	8.0±2.4		66\79(88%) ***18(82%)***	48\97(100%) ***100(0%)***	62\83(97%) ***89(11%)***
MOR	8.2±2.6	79\66(16%) ***82(18%)***		54\91(100%) ***99.7(0.2%)***	71\74(63%) ***98(2%)***
SVM	6.6±2.6	97\48(0.00%) ***0(100%)***	91\54(0.1%) ***0.2(99.7%)***		87\58(0.9%) ***100(0%)***
Neural Net	6.9±2.6	83\62(4.8%) ***11(89%)***	74\71(43%) ***2(98%)***	58\87(99%) ***0(100%)***	

RIGHT HIP	RMS	Median	MOR	SVM	NeuralNet
Median	8.9±3.3		90\55(0.2%) ***0.2(100%)***	58\87(99%) ***96(4.5%)***	67\78(84%) ***63(37%)***
MOR	9.4±3.4	55\90(100%) ***100(0.2%)***		55\90(100%) ***100(0%)***	57\88(100%) ***100(0%)***
SVM	8.8±4.7	87\58(1%) ***4.5(96%)***	90\55(0.2%) ***0(100%)***		72\73(50%) ***21(78%)***
Neural Net	8.9±4.6	78\67(20%) ***37(63%)***	88\57(0.6%) ***0(100%)***	73\72(50%) ***78(21%)***	
RIGHT KNEE	**RMS**	**Median**	**MOR**	**SVM**	**NeuralNet**
Median	9.5±3.8		99\46(0%) ***0(100%)***	69\76(75%) ***100(0%)***	70\75(69%) ***96(4%)***
MOR	10±3.7	46\99(100%) ***100(0%)***		44\101(100%) ***100(0%)***	47\98(100%) ***100(0%)***
SVM	9.7±5.8	76\69(31%) ***0(100%)***	101\44(0%) ***0(100%)***		71\74(63%) ***94(6%)***
Neural Net	9.9±5.9	75\70(40%) ***4(96%)***	98\47(0%) ***0(100%)***	74\71(43%) ***94(6%)***	
RIGHT ANKLE	**RMS**	**Median**	**MOR**	**SVM**	**NeuralNet**
Median	8.4±3.7		79\66(16%) ***20(80%)***	71\74(63%) ***99.7(0.2%)***	67\78(84%) ***100(0%)***
MOR	8.6±3	66\79(88%) ***80(20%)***		56\89(99.8%) ***94(6%)***	62\83(97%) ***98.5(1.4%)***
SVM	7.9±5.7	74\71(43%) ***0.2(99.8%)***	89\56(0.3%) ***6(94%)***		82\63(6.7%) ***90(10%)***
Neural Net	7.7±5.5	78\67(20%) ***0(100%)***	83\62(4.8%) ***1.4(98.5%)***	63\82(95%) ***10(90%)***	

Table 1: Comparison of the different algorithms (Median, MOR, SVM and NeuralNet) used to predict the lower limb joint angles during the gait cycle.

DISCUSSION and CONCLUSIONS

From these results, it appears that SVM always beat the Median, SVM always beat the MOR, Neural Network beat, the majority of the time, the Median. The first conclusion is that linear method (MOR) doesn't give good results (worse than median) but, on the contrary, non linear methods were better. Secondly, it appears that Neural Network and SVM were mostly tied except in one case where SVM is better than Neural Network. In conclusion, studies of more advanced methods than linear are needed to make predictions of pathological gait. Indeed, clinicians are able to determine the links between clinical data and CGA to interpret gait deviations and choose therapeutic strategies; however, our results highlight the difficulty in finding these links using a mathematical approach.

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A NEW LOWER LEG PROSTHESIS TO IMPROVE LATERAL BALANCE IN PROSTHETIC WALKING

E.S. van Hal (1), E. Otten (1), J.M. Hijmans (2), K. Postema (2)
(1) University of Groningen, University Medical Center Groningen, Center for Human Movement Sciences, Groningen, The Netherlands
(2) Department of Rehabilitation Medicine, University Medical Center Groningen, University of Groningen, Groningen, The Netherlands

Main topics: Technical developments in movement science, Prosthetics, Rehabilitation, Motor control and motor learning, Analysis of gait and motor disorders

INTRODUCTION
The walking pattern of prosthetic walkers differs from that of unimpaired humans. For instance, they tend to stand longer on their sound leg and have a wider stride on the prosthetic side [2,1]. These differences may be explained by a deficient **lateral balance control.** A lack of active muscle control at the prosthetic foot leaves prosthetic walkers unable to actively change the horizontal ground reaction force (hGRF) or the centre of pressure (CoP) under the foot during standing and walking [1]. This forces prosthetic walkers to compensate, for instance by bending their trunk towards the prosthetic side when walking [2]. In order to improve lateral balance control in prosthetic walking a new, patented prosthetic prototype has been developed at the Center for Human Movement Sciences, University of Groningen, the Netherlands.

Prototype
The prototype is connected distally at the prosthetic foot and proximally at the knee (Figure 1). The prototype consists of nine metal bars and six hinges, and allows for sideways motion in the frontal plane only (one degree of freedom). When the hip adductor or abductor muscles contract, the prototype **rotates and translates** the leg with respect to the foot. The foot responds with a coupled but much smaller counter-rotation. This results in a combined functional change in hGRF and CoP**.** As such the prototype allows for active lateral balance control.

Figure 1. Lateral (left) and frontal (right) views of the prototype, mounted on a prosthetic simulator between the (right) foot and knee

PATIENTS/MATERIALS and METHODS
The prototype has been tested on 15 healthy individuals wearing a prosthetic simulator (Figure 1). A direct comparison between the prototype and a classic prosthetic setup has been made, outcome measures being functional hGRF and CoP excursions during standing and walking.

EXPECTED RESULTS, DISCUSSION and CONCLUSION
Expectations are that small functional variations will be seen in the CoP pattern under the prosthetic foot during standing and walking. This is an indication of an improved lateral balance control, and will result in better performance of activities of daily living, an improved safety during walking, and an improved quality of life.

ACKNOWLEDGEMENTS
This study is being performed on behalf of research center SPRINT.

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ANALYSIS OF LOADING OF OPERATED AND NON-OPERATED LIMB DURING WALKING AFTER TOTAL KNEE REPLACEMENT

M. Kubisová, Z. Svoboda, M. Janura
Faculty of Physical Culture, Palacký University, Olomouc, Czech Republic

Main topics: Analysis of gait and motor disorders, Orthopaedics

INTRODUCTION and AIM

The increasing prevalence of total knee replacement (TKR) emphasizes the need to appropriately assess post-operative outcome of this procedure [1]. The aim of this study was to compare the differences in ground reaction force variables during gait between the operated and non-operated limb about one year after surgery.

PATIENTS/MATERIALS and METHODS

Twelve patients (8 female, 4 male, age 70.7±8.6 years, weight 80.8±, and 1.3±0.62 years after surgery) after TKR participated in this study. For ground reaction force measurement two Kistler force plates 9286AA (Kistler Instrumente AG,) were applied. Gait was performed barefoot at self selected speed, 6 successful trials per person were assessed. The load was assessed using the basic parameters of the components of ground reaction force. All calculations and statistical procedures were carried out in Statistica 10.0 (Stat-Soft, Inc.,). Differences between operated and non-operated limb were assessed by the Wilcoxon test and the effect size – Cohen's d.

RESULTS

The results showed that the difference between values of the first vertical peak is statistically significant (see Table 1). The operated limb produced less force than the non-operated one. Medium effect sizes were found for time of propulsion peak, force impulse in medial direction and braking force impulse. Time of propulsion peak was longer by operated limb by 4.9%. Medial force impulse and braking force impulse were higher by operated limb.

Table 1: Mean values of force variables for operated and non-operated limbs.

	Operated limb		Non-operated limb		Significance	
Variable	Mean	SD	Mean	SD	p	Cohen's d
F1 (N/kg)	3.3	2.3	3.2	2.1	0.695	0.06
F2 (N/kg)	-4.7	2.7	-3.1	4.5	0.099	0.43
F3 (N/kg)	-9.5	3.7	-9.8	3.2	0.875	0.09
F4 (N/kg)	10.6	5.2	8.9	5.7	0.239	0.30
F5 (N/kg)	102.8	8.0	106.7	8.2	0.028	0.48
F6 (N/kg)	102.2	10.7	104.4	6.5	0.272	0.25
F7 (N/kg)	87.2	9.6	89.8	6.4	0.433	0.32
I1 (Ns/kg)	0.4	0.5	0.2	0.7	0.272	0.29
I2 (Ns/kg)	-0.3	1.9	1.1	1.8	0.182	0.74
I3 (Ns/kg)	-2.0	1.2	-2.7	1.1	0.071	0.55
I4 (Ns/kg)	1.9	0.9	1.5	1.2	0.239	0.32
I5 (Ns/kg)	38.2	15.0	40.3	16.8	0.754	0.13
I6 (Ns/kg)	38.9	14.1	44.2	21.2	0.084	0.29
I7 (Ns/kg)	77.1	25.8	84.5	35.0	0.272	0.24

Legend: F1, lateral peak; F2, medial peak; F3, braking peak; F4, propulsion peak; F5, first vertical peak; F6, second vertical peak; F7, minimal vertical force; I1, lateral force impulse; I2, medial force impulse; I3, braking force impulse; I4, propulsion force impulse; I5, first vertical force impulse; I6, second vertical force impulse; I7, total vertical force impulse SD, standard deviation

DISCUSSION and CONCLUSIONS

The outputs indicate that even one year after surgery patients rest their limb and put more load on the non-operated one. So they increase the loading of the opposite knee. Therefore the subsequent physiotherapy should be focused not only on the range of motion enlargement and strengthening the muscles but also on an improvement of walking stereotype and on the load equalization of both limbs. Further research with a larger number of subjects and observation before and after surgery would be appropriate.

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UPPER BODY MOVEMENT ANALYSIS DURING SIT-TO-STAND IN TYPICALLY DEVELOPING AND CEREBRAL PALSY CHILDREN USING INERTIAL SENSORS

A. Summa [(1)], G. Vannozzi [(1)], F. Paradisi [(1,2)], M. Iosa [(2)], D. Morelli [(2)], A. Cappozzo [(1)]
(1) Interuniversity Centre BOHNES - University of Rome “Foro Italico”, Rome, Italy.
(2) IRCCS Fondazione Santa Lucia, Rome, Italy

Main topics: Analysis of clinical movement data, Experimental studies in human movement science.

INTRODUCTION and AIM

The sit-to-stand movement (STS) is a biomechanical demanding task which requires high levels of neuromuscular coordination, muscle strength and static and dynamic postural control during horizontal and vertical momentum transfer [1]. All these abilities are impaired in children affected by cerebral palsy (CP) with respect to typically developing children (TD). The literature reports between-group differences based on STS phase durations, kinematic, kinetic and electromyographic parameters. Even though not in CP patients, magneto inertial sensors (MIMUs) has already been fruitfully used to characterize STS using a single sternum-mounted MIMU [2]. Aim of this study was to characterize the upper body movement of CP patients during STS using a multi-sensor MIMU protocol. The analysis was expected to highlight the differences between STS parameters in both groups and to identify the presence of pathology-dependent correlations between the same parameters, as caused by motor and neurological disease in CP children.

PATIENTS/MATERIALS and METHODS

Two age- (2-9 years) and gender-matched groups of 20 TD and of 19 CP children were recruited for an instrumented STS test. Three MIMUs (Opal APDM, sampling frequency 128 Hz) were positioned at head, sternum and pelvis level respectively, using appropriate elastic bands, recording 3D acceleration, 3D angular velocity, and body segment orientation. STS task and sub-phases durations and kinematics (peak and peak-to-peak acceleration and angular velocity, angular acceleration, relevant maximum jerk) were computed in MATLAB based on angular velocity peaks in the sagittal plane (gyroSP) and on the antero-posterior acceleration (accAP) [2]. Angular 3D movements (peaks and range of motion - ROM) of the rotation around each anatomical axis) were estimated at all anatomical levels. The average values of the above mentioned variables over three trials for each participant were used for successive statistical analysis. Spearman correlation test ($p<0.05$) was performed for both CP and TD groups to extract movement-dependent and pathology-dependent correlations ($r>0.7$) between temporal and kinematic parameters. A Multiple Analysis of Variance (MANOVA) was also performed to analyse between group differences ($p<0.05$).

RESULTS

Pre seat-off and post seat-off (pSOd) durations were positively correlated with the initial (from start to maximal trunk flexion) and final (from maximal trunk extension to the end) STS sub-phases durations, respectively. They also correlated with trunk angular acceleration in the sagittal plane only in CP. STS total duration positively correlated with pSOd, more in CP than in TD, differently from pre sit-off duration in both groups. Moreover, pSOd was significantly higher in CP than in TD ($p<0.05$). Peak to peak (p2p) values of the pitch angle at the pelvis level was correlated with p2p of accAP. Moreover, p2p roll correlated with p2p yaw at pelvis and head level, in both groups. The same p2p roll angles were significantly higher in CP than TD ($p<0.05$).

DISCUSSION and CONCLUSIONS

According to Hennington et al. [3], CP differed from TD while performing the STS task as far as temporal and kinematics parameters were concerned. These results confirmed that CP children did not perform the STS movement only in the sagittal plane, but also in the frontal plane, determining higher ROMs in the frontal plane and higher time durations after seat-off than TD. The correlations between p2p angles at pelvis and head levels highlighted the key role of the sternum acting as a hinged joint. The proposed MIMU protocol was able to describe the upper body during STS in terms of temporal and 3D kinematic parameters allowing to translate quantitative STS analysis to in-field clinical applications.

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INFLUENCE OF GAZE TARGET DURING GAIT IN CHILDREN WITH BILATERAL SPASTIC CEREBRAL PALSY

Å Bartonek (1), C Lidbeck (1), E Gutierrez-Farewik (2)
(1) Dept. of Women's and Children's Health, Karolinska Institutet, Stockholm, Sweden
(2) KTH Mechanics, Royal Institute of Technology, Stockholm, Sweden

INTRODUCTION and AIM

In children with cerebral palsy (CP) disturbances in sensation, perception and cognition occur beside impaired motor function [1]. To maintain posture and to position the limbs during gait, persons with CP tend to rely excessively on visual input [2] .The aim of this study was to investigate whether gait in children with bilateral spastic CP (BSCP) was influenced when the children were asked to focus their gaze on a target.

PATIENTS/MATERIALS and METHODS

Thirty-five children with BSCP median age 11.6 years; 8 children GMFCS level I (CP1), 12 level II (CP2), 10 level III (CP3), and 22 typically developing children (TD), median age 9.1. All children underwent a three-dimensional, eight camera, motion analysis (Vicon), with a full-body biomechanical model with retro-reflective markers. The children were instructed to focus their gaze on a red-light lamp (Gaze Target) placed at eye level and thereafter to return to the starting point (No Target). Non-parametric statistics were used. Significant differences were determined at $p \leq 0.05$. Time and distance parameters were normalized [3].

RESULTS

During Gaze Target compared to No Target, TD walked slower ($p=0.010$) with shorter step length ($p=0.023$); CP2 had shorter single support time ($p=0.028$); CP3 had lower cadence ($p=0.013$), lower walking velocity ($p=0.007$) and shorter step length ($p=0.047$), TD had smaller movements in Head SP (sagittal plane) ($p=0.006$), Neck SP ($p=0.017$), Head FP (frontal plane)($p=0.039$), Head TP (transversal plane) ($p=0.008$) and Neck TP ($p=0.011$); CP1 had smaller movements in Head SP ($p=0.05$) Neck SP ($p=0.036$), Head FP ($p=0.025$) and Head TP ($p=0.036$).

DISCUSSION and CONCLUSIONS

Children with BSCP may have difficulties to perceive limb movements primarily observed in CP3 who walked with significantly lower cadence, lower walking velocity and with shorter steps during Gaze Target than No Target. CP1 behaved most similarly as TD reducing head and neck movements, but opposite to TD, without changing time and distance parameters. CP2 did only modify gait by reducing single support time without any movement changes, reflecting less ability to modify gait pattern due to motor disorder.

The GMFCS levels had various solutions when focusing on a visual target, related to differences in motor ability, but possibly also in joint proprioception and spatial perception.

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WALKING SPEED AND MORTALITY AFTER STROKE

Jacques Riad[1], Caroline Hattevig[1], Andrew Roberts[2] and Hemant Ishwaran[3]
1, Dept. Orthopaedics, Skaraborg Hospital Skövde, Sweden
2, Dept. Orthopaedics, The Robert Jones and Agnes Hunt Orthopaedic Hospital, Oswestry, UK
3, Division of Biostatistics, University of Miami, Miami, USA

INTRODUCTION

Stroke is the commonest acquired neurological handicap affecting a million patients in the United Kingdom with almost 40% of patients exhibiting spasticity producing poorer function. Effective treatment to increase mobility including surgery with tendon transfer and tendon lengthening is surprisingly uncommon given the size of the problem.

AIM

To study walking speed and death after stroke.

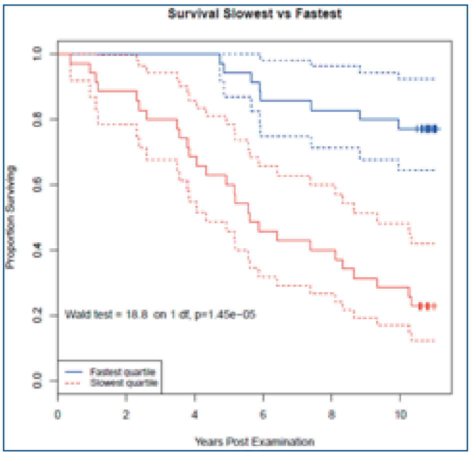
PATIENTS/MATERIALS

253 consecutive patients with stroke were registered at Skövde Hospital, Sweden, 2002. Patients with previous stroke, dementia or an inability to walk at all were excluded. 141 participated and 10 years after stroke 138 patients were traced and followed up to identify whether they had survived.

METHODS

Walking speed over 5 metre bare foot and in shoes was measured between 3 and 5 months after a stroke. Analysis of the relationship between walking speed and mortality was disentangled from the effect of age using a random forest survival technique. Additionally a traditional Cox proportional hazard estimation was performed.

RESULTS



As walking speed increases mortality reduces in a linear fashion until approximately 0.85m/s at which point
further increases in walking speed are related to only a modest reduction in mortality. An inflexion in the age mortality relationship occurs at 74 years of age. Sex has a minor influence on mortality compared with walking speed.
The fastest quartile of patients was compared with the slowest. Slow walking patients had a four fold risk of 10 year mortality compared with the fastest walkers.

DISCUSSION/CONCLUSION

Walking speed is associated with mortality in patients after stroke. Whether this is a relationship that is amenable to manipulation by altering walking speed is untested. Interestingly in an ROC analysis of the walking speed needed to achieve to avoid dying Stanaway et al identified 0.84m/sec as the cut-off point separating those destined for an early grave from the long livers. A probable explanation for the relationship between walking speed and mortality is that slow walking speed results from a person having insufficient spare metabolic energy to allow speedy gait. If the subject's energetic reserve is small, otherwise survivable intercurrent illness has a chance of overwhelming them leading to death.

ASYMMETRIC INTERNAL ROTATION GAIT IN CHILDREN WITH BILATERAL CEREBRAL PALSY: UNI- OR BILATERAL FEMORAL DEROTATION OSTEOTOMY?

M. Niklasch (1), L. Doederlein(2), S. I. Wolf (1), T. Dreher (1)
(1) Department of Orthopaedic and Trauma Surgery, Heidelberg University Clinics, Heidelberg, Germany.
(2) Pediatric Orthopaedic clinic, Aschau, Germany.

Main topics: Analysis of clinical movement data, Analysis of gait and motor disorders, Movement deviation indexes, Outcomes after clinical intervention, Orthopaedics

INTRODUCTION and AIM

Internal rotation gait (IRG) is common among children with CP and is often thought to be a bilateral problem and commonly treated with bilateral femoral derotation osteotomy (FDO) since anteversion angle is often increased bilaterally. However, some authors reported variable outcome after FDO, especially in cases with mild IRG [1,2,3]. Recently, it could be demonstrated that IRG is predominantly a unilateral phenomenon in patients with bilateral CP [4]. A major issue in the treatment is how to identify and address asymmetric IRG. The purpose of this study was to define an asymmetryindex and to evaluate if unilateral treatment is superior to bilateral treatment in patients with large asymmetry.

PATIENTS/MATERIALS and METHODS

109 children with bilateral CP and IRG aged 10.7±3.2yrs that all underwent FDO without any supramalleolar derotation were retrospectively collected. The asymmetryindex was defined as preoperative norm deviation of the difference in hip rotation in stance obtained through gait analysis between both limbs. All patients with an asymmetryindex more than 3 standard deviations larger than normal were selected. 28 patients fit these criteria and were classified into two groups: 1) obtained a *unilateral FDO* (12 patients), 2) obtained a *bilateral FDO* (16 patients). Improvement in asymmetry was calculated as the difference between pre- and postoperative norm (50 typically developed children aged 9.3±3.2yrs) deviation.

RESULTS

Both groups didn't have any significant differences neither in hip rotation in stance on any side pre- and surprisingly also postoperatively nor in asymmetryindex nor in improvement. Hip rotation in stance of the less internal rotated limb didn't change significantly from pre- to postoperatively in both groups even though the derotation angle averaged 25.3° ± 7.6° in the group with bilateral FDO.

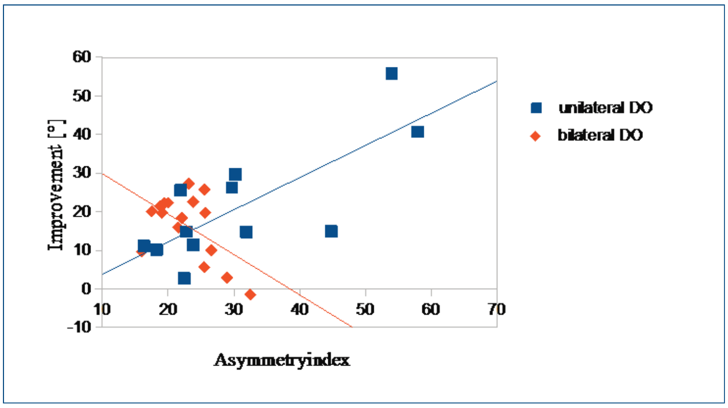


Figure 1: Improvement in asymmetry after FDO comparing the group with unilateral FDO and the group with bilateral FDO

DISCUSSION and CONCLUSIONS

The results of this study suggest that there is no difference in the outcome after FDO concerning hip rotation in gait analysis whether a uni- or bilateral FDO is performed in children with bilateral CP and a large asymmetryindex. Unilateral FDO should be performed in patients with a large asymmetryindex, where the less involved side doesn't exceed 15° of internal rotation [2] independent of physical exam.

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Foot and ankle motion analysis of the support leg in soccer kicks using the Oxford foot model

J. Sasadai (1), Y. Urabe (1), N. Maeda (1), E. Fujii (1), K. Hirata (2)
(1) Graduate School of Biomedical & Health Sciences, Hiroshima University, Hiroshima, Japan
(2) Department of Rehabilitation, Division of Clinical Support, Hiroshima University Hospital, Hiroshima, Japan

Main topics: Experimental studies in human movement science, Rehabilitation

INTRODUCTION and AIM

While much is known about the joint dynamics of the kicking leg, that of the support leg has received little interest in the research literature [1]. The support leg in soccer kicks are exposed to large ground reaction force (GRF) that may influence foot and ankle motion [2]. Therefore, this study aimed to examine foot and ankle biomechanics during maximal instep soccer kicks from three different approach angles.

PATIENTS/MATERIALS and METHODS

Nine male experienced soccer players (age = 23.2 ± 5.1 years, height = 174.5 ± 3.2 cm, weight = 66.8 ± 4.2 kg; mean ± SD) participated in this study. The magnitude and timing of peak GRF and peak angular displacement of the hindfoot relative to tibia (HFTBA), forefoot relative to tibia (FFTBA), and forefoot relative to hindfoot (FFHFA) during instep soccer kicks were compared among three different approach angles (0°, 45°, and 90°, respectively) using a 3D motion analysis system incorporating the Oxford foot model. Kinematic and kinetic data were filtered at 8 Hz and 20 Hz using a digital Butterworth filter. The period from 0% to 100% (from the touch-down to the ball impact) were termed support phase. The data were compared among three approach angles using repeated measures ANOVA. This protocol was approved by the Graduate School of Biomedical and Health sciences, Hiroshima university (ID: 1377).

RESULTS

Maximum vertical GRF were not different significantly among the three kicks. The 45° and 90° conditions of lateral GRF were significantly higher compared with 0° ($P < .05$). Posterior GRF were higher in the order of 0°, 45°, and 90° ($P < .05$). Table 1 shows peak angular displacement of HFTBA, FFTBA, and FFHFA.

Table 1. Comparison of peak angular displacement between three approach angles

Angles	Positive(+) / Negative(-)	0°	45°	90°
HFTBA	Dorsal / Plantar flexion	6.4 ± 5.1*	6.4 ± 5.7	10.2 ± 4.8
	Internal / External rotation	-18.7 ± 4.3*	-20.8 ± 3.4	-20.6 ± 3.2
	Inversion / Eversion	- 5.2 ± 2.9*	- 7.1 ± 3.1	- 8.9 ± 2.5
FFTBA	Dorsal / Plantar flexion	6.8 ± 5.5*†	13.5 ± 3.9	12.7 ± 6.3
	Adduction / Abduction	-20.2 ± 6.1	-23.3 ± 6.0	-21.6 ± 5.0
	Supination / Pronation	-14.0 ± 4.5*†	-23.1 ± 7.2	-22.9 ± 4.1
FFHFA	Dorsal / Planter flexion	- 0.2 ± 5.5	5.8 ± 5.1	1.7 ± 6.1
	Adduction / Abduction	- 2.9 ± 3.8	- 5.5 ± 4.8	- 3.7 ± 4.2
	Supination / Pronation	- 6.3 ± 2.6*†	-12.1 ± 6.0	-11.0 ± 3.3

* versus 90°; † versus 45° ($P < .05$).

DISCUSSION and CONCLUSIONS

Instep soccer kicks using a high angle of approach increased the lateral GRF, in contrast with posterior GRF. It may cause such differences of peak intersegmental angular displacement, e.g. eversion of HFTBA and pronation of FFTBA and FFHFA (Table 1). In our results, differences in pronation of FFTBA and FFHFA were greater than other parameter especially, therefore forefoot motion is likely to be affected by the approach angles. Inoue et al. indicated that ankle joint works exclusively for absorbing the large GRF from the result of ankle moment and angular velocity during instep kicks [3]. It seems that the subjects with foot and ankle impairment, such as ankle instability, may not be able to stabilize their support leg, thus it may cause harmful effect on kicking leg ultimately.

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EFFECT OF TRANSCRANIAL DIRECT CURRENT STIMULATION OF PRIMARY MOTOR CORTEX ON STATIC BALANCE IN HEALTHY INDIVIDUALS

Luanda André Collange Grecco[1]; Natália de Almeida Carvalho Duarte[1]; Roberta Delasta Renan Lima[1]; Hugo Pasini[1]; Manuela Galli[2]; Felipe Fregni[3] e Claudia Santos Oliveira[1].
(1) Doctoral and Master's Program in Rehabilitation Sciences, Nove de Julho University, Brazil
(2) Department of Electronics, Information and Bioengineering, Politecnico di Milano, Milano, Italy
(3) Department of Physical Medicine and Rehabilitation, Spaulding Rehabilitation Hospital, USA

INTRODUCTION and AIM

The effects of transcranial direct current stimulation (tDCS) on cortical excitability of motor cortex with the behavioral effects of increasing movement speed and accuracy have led to the hypothesis that its application to the primary motor cortex may lead to also better balance (reduction in sway). The aim of the present study was to assess the effects of a single session of tDCS applied to the primary motor cortex of the dominant hemisphere on static balance (bipedal and unipedal support with and without visual restriction) in healthy young adults.

PATIENTS/MATERIALS and METHODS

The present exploratory, cross-sectional, open-label study with a blinded examiner received. Fifteen healthy right-handed volunteers with a mean age of 28.2 years participated in the study. Four stabilometric evaluations were performed: 1) 10 minutes prior to tDCS; 2) immediately following the onset of tDCS; 3) immediately following the cessation of tDCS; and 4) ten minutes after the cessation of tDCS. Readings were performed under four conditions: 1) bipedal support with eyes open; 2) bipedal support with eyes closed; 3) unipedal support with eyes open; and 4) unipedal support with eyes closed. A tDCS (anode electrode) of 2 mA was applied to motor cortex (M1) for 20 minutes.

RESULTS

There was a significant reduction in the oscillations immediately following the onset of tDCS (Evaluation 1) and immediately following the cessation of tDCS (Evaluation 2) ($p < 0.05$). The reducing oscillations were not maintained after ten minutes from the end of stimulation (Table 1).
Table 1: Oscillations from COP at four evaluation times (10 minutes prior to tDCS, immediately after onset of tDCS, immediately after 20 minutes of tDCS and 10 minutes after cessation of tDCS)

	Evaluation 1	Evaluation 2	Evaluation 3	Evaluation 4
AP bipedal EO (mm)	24.6(2.7)	18.5(7.4)	11.1(2.8)	13.6(3.6)
AP bipedal EC (mm)	23.4(7.5)	15.6(5.7)	9.8(0.7)	20.3(6.1)
ML bipedal EO (mm)	21.0(3.5)	21.8(8.0)	11.4(2.1)	16.7(3.5)
ML bipedal EC (mm)	24.9(5.0)	20.4(3.2)	12.0(3.4)	27.1(8.0)
AP unipedal EO (mm)	32.6(3.8)	33.5(10.5)	15.3(6.5)	27.7(6.0)
AP unipedal EC (mm)	44.1(8.9)	45.4(16.4)	20.0(1.9)	36.1(13.1)
ML unipedal EO (mm)	35.0(6.4)	46.5(22.7)	17.1(6.8)	48.8(18.7)
ML unipedal EC (mm)	54.3(14.7)	63.0(19.1)	20.3(1.9)	48.6(19.4)

Legend: AP: anteroposterior; EO: eyes open; EC: eyes closed; ML: mediolateral; mm: millimeters

DISCUSSION and CONCLUSIONS

Twenty minutes of tDCS led to a reduction in oscillations from the center of pressure in healthy individuals. However, the results were not maintained for ten minutes after the cessation of the stimulation.

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NET KNEE MOMENT-KNEE ANGLE CHARACTERISTICS OF CHILDREN WITH SPASTIC CEREBRAL PALSY UNDERGOING MEDIAL HAMSTRING LENGTHENING

H. Haberfehlner (1,2), H. Maas (1), A.I. Buizer (2), J. Romkes (3), M. Freslier (3), J.A. van der Sluijs (4), M.M. Witbreuk (4), E. Rutz (3), R. Brunner (3) J.G. Becher (2) R.T. Jaspers (1)
(1) Laboratory for Myology, MOVE Research Institute Amsterdam, Faculty of Human Movement Sciences, VU University Amsterdam, The Netherlands
(2) Department of Rehabilitation Medicine, VU University Medical Center, Amsterdam, The Netherlands
(3) Pediatric Orthopaedic Department, University Children's Hospital Basle, Switzerland
(4) Department of Orthopaedic Surgery, VU University Medical Center, Amsterdam, The Netherlands

Main topics: Analysis of clinical movement data, Outcomes after clinical intervention

INTRODUCTION and AIM

Distal lengthening of the muscle-tendon-complex (MTC) of medial hamstring is a commonly applied procedure within multilevel surgery in children with spastic cerebral palsy (SCP) to increase knee extension. However, recurrence and reoperation rates are high. Improvement of the intervention, requires insight in mechanical muscle properties of SCP children. Therefore, the aims of this study were: (1) to assess how net knee moment-knee angle characteristics of SCP children before surgery differ from those of typically developing (TD) children and (2) to investigate short-term effects of surgical medial hamstring lengthening on net knee moment-knee angle characteristics.

PATIENTS/MATERIALS and METHODS

Knee net moment-angle characteristics were determined in five SCP children before surgical lengthening of medial hamstring muscles and in five TD children (age and gender matched; age range 10-18 years). Three of the SCP children were measured also after surgery (10-20 weeks). Children were positioned on their left side on a treatment table, with the hip of the measured (right) leg at 70° flexion. Pelvis and upper leg were tightly secured. The lower leg was positioned on a low-friction movable plate. Then the lower leg was moved through its range of motion and the net knee moment was assessed at various knee angles in steps of 5°. Data points were excluded when EMG activity of knee extensor and/or flexor muscles exceeded mean rest-EMG level more than two standard deviations.

RESULTS

Two-way ANOVA (mixed model) did not show a significant group effect between SCP children before surgery and TD children (p=0.057) (Fig. 1). However, there was a significant interaction effect between group (SCP and TD) and knee flexion angles at net knee moment ranging from 0-4 Nm (p=0.003). Knee angle at 0 Nm in SCP was not significantly different compared to TD children (p=0.3). Post-surgery, data from three SCP children revealed a mean shift of the 0 Nm knee angle towards knee extension by 20°. In addition, after surgery the slope of the curve was substantially lower (Fig. 2).

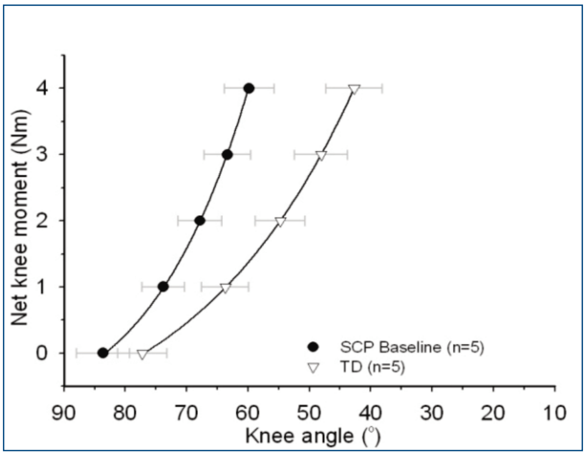

Figure 1: Pre-surgery: Net knee moment–knee angle curves of five SCP and five TD children. Dots express the mean±standard error of the mean.

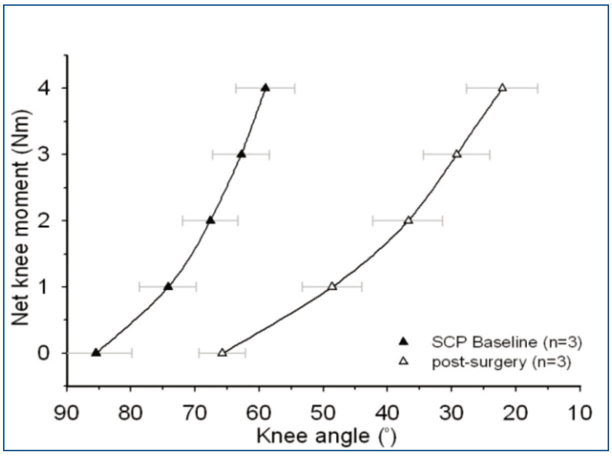

Figure 2: Net knee moment–knee angle curves of repeated measurements of three SCP children before and 10-20 weeks after distal lengthening of the medial hamstrings.

DISCUSSION and CONCLUSIONS

The higher slope of the knee moment-knee angle curve in SCP children indicated for medial hamstring lengthening suggests that knee extension in these children is likely limited due to an increased stiffness of the MTC of hamstring muscles and/or increased stiffness of the knee joint. In the short-term, surgical lengthening causes a shift of the moment-angle curve towards knee extension and a reduction of its slope. These changes are in agreement with the goal of the surgery and could be the result of an increased MTC slack length and decreased MTC stiffness.

THE INFLUENCE OF CROCS SHOE ON ANKLE JOINT MOTION DURING GAIT

Kim H.Y, Ikegami Hisako
(1) Faculty of Policy Studies, Nanzan University, Seto-city, Japan

Main topics: Analysis of clinical movement data, Experimental studies in human movement science

INTRODUCTION and AIM

Shoes not only protect the foot from external stimuli but also play an important role in maintaining the stability of joints of the lower leg and foot during movement. Therefore, shoes have been designed to control the physiological movement of the foot and ankle joint during physical activities such as walking and running [1]. In contrast, in recent years, Crocs shoes, whose basic functions are to emphasize a barefoot-like comfort fit, have gained much popularity. However, the influence of the Crocs shoe on the ankle joint motions has not been investigated. Especially for elderly individuals, careful selection of shoes is required to prevent falls that may occur while walking. Therefore, the purpose of this study was to clarify the effect of Crocs shoe on the ankle joint motion during gait.

PATIENTS/MATERIALS and METHODS

Eight female college students (age, 19.6 ± 0.5 y; height, 160.3 ± 4.8 cm; and weight, 52.1 ± 5.1 kg) were selected as subjects. The subjects walked on a 10-m walkway at a self-selected pace. Photoelectronic sensors were installed at the starting point and goal point to automatically measure travel time. The 3D coordinate data of 30 reflective markers attached to the pelvic area and left/right lower legs were recorded using 10 infrared cameras (Vicon-Nexus, Oxford Metrics Group, Oxford, UK) at a sampling frequency of 250 Hz. Two force plate (1000 Hz) were located at the center of walkway to determine the stance phase during gait. The high-frequency noise of the 3D coordinate data was smoothed using the fourth-order Butterworth low-pass filter proposed by Winter [2]. The 3D angles of the foot relative to the lower leg segments were calculated based on Cardan angle and were performed by the order of xyz rotations. Each time-series curve data was normalized to 100% and converted to an average value. One-way analysis of variance was performed to compare the changes in joint angle (bare foot, normal shoe, and Crocs shoe). In addition, for post-comparison of the average values, Bonferroni multiple comparison was performed. Statistical analyses were performed using the Statistical Analysis System release 9.1.2 (SAS Institute Inc., NC, USA). Significance was set at an α level of ≤ 0.05.

RESULTS

Gait speeds under the three walk conditions were respectively, indicating no statistically significant difference among them. The maximum dorsiflexion showed significant differences according to shoe type, and the Crocs shoes showed the greatest difference(Fig1, Table1). The maximum plantar flexion also showed significant differences according to shoe type. However, there was no statistically significant difference in the changes of the inversion and eversion angles by shoe type.

Table1. Group means and standard deviations for all measured parameters for each experimental condition (Barefoot, Normal shoes, and Crocs shoes)

	Gait speed (m/s)	Dorsiflexion(°)	Plantarflexion(°)	Eversion(°)	Abduction(°)
Barefoot	1.75 ± 0.23	10.3 ± 4.27	-18.6 ± 3.27	-6.54 ± 2.09	-10.6 ± 2.02
Normal	1.81 ± 0.18	11.1 ± 2.24	-15.5 ± 4.26	-6.80 ± 2.52	-8.9 ± 3.12
Crocs	1.76 ± 0.19	17.6 ± 3.25*†	-13.3 ± 3.79*†	-4.79 ± 3.02	-9.4 ± 3.92

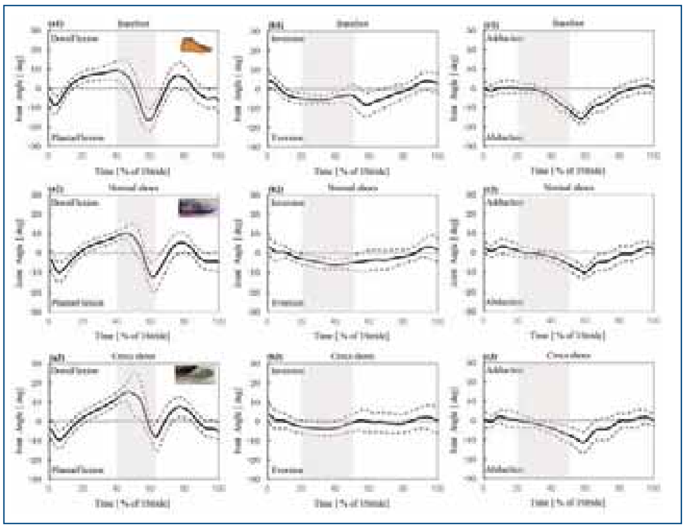

Figure 1: Changes of 3-D ankle joint angle during 1 cycle of gait.

DISCUSSION and CONCLUSIONS

Changes in 3D angles by shoe types appeared similar. However, some angles showed a statistically significant difference. Specifically in Crocs shoes, high dorsiflexion resulted from the fact that the percentage of time for the loading phase was relatively higher than those of the other conditions. This was thought to be characterized by the small and short plantar flexion in the swing phase that compensated for the consequent delay in the stance phase. However, the small and fast plantar flexion in the swing phase can cause stumbling over projections that can exist between irregular support surfaces. The consequential fall can lead to fatal accidents in the elderly. Therefore, Crocs shoes are thought to have a negative influence on elderly individuals. For this reason, we postulate that elderly individuals should refrain from wearing Crocs shoes.

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VALIDITY OF COMPUTER-BASED VIDEO ANALYSIS SOFTWARE FOR THE DETECTION OF FIDGETY MOVEMENTS

LA LarsAdde (1),YH Hong Yang [2], ARJ Alexander Refsum Jensenius [3], RS Rannei Sæther [4], EI Espen Ihlen [5], Jia-yan Cao [6], RS Ragnhild Støen [6]

(1) Department of Laboratory Medicine, Children's and Women's Health, Norwegian University of Science and Technology, Trondheim, Norway AND Clinics of Clinical Service, St. Olavs Hospital, Trondheim University Hospital, Trondheim, Norway
(2) Rehabilitation Department, Children's Hospital of Fudan University, Shanghai, China
(3) Department of Musicology, of ,
(4) Department of Laboratory Medicine, Children's and Women's Health, Norwegian University of Science and Technology, Trondheim, Norway AND Department of Pediatrics, St. Olavs Hospital, Trondheim University Hospital, Trondheim, Trondheim, Norway
(5) Department of Neuroscience, Norwegian University of Science and Technology
(6) Rehabilitation Department, Children's Hospital of Fudan University, Shanghai, China.
(7) Department of Laboratory Medicine, Children's and Women's Health, Norwegian University of Science and Technology, Trondheim, Norway AND Department of Pediatrics, St. Olavs Hospital, Trondheim University Hospital, Trondheim, Trondheim, Norway

Main topics: Movement analysis in clinical practice, clinical decision making processes

The assessment of general movements in young infants can be used as a prognostic tool to identify infants that will develop cerebral palsy, especially during the fidgety movement's period (9-18 weeks post term age) (1). At 6 to 9 weeks post term age general movements (GMs) change from writhing movements to the fidgety movement's (FMs) type(1). Previous studies have shown that FMs can be detected and cerebral palsy can be predicted by use of computer-based video analysis software (2, 3). The aim of this study was to evaluate the validity of computer-based movement variables for the detection of FMs.

PATIENTS/MATERIALS and METHODS

30 low risk preterm infants, 8girls and 22 boys, with mean gestational age 32 (SD 2.7) weeks; mean birth weight 1787 grams (SD 437) were included. Video recordings at mean 44 (SD 0.81) weeks (writhing period) and mean 53 (SD 1.6) weeks (FMs period) were analyzed according to Prechtl's General Movement Assessment and by use of computer-based video analysis software. Motiongrams were used to display examples of the structure of movements from the two periods. The variability of a spatial Centroid of Motion (CoM_{sd}) derived from calculating the pixel difference between subsequent video frames was compared between GM periods.

RESULTS

15 out of 30 videos from the writhing period were classified as poor repertoire, and 3 out of 30 videos from the FMs period were abnormal (2 sporadic and 1 absent). The mean CoM_{sd} was 0.45(SD 0.09) and 0.38(SD 0.08) during the writhing and the FMs period, respectively (mean difference -0.07 (SD 0.1), p< 0.005).

DISCUSSION and CONCLUSIONS

The variability of the spatial Centroid of Motion was significantly lower during the FMs period. This finding supports that the CoM_{sd} reflects small, variable and continual ongoing circular movements in the whole body typically observed as present FMs. This finding is additionally supported by the structure of movement displayed in representative motiongrams shown in Figure 1.

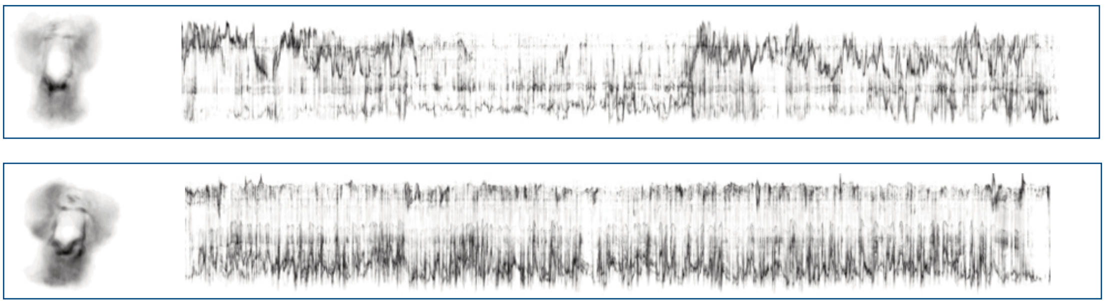

Figure 1: Motiongrams of infant movements with time running from left to right. Upper motiongram is from the writhing movement period and lower motiongram is from the fidgety movement's period. The structure of the movement sequence shows that the infant predominately moved the upper extremities with a stiller period in the middle part of the recording during the writhing period, while a continual movement structure in all extremities is observed in the motiongram from the fidgety movement's period.

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A SIMPLE GEOMETRICAL METHOD TO DETERMINE HIP ROTATION PROFILE DURING CLINICAL GAIT ANALYSIS

A. NAAIM(1-2), A. BONNEFOY-MAZURE(3), R. DUMAS(1), S. ARMAND(3)
(1) Université de Lyon, IFSTTAR, UMR_T9406, LBMC, Université Lyon 1, Lyon, France
(2) CNRFR-Rehazenter, Laboratoire d'analyse du mouvement, Luxembourg, Luxembourg
(3) Willy Taillard Laboratory of Kinesiology, Geneva University Hospitals and Geneva University, Geneva, Switzerland

INTRODUCTION and AIM

The Davis protocol is strongly dependant on the position of a wand on the thigh. Error on the position of the wand can lead to errors in the hip Internal External Rotation (IER) and in knee Abduction Adduction (AA) profiles due to axis misorientation [1]. Several methods have been already proposed to improve the quality of the obtained kinematics, however the correction obtained were not always satisfying [1]. Therefore, the purpose of this study was to propose an aposteriori simple geometrical method allowing reorientating the normal to the frontal plane of the thigh in order to correct hip IER and knee AA.

PATIENTS/MATERIALS and METHODS

The thigh anteroposterior axis is initially constructed thanks to the normal to the plane defined by the hip center, the knee center and the wand marker [2]. The geometrical method proposed in this study aims to correct this axis. First, the sagittal plane of the lower limb is defined by three virtual markers: hip, knee and ankle joint centers. Second, in order to obtain a correct orientation axis of the normal to this sagittal plane, the mean normal has been only calculated when the knee flexion was superior to 20° during the entire cycle. Third, the thigh anteroposterior axis was replaced (reorientated) by the cross product between the mean normal defined previously and the axis formed by the hip and knee joint centers. A gait analysis was performed on one healthy subject with a Vicon® systems using the plug-in-gait model for the placement of the markers. In order to test the method, the thigh wand was intentionally mispositioned at different approximative angles around the thigh (-30°,-15°,15°,30°). The Root Mean Square Errors (RMSE) between the IER the initial condition and of the mispositioned conditions (-30°, -15°, 15° 30°) was also calculated with and without the axis correction the by geometrical method. Moreover, the knee AA amplitude was calculated for each condition. Segment and joint axis definitions and kinematic calculations were performed following ISB recommendations [3].

RESULTS

The geometrical method has permitted to decrease the difference between the initial and mispositioned conditions and the knee AA amplitude (Figure 1 and Table 1). The hip Flexion-Extension and AA angle patterns and amplitudes (not displayed here) were not modified by the geometrical method.

Table 1 : Hip IER RMSE between the initial and mispositioned conditions and knee AA amplitude

		-30°	-15°	initial	+15°	+30°
Hip IER RMSE difference	Without correction(°)	13.0	5.3	0	9.0	15.9
	With correction(°)	2.2	1.2	0	2.7	3.3
Knee AA amplitude	Without correction(°)	9.3	12.7	14.3	16.3	24.1
	With correction(°)	5.7	5.5	4.2	4.3	3.6

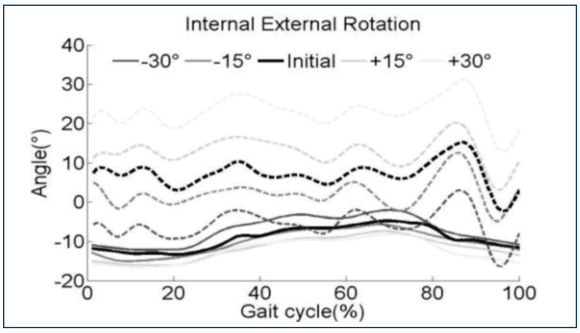

Figure 1: Hip IER during one gait cycle (dashed line: no axis correction, solid line: geometrical method applied)

DISCUSSION and CONCLUSIONS

From these preliminary results, we observed that the geometrical method permits to reduce the error generally due to the thigh axis misorientation. Hip IER becomes less sensitive to wand misposition and the cross-talk phenomenon is reduced for knee AA. There is still a need for a clinical validation and comparison with existing methods of correction. Nevertheless, the proposed geometrical method is a simple method than be performed without any modification of the clinical protocol (not additional markers, no calibration movements …).

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SPATIAL-TEMPORAL VARIABLES OF GAIT IN PATIENTS WITH CHRONIC OBSTRUCTIVE PULMONARY DISEASE

S. Guglielmetti (1), B. Balbi (1), M. Grasso (1), C. Giordano (1), M. Schieppati (3,4), A. Nardone (1,2)
(1) Fondazione Salvatore Maugeri (IRCCS), Veruno (NO), Italy
(2) University of Eastern Piedmont, Novara, Italy
(3) Fondazione Salvatore Maugeri (IRCCS), Pavia, Italy
(4) University of Pavia, Pavia, Italy

Main topics: Analysis of clinical movement data, Functional outcome measures in mobility

INTRODUCTION and AIM

Patients with chronic obstructive pulmonary disease (COPD) show postural instability and gait abnormality [1]. In particular, reduction of gait speed is associated with pulmonary function [2]. However, it is not known if gait abnormality is related to severity of COPD or to postural instability. In this study, we assessed the gait pattern by recording spatial-temporal variables of gait in patients with COPD and in healthy subjects (HS) searching for correlations with either or both severity of disease and balance performance.

PATIENTS/MATERIALS and METHODS

We recruited 33 patients with COPD staged from 1 to 4 according to the Global Initiative for Chronic Obstructive Lung Disease (GOLD) 2007 criteria, and 29 age- and sex-matched HS. The following evaluations were performed in both patients and HS: lower-limb muscle strength (Medical Research Council grades), quadriceps and Achilles' tendon reflexes (Myotatic Reflex Scale), sensation at the level of the big toe (Neuropathy Impairment Score), balance performance (Mini-BESTest, max score = 28), and walking distance (6-minute walking test, 6MWT). Body sway during quiet stance was assessed with a force platform recording two trials with eyes open (EO) and two with eyes closed (EC). Spatial-temporal variables of gait (speed, cadence, step length and width, foot yaw angle, single and double support duration, and cycle duration) were assessed through four walking trials on a 4-m sensorized walkway (GAITRite).

RESULTS

Strength of hip flexor, extensor and abductor muscles was slightly reduced in patients with COPD with respect to HS, whilst strength of leg muscles, as well as tendon reflexes and sensation, were unaffected. The score of the Mini-BESTest was lower in patients with COPD than HS (21.8 ± 4.2 and 24.2 ± 3.2, respectively). The distance travelled by the patients with COPD during 6MWT was 305.5 m ± 89.2, lower than normal value. Sway path with EC was larger in patients (856.4 mm^2 ± 482.7) than HS (600.4 mm^2 ± 233.8), whilst it was only slightly larger with EO. In patients, walking speed was lower than in HS (respectively, 105.4 cm/s ± 23.2 and 118.7 cm/s ± 19). Cadence was reduced in patients (111.1 step/min ± 15.9) with respect to HS (118.3 step/min ± 12.6). Foot yaw angle was larger in patients than HS, being 9.5 deg ± 4.8 and 6.6 deg ± 4.2, respectively. In patients, double support time in percent of the gait cycle (27.7% GC ± 4.4) was longer than in HS (25.4% GC ± 3.3). GOLD stage negligibly affected gait variables, which were instead correlated with body sway, being worse the larger the sway.

DISCUSSION and CONCLUSIONS

In spite of minimal weakness of hip muscles and absence of signs of peripheral nerve disease, patients with COPD have remarkably altered spatial-temporal gait variables. The lack of relationship between disease severity and gait variables points to the insufficiency of the GOLD spirometric stage for predicting gait problems in COPD. On the contrary, the clear relationship of several gait variables with body sway suggests that gait abnormality is connected with balance impairment. These changes cannot be accounted for by only aerobic impairment, as in the case of the reduced performance at the 6MWT, since the assessment of gait variables was performed on a short walkway. We propose that training of balance and gait should be included in the rehabilitation of patients with COPD regardless their GOLD staging.

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SECONDARY EFFECTS OF AN INDUCED KNEE EXTENSION RESTRICTION ON THE LOWER EXTREMITIES DURING GAIT IN HEALTHY YOUNG ADULTS

M. Niederer (1), S. Schmid (2), M. Furrer (2), P. Eichelberger (2), H. Baur (2)
(1) Zurich University of Applied Sciences, Institute for Physiotherapy, Zurich, Switzerland
(2) Bern University of Applied Sciences, Health Division, Discipline of Physiotherapy, Bern, Switzerland

Main topics: 1) Orthopaedics, 2) Analysis of gait and motor disorders

INTRODUCTION and AIM

Major trauma, arthritis, and knee surgery often lead to a contracture at the knee joint [1]. The usual resting position for a swollen knee is about 30° in flexion [2], which is why this position is characteristic for a knee contracture. Therefore, in orthopedic rehabilitation unilateral knee flexion contractures are frequently seen. In order to get a more comprehensive knowledge concerning secondary gait deviations of such a contracture and for planning the best possible treatment thereof, we artificially induced a knee extension restriction to healthy young adults. In particular we wanted to identify secondary gait deviations in both hips, knees, and ankles in the sagittal plane during the stance phase of gait.

MATERIALS and METHODS

Twenty-four healthy adults performed ten walking trials at a self-selected speed at a motion laboratory. Kinematics and kinetics were recorded using a motion capture system, two force plates, and a full body marker set. Two knee conditions (no restriction and 30° extension restriction) were simulated with a knee brace. Sagittal joint angles and joint moments in both hips, knees, and ankles as well as the vertical ground reaction forces (GRF) were parameterized accordingly and compared between the two conditions using paired t-tests (p=0.05).

RESULTS

The analysis revealed significant differences between the two conditions for most kinematic and kinetic outcome variables of interest at the hip, knee, and ankle joint on both sides. The true angle of restriction was less than the angle set on the brace. On average, on the braced side we found increased peak (dorsi)flexion at the knee and ankle, decreased peak hip extension, increased mean extension moments at the knee, decreased peak flexion moments at the hip, and decreased peak plantarflexion moments at the ankle at the 30° knee brace condition. On the contralateral side differences were in general smaller.

Table 1: Values of kinematic and kinetic outcome variables for each condition and both limbs

Variable	Braced side		Unbraced side		t-test (p-value)	
	No Restriction	30° Restriction	No Restriction	30° Restriction	Braced side	Unbraced side
Gait velocity (m/s)	1.08 ± 0.11		1.03 ± 0.10		<0.001	
Peak hip extension (°)	8.2 ± 5.0	5.8 ± 5.0	11.8 ± 4.8	10.8 ± 4.7	<0.001	<0.05
Peak knee extension (°)	−10.7 ± 5.2	−16.1 ± 3.6	−2.8 ± 4.2	−3.5 ± 4.3	<0.001	0.058
Peak ankle DF (°)	21.1 ± 3.0	22.6 ± 2.7	18.1 ± 3.0	18.1 ± 3.1	<0.001	0.909
GRF peak (% bodyweight)	112.3 ± 4.2	110.7 ± 4.3	112.6 ± 4.9	110.9 ± 4.7	<0.01	<0.01
Peak hip flex. moment (Nm/kg)	0.58 ± 0.18	0.54 ± 0.15	0.55 ± 0.18	0.50 ± 0.16	0.081	<0.01
Mean knee ext. moment (Nm/kg)	0.11 ± 0.13	0.20 ± 0.11	0.09 ± 0.14	0.09 ± 0.15	<0.001	0.64
Peak ankle PF moment (Nm/kg)	1.55 ± 0.13	1.52 ± 0.13	1.56 ± 0.12	1.54 ± 0.12	<0.01	<0.05

DISCUSSION and CONCLUSIONS

The results of this study show that an induced sole knee flexion contracture leads to numerous secondary gait deviations on both sides and asymmetric joint loading. These results may suggest that knee flexion contractures should be addressed early in orthopedic rehabilitation in order to prevent long-term abnormal joint loading. Future research should focus on the differentiation between passive physical effects and active compensations by including the measurement of muscle activity and upper body kinematics and kinetics.

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LINARM: A LOW-COST ROBOTIC DEVICE FOR UPPER-LIMB REHABILITATION AT HOME

M. Malosio (1), M. Caimmi (1), L. Molinari Tosatti (1)
(1) Inst. of Industrial Technologies and Automation, National Research Council of Italy, Milan, Italy

Main topics: Robotic devices in human movement science and rehabilitation, Rehabilitation.

INTRODUCTION and AIM

Neurorehabilitation can take advantage of robotic devices designed to assist the patient and the medical personnel during the recovery. Specifically designed robots can partially relieve therapists' physical effort during therapies, make patients independent during exercises, optimize therapist's availability during parallel rehabilitation sessions and make motor function assessments objective. Patients typically benefit of a period of hospitalization in the first weeks after the event, during the acute and part of the sub-acute period, in which neuroplasticity allows the best rehabilitation recovery results. However, experimental studies show that the rehabilitation training can be relevant even in the chronic phase, after the discharge from hospital [1-3]. Some clinical centers can afford the purchase of expensive and complex devices, but these same aspects make them unsuitable for installation and use in majority of rehabilitation centres and at patients' homes. The development of widely affordable devices can represent a breakthrough solution to increase the quality of recovery for a number of neurologically impaired people.

PATIENTS / MATERIALS and METHODS

Taking inspiration from the simplicity and the low number of degrees of freedom of passively constrained rehabilitation devices [4] as the Tailwind, an extremely affordable robotic device, namely *LINarm*, is being specifically developed to perform robot-assisted upper-limb rehabilitation exercises at home (Fig. 1). A variable stiffness mechanism and force-based control strategies allow to adjust the level of assistance on the basis of the actual patient's and therapy requirements. Both mechanics and electronics have been specifically optimized to fulfill low-cost stringent requirements. Many mechanical parts have been specifically designed to be effectively produced by more and more widespread and affordable low-cost 3D printers. Electronics and software components widely exploit open-hardware and open-software elements.

RESULTS

Mechatronic simulation results confirm the good exploitability of the variable-stiffness mechanical structure for rehabilitation purposes. The final software architecture is currently being developed and tested in low-cost control units and the mechanical structure is currently being manufactured and assembled.

DISCUSSION and CONCLUSIONS

LINarm is a low-cost upper-limb rehabilitation device specifically designed to perform robot-assisted therapies at home. Specific benefits derive from its variable-stiffness architecture: adjustable compliancy, safety, suitability to human-robot interaction, cheapness, lightness and compactness. In the next weeks it will be experimentally evaluated by a set of healthy subjects. Its suitability to be exploited in Reaching and Hand-to-Mouth assessment and rehabilitation movements will be evaluated [5]. Two *LINarm*, properly interfaced through a real-time communication protocol, will allow to execute bimanual rehabilitation therapies. The first prototype will be presented during the 1st Clinical Movement Analysis World Conference.

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Figure1. Assembly view of the LINarm prototype (left) and variable stiffness actuation of the handle (right)

STUDY ON GAIT CHARACTERISTICS IN PATIENTS WITH LUMBAR DISC HERNIATION AND EVALUATION OF MASSAGE THERAPY EFFECTIVENSS

Xuchen Tao[1],PT, Gaofeng Zhu[2],MM, Shuyun Jang[1],MD, Yan Yu[1],PT, Xin Kan[1] ,PT,
[1]Massage Department,&[1]Gait Laboratory, Yueyang Hospital of Integrated Traditional Chinese and Western Medicine, Shanghai, China
[2] Hospital of Chinese Medicine , JiaXing city, ZheJiang province, China - Email:taoxuchen1991@gmail.com

Keywords: Gait analysis, Massage Therapy, Lumbar Disc Herniation, effectiveness

INTRODUCTION and AIM

Our study is focusing on the characteristics of lower extremity kinematics parameters in patients with lumbar disc herniation (LDH). The aim of our experiment is to make an assessment of Massage therapy effectiveness on those who have lumbar disc herniation. We also want to explore the feasibility of using gait data in evaluation to the clinical efficacy of massage therapy in order to increase people's awareness of the application of gait analysis when they need to use some reliable and objective method for assessment.

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PATIENTS/MATERIALS and METHODS

20 patients were enrolled as Normal group ,while 40 patients with LDH were enrolled based on the inclusion criteria from the outpatient of massage department in Yueyang Hospital of Integrated Traditional and Western Medicine in China.A trial of clinical efficacy assessments was adopted. Lower extremity three-dimensional gait parameters data was calibrated and evaluated before and after a 20-day course of Massage therapy for patients with LDH.

Table1 **Study sample** （$\overline{X}$ ±SD）

	Age	Height	Weight	Male/Female	Amount
Normal group	31.90±7.80	167.30±7.90	65.50±9.70	12/8	20
LDH patients group	35.90±9.96	169.98±7.49	67.51±9.78	18/12	40

CLINICAL DATA

MPQ-SF scores were statistical significantly decreased in patients with LDH after massage therapy, ($p<0.05$). The statistics indicated that pain could be reduced though massage therapy. ODI scores were statistical significantly decreased in patients with LDH after massage therapy, ($p<0.05$). The results showed that massage therapy is helpful to improve patients' ability of daily life activity.

Table 2: **Change in MPQ-SF, p<0.05** （$\overline{X}$ ±SD）

	Pre-massage Therapy	Post-massage Therapy	t value	P value
PRI Sensory	6.00±1.21	2.30±0.91	12.71	0.000★
PRI Affective	4.33±1.49	1.22±1.09	8.75	0.000★
PRI Score	10.33±2.48	3.56±1.73	11.62	0.000★
VAS	8.36±0.74	2.38±0.69	30.78	0.000★
PPI	3.93±0.78	1.63±0.57	12.38	0.000★
MPQ Total Score	23.23±3.30	7.29±2.09	24.82	0.000★

Table 3: **Change in ODI, p<0.05** （$\overline{X}$ ±SD）

	Pre-massage therapy	Post-massage Therapy	t value	p value
Pain	3.96±0.44	1.11±0.42	24.35	0.000★
Ability of ADL	3.26±0.81	1.26±0.59	10.32	0.000★
Pick up Objects	3.44±0.97	1.59±0.57	8.52	0.000★
Walk	3.26±0.90	1.74±0.59	7.30	0.000★
Sit	3.59±0.80	2.26±0.90	5.75	0.000★
Stand	3.63±0.79	2.26±0.59	7.19	0.000★
Sleep	2.19±1.00	0.41±0.57	8.01	0.000★
Social Activities	3.48±0.70	1.78±0.80	8.32	0.000★
Travel	3.59±1.19	1.48±0.75	7.81	0.000★
ODI Total Score	33.54±6.85	15.24±5.85	12.36	0.000★

GAIT DATA

According to the results, after doing massage therapy, some gait parameters changed. The walking velocity and step length was significantly decreased. The affected lower extremity single support phase was reduced, and double support phase in unaffected lower extremity was also increased. Bilateral lower extremity walking velocity, step length and affected lower extremity single support phase increased ($p<0.05$), unaffected lower leg double support phase increased ($p<0.05$). But statistical significantly differences did not occur for the cadence change in patients with LDH before and after Massage therapy.

Table 4: **Affected vs. Unaffected Lower Extremity vs. Normal Group** ($\bar{X}$ ±SD)

	Affected Lower Extremity	Unaffected Lower Extremity	Normal Group
Gait Parameters	Pre/Post	Pre/Post	
Step Velocity (m/s)	0.81±0.32▲/1.05±0.13	0.81±0.31▲/ 1.06±0.12	1.18±0.17
Cadence (steps/min)	98.16±21.90 /105.16±11.10	97.65±19.52/ 105.15±10.94	109.66±8.29
Step Length (m)	0.47±0.14▲ / 0.61±0.06	0.48±0.13▲/ 0.59±0.03	0.65±0.07
Single Support Time (Gait Cycle%)	35.71±7.13▲/ 39.54±2.00	38.38±4.23/ 38.40±2.61	39.51±1.07
Initial Double Support Time (Gait Cycle%)	11.33±3.95 / 11.29±1.45	13.85±4.93▲/ 10.90±2.76	0.81±0.89

Affected vs. Unaffected Extremity vs. Normal ($p<0.05$)

table 5: **Change in Affected Lower Extremity** ($\bar{X}$ ±SD)

Gait parameters	Pre-massage Therapy	Post Massage Therapy	P value
Forward Velocity (m/s)	0.81±0.32	1.05±0.13	p =0.008★
Cadence (steps/min)	98.16±21.90	105.16±11.10	p =0.25
Step Length (m)	0.47±0.14	0.61±0.06	p =0.001★
Single support Time (Gait Cycle%)	35.71±7.13	39.54±2.00	p =0.04★
Initial Double Support Time (Gait Cycle%)	11.33±3.95	11.29±1.45	p =0.96

Pre- vs. Post-massage Therapy ($p<0.05$)

table 6: **Change in Unaffected lower extremity** ($\bar{X}$ ±SD)

Gait parameters	Pre-massage Therapy	Post-massage Therapy	P value
Forward Velocity (m/s)	0.809±0.313	1.059±0.117	p=0.005★
Cadence (steps/min)	97.65±19.52	105.15±10.94	p=0.22
Step Length (m)	0.480 ±0.13	0.593±0.032	p=0.002★
Single Support Time (Gait Cycle%)	38.38±4.23	38.40±2.61	p=0.99
Initial Double Support Time (Gait Cycle%)	13.85±4.93	10.90±2.76	p=0.04★

Pre- vs. Post-massage Therapy ($p<0.05$)

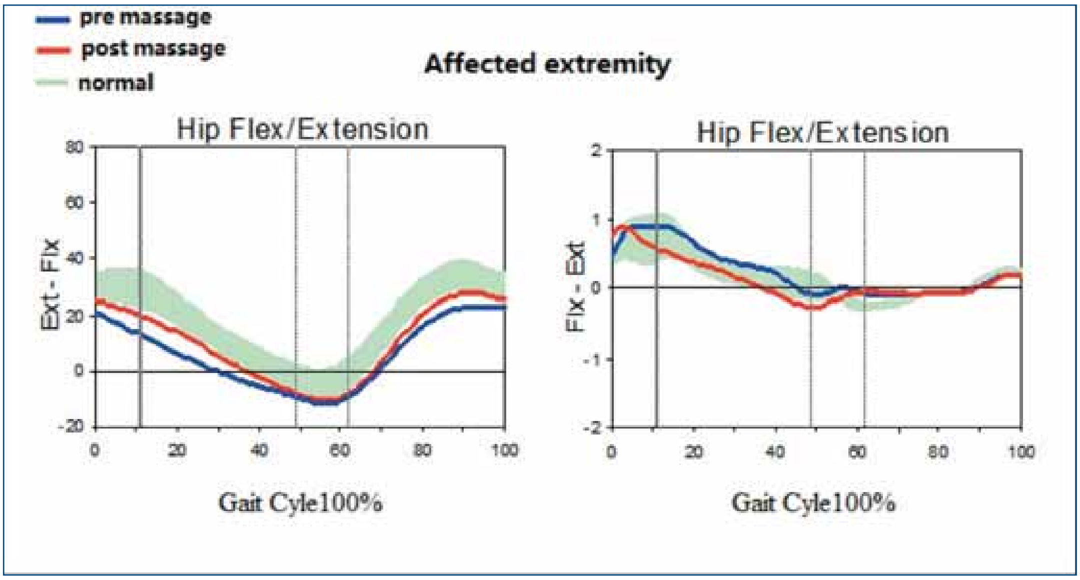


Figure1: Decreased joint angle is performed in hip flexing during both initial&mid stance phrase and initial&mid swing phrase, indicating the hip flexion function of LDH patients is not sufficient. We considered it as dysfunction caused by LDH. This situation was improved after targeted massage therapy. The hip moment was close to the normal level pre& post massage therapy.

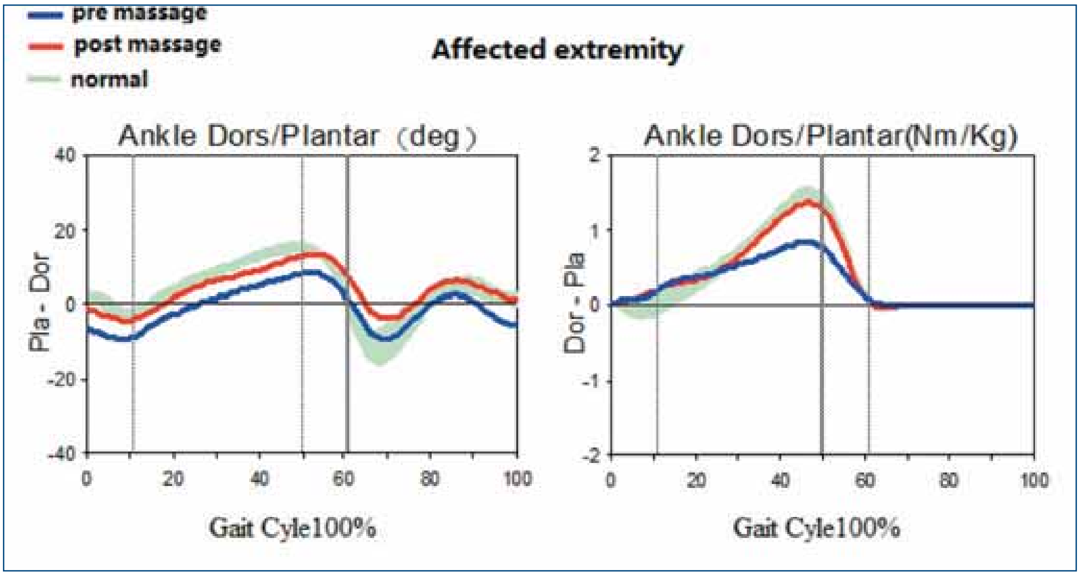


Figure2: Compared with normal group, LDH patients performed decreased joint angle in ankle dorsiflexion during terminal stance phrase and terminal swing phrase. The ankle joint angle in plantar flexion was increased, but the moment is generally decreased from mid stance phrase to terminal stance phrase. We consider it as some dysfunction of plantar flexion muscle related to LDH. After targeted massage therapy, the moment of ankle plantar flexion turned close to the normal level.

DISCUSSION and CONCLUSIONS

Some changes in Time-Space and kinetic parameters were the main characteristics of abnormal gait of the patients with LDH. A session of massage therapy made a great progress to the function of lower extremities and improved the walking ability of patients with LDH. The three-dimensional gait analysis was not only monitors some targets of the massage therapy, but also provides an insight view with objective evidences in evaluation of making for the progress of patients of lower extremities functional recovery. We hope that gait analysis can be used as a reliable and objective method for assessment. And for future research direction, we believe that it will be applied to more experiment fields that can bring benefits to more people.

THE INTENSITY OF ANTERIOR KNEE PAIN MODIFIES THE KINEMATICS OF THE TRUNK AND LOWER LIMBS

NDA. Rabelo (1), BM. Lima(1), LBG. Contani(1), CL. Ferreira (2), AC. Reis (1), AS Bley (1), TY. Fukuda (3), PRG. Lucareli (1)
(1) Department of Rehabilitation Science, Human Motion Analysis Laboratory, *Universidade Nove de Julho*, São Paulo, Brazil
(2) Universidade Federal de São Paulo, UNIFESP, São Paulo, Brazil
(3) Irmandade da Snata Casa de Misericórdia de São Paulo, São Paulo, Brazil

Main topics: Movement analysis in clinical practice; Clinical decision-making processes.

INTRODUCTION and AIM

Despite the growing recognition that there is an association between patellofemoral pain syndrome (PFPS) and alterations in the kinematics of the trunk and lower limbs, little is known about whether the intensity of the pain alters the mechanics of these segments. Therefore, the aim of the present study was to identify whether there is a difference between the kinematics of the trunk and lower limbs of women without pain, women with lower pain and those with higher pain.

PATIENTS/MATERIALS and METHODS

Twenty-eight women, 19 of whom exhibited bilateral PPS and nine of whom were asymptomatic, were divided into three groups: 9 without pain; 9 with lower pain and 10 with higher pain. The level of pain was assessed using the Numerical Pain Rating Scale (NPRS). The group stratification was based on the NPRS scores: for lower pain, the criterion score was ≤5; for higher pain, the score was >5. Nine kinematic trials of the trunk, pelvis, hip, knee and ankle of each lower limb of the volunteers in the three groups were captured by the Vicon® system, composed of eight cameras, during the descent phase of the anterior step down task. The differences between the mean ranges of motion in the groups were assessed using multivariate analysis of variance (MANOVA).

RESULTS

Significant differences were found between the three groups studied (Table 1).

Table1: Kinematics of the trunk and lower limbs during the step down task in women without pain, with lower pain and with higher pain

				WPG vs. LPD		WPG vs. HPG		LPG vs. HPG	
	Mean Range (SD) WPG	Mean Range (SD) LPG	Mean Range (SD) HPG	*P*	Effect size	*P*	Effect size	*P*	Effect size
Trunk Tilt (°)	3.26(2.0)	2.88(2.2)	4.65(2.8)	0.347	-	0.000	0.56	0.000	0.69
Trunk Obliquity (°)	3.12(2.2)	3.46(3.6)	5.13(4.7)	0.692	-	0.000	0.54	0.000	0.39
Trunk Rotation (°)	7.00(3.3)	7.80(6.1)	9.11(4.5)	0.290	-	0.000	0.61	0.030	0.24
Pelvic Tilt (°)	5.09(3.2)	6.09(4.5)	6.73(5.1)	0.103	-	0.002	0.38	0.366	-
Pelvic Obliquity (°)	8.52(2.6)	6.82(4.0)	7.53(3.7)	0.000	0.50	0.025	0.31	0.148	-
Pelvic Rotation (°)	9.36(4.6)	9.73(5.8)	10.83(5.2)	0.806	-	0.028	0.29	0.131	-
Hip Flexion (°)	31.65(5.4)	26.60(7.5)	30.70(8.5)	0.000	0.13	0.458	-	0.000	0.51
Hip Adduction (°)	13.54(6.0)	12.40(7.4)	14.00(6.8)	0.285	-	0.805	-	0.075	-
Hip Rotation (°)	10.43(3.5)	9.01(4.0)	9.34(4.4)	0.004	0.38	0.034	0.27	0.716	-
Knee Flexion (°)	59.43(8.2)	51.79(6.4)	55.26(8.4)	0.000	1.03	0.000	0.50	0.000	0.46
Dorsiflexion (°)	29.41(4.24)	26.16(5.38)	26.86(5.87)	0.000	0.66	0.000	0.49	0.439	-

Abbreviations: WPG, Without Pain Group (0/10); LPG, Lower Pain Group (≤5/10); HPG, Higher Pain Group (≥6/10).
Effect size (Cohen's d): < 0.2 = trivial, 0.2 to 0.5 = small, 0.5 to 0.8 = medium and > 0.8 = large.

DISCUSSION and CONCLUSIONS

Based on the results of the present study, it is possible to infer that during the descent phase of the step down task, individuals with lower pain seemed to use compensation strategies in joints near the location of the pain, demonstrating a reduction in the range of motion of the hip, knee and ankle. On the other hand, individuals with higher pain exhibited kinematic alterations in the lower segments and also used compensation of the trunk and pelvis, with an increase in the range of motion in these segments. Furthermore, the differences between the groups with pain seem to be concentrated in the trunk. Thus, it was possible to conclude that there is a difference between the kinematics of the trunk and lower limbs among women with different intensity of anterior knee pain.

EMG PATTERNS OF UPPER ARM MUSCLES DURING ROBOTIC REHABILITATION

L. Iuppariello (1), G. D'Addio (2), N. Pappone (2), B. Lanzillo (2), P. Bifulco (1), M. Romano(1), M. Cesarelli (1)
(1) Dept. of Electrical Engineering and Information Technology University of Naples, "Federico II", Naples, Italy
(2) S. Maugeri Foundation IRCCS, Telese Terme, Italy

Main topics: Human movement modelling and simulation in clinics; Clinical movement analysis of upper limb;

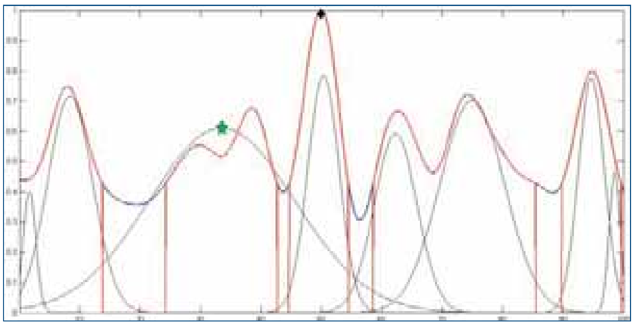
INTRODUCTION and AIM

Changes in muscle activation, underlying improvements in muscle strength and function in response to training of patients affected by congenital or acquired brain injury, remain to date poorly understood. It is thought that the mechanisms involved may be neural or muscular in origin. Better outcomes in sensorimotor as well as in cognitive processes are promised by emerging robot-mediated therapy (RMT), which allows quantitative kinematics and dynamics evaluations to estimate the patient's progress. Although RMT have been differently applied for rehabilitation of patients affected by various diseases orthopaedic or neurological, at the best of our knowledge, no studies proposed a standardized quantitative electromyographic evaluation during robot assisted upper arm point-to-point movements. The aim of this paper is to describe the EMG patterns of upper arm muscles in 5 healthy subjects (HS) modelling the electromyographic linear envelope as summation of un-normalized Gaussian pulse.

PATIENTS/MATERIALS and METHODS

All subjects were instrumented by wireless footswitches and surface EMG electrodes over medial deltoid(MD), brachial biceps(BB) brachial triceps(BT) AND sternal major pectoralis(SMP). The shoulder rehabilitation device used for this study was the Multi-Joint-System (in the following MJS) of the Tecnobody. The kinematic task required each subject to move from the center position to four target, equally spaced of 30°, and then return to the center with an 4 horizontal movements sequence: horizontal abduction of the right/left shoulder from the middle position to the outer right/left and return (RH1 and LH1 respectively), horizontal abduction of the right/left shoulder from the middle position to left/right external one and return (LH2 and RH2 respectively).

EMG analysis has been performed by LEGLab, a software package specifically developed by authors which models the linear envelope (LE) of the EMG signal as summation of un-normalized Gaussian pulses of various length and amplitude, identifying the peak phase as the peak of the dominant component having the highest amplitude. The position of the peak phase is expressed over the movement time duration (%). A physical significance of this dynamic index can be attributed to the phase involving a considerable underlying muscle effort while the peak of the LE, used increasingly for the assessment of normal and pathological muscle activity, gives information to the maximum strength developed in a short period.



RESULTS and DISCUSSIONS

The purpose of this investigation has been to define the EMG linear envelopes of healthy individuals. This is accomplished by temporal feature extraction from LE's. The temporal feature extraction which converts a LE from gait EMG to a series of phases of activity has been developed modelling the LE as the summation of Gaussian pulses of various lengths. Results shown in the table shows mean and standard deviation of the peak phase position position for all studied muscle and for each movement. In the figure is reported an example of the analysis on one muscle (SMP) over the RH1 movement duration (%). EMG LE represented with blue line and its peak with black star and the peak phase in green star.

Table 1: mean ± standard deviation of the peak phase position for each muscle and for each movement

	DM	BB	BT	SMP
RH1	66.00 ± 8.90	75.00 ± 6.00	67.00 ± 10.00	29.00 ± 15.00
LH1	24.00 ± 10.00	29.00 ± 7.00	57.00 ± 9.00	37.00 ± 11.00
LH2	61.00 ± 16.00	29.00 ± 19.00	61.00 ± 12.00	66.00 ± 6.20
RH2	28.00 ± 11.00	66.00 ± 14.00	42.00 ± 11.00	55.00 ± 13.00

This innovative approach have been shown to very effectively describe temporal EMG patterns, sharpening timing activations not directly observable by the simple LE usually available through commercial packages EMG Analysis. Knowledge and comprehension of EMG patterns is at the base of a correct clinical use of the rehabilitation device and of a quantitative evaluation of the rehabilitation outcomes, so the next step is to study the EMG pattern pathological subjects using the methodology described above in order to compare the position of the peak phase with respect to a normal pattern, and finally to study their variations during RMT.

A NOVEL METHOD FOR 2D MARKERLESS GAIT ANALYSIS: PRELIMINARY VALIDATION

A. Castelli (1, 2), G. Paolini (1, 2), A. Cereatti (1, 2), U. Della Croce (1, 2)
(1) Information Engineering Unit, POLCOMING Department, University of Sassari, Sassari, Italy
(2) Interuniversity Centre of Bioengineering of the Human Neuromuscoloskeletal System, Sassari, Italy

Main topics: Technical developments in movement science; Experimental studies in human movement science

INTRODUCTION

Marker-based 3-D gait analysis is generally recognised to play an important role in the assessment of gait related disorders. However, marker-based optoelectronic systems are expensive, and require dedicated space and technical expertise. Video-based, markerless (ML) systems, can represent a valuable alternative [1], leading to a significant reduction of the setup time and complexity. In this study, we present a monocular, model-based ML method, providing unilateral sagittal lower limbs joint kinematics (JK), and gait spatio-temporal parameters (STP). The method is validated using the estimates provided by an optoelectronic system as gold standard (GS).

METHODS

Nine healthy subjects (8 males, 33 ± 6 y.o.) wearing white ankle socks and white underwear garments, walked along a walkway (5 trials x 3 speeds). A RGB video camera (*Vicon Bonita*, 50fps) was placed laterally to the walkway, with a blue background on the opposite side. Synchronous marker data were captured using a Vicon system (*T20*), and the Plug-In-Gait model was used for the GS kinematics and STP estimate. The model calibration was performed on a static reference image: the foot template was defined as the posterior portion of the sock contour, while the shank and thigh templates were defined using selected reference points. The lateral malleolus (LM), lateral epicondyle (LE) and greater trochanter (GT) were manually identified and calibrated to the corresponding templates. The pelvis was assumed to coincide with the segment interpolating a portion of the underwear upper contour, centred in its most lateral point PL (Fig. 1). For each gait trial, the silhouette contour of the moving subject was extracted [2], and the foot and pelvis segments were identified using a white color filter (Fig. 2). The foot orientation was determined by matching the foot template with the foot current image. The shank and thigh reference points on the deformed silhouette contour were identified for each frame, and the corresponding templates fitted using a SVD procedure. STP were estimated from pelvis and foot centroids. JK estimates were assessed in terms of correlation coefficient (CC) and root mean square deviation (RMSD). STP errors were quantified using the Mean Absolute Error (MAE).

RESULTS

Results are reported in Table 1.

DISCUSSION

Joint kinematics were estimated with limited errors (2.3° ≤ RMSD ≤ 5.0°). Correlation between ML and GS was excellent (0.82 ≤ CC ≤ 0.99). STP were estimated with good accuracy, suggesting that the method may represent a valid alternative to more expensive systems, for ambulatory environments. The main limitations consist in the need of a blue background to improve the silhouette extraction phase, and in the joint kinematics being available only for the leg in the foreground. Further work is needed to extract bilateral joint kinematics.

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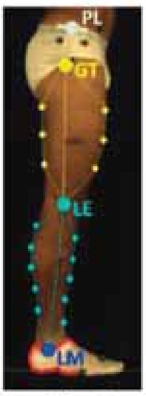

Fig. 1

Fig. 2

Table 1: JK and STP – Average on all trials and subjects, for each gait velocity

		Hip Fl-Ex		Knee Fl-Ex		Ankle Dor-Plan		walking speed [m/s]	stride time [s]	stride length [m]
		CC	RMSD [°]	CC	RMSD [°]	CC	RMSD [°]	MAE		
Speed	Norm	0.98	4.1	0.99	2.6	0.87	3.1	0.036	0.013	0.036
	Fast	0.97	5.0	0.99	3.5	0.86	3.3	0.022	0.019	0.038
	Slow	0.98	3.3	0.99	2.3	0.82	3.2	0.013	0.016	0.017

THE EFFECT OF DIFFERENT SHOE OUTSOLE STRUCTURES ON PLANTAR LOADING DURING RUNNING

Luming. Yang (1)(2), Shuwen. Wu (1)(2), Yanbo. Liu (1)
(1) National Engineering Laboratory for Clean Technology of Leather Manufacture, Chengdu, 610065, China
(2) Key Laboratory of Leather Chemistry and Engineering (Sichuan University), Chengdu, 610065, China
Main topics: Analysis of gait and motor disorders, Experimental studies in human movement science

INTRODUCTION and AIM

Running is one of the most popular forms of exercise around the world. With increased participation comes an increase in injury rates. Running injuries have been reported to relate to plantar loading during running and plantar loading was related to the cushion properties of running shoes [1]. Former studies have reported that the relationship between midsoles and plantar loading [2]. However, the differences in structures of running shoe outsole might also affect plantar loading. Therefore, the purpose of this study was to examine the effect of different shoe outsole structures on plantar loading during running. We hypothesized that the outsole structures of running shoes will affect plantar loading.

PATIENTS/MATERIALS and METHODS

Twenty healthy male recreational runners were recruited for this study. A pedar- X in- shoe pressure measure system (Novel GmbH, Munich, Germany) was used to collect the plantar loading data. Three pairs of shoes with different outsole structures were selected, which were Skechers Go Run Ultra- C (shoe 1), NIke Free 5.0 (shoe 2) and Mizuno Wave Ascend 8 (shoe 3). The midfoot area of outsole in shoe 2 was flat while shoe 1 had an arc- shaped outsole, and the outsole of shoe 3 was inset in the midfoot area (Figure 1). A pair of common running shoe (shoe 4) without any special outsole structures was also selected as a control condition. Subjects were asked to wear each pair of shoes and ran at 2.2m/s on a treadmill. The order of shoes was randomized. The data of right foot was collected for the statistical analysis and five foot strikes were averaged for each trail. The foot was divided to eight anatomic regions (rearfoot, medial midfoot, lateral midfoot, medial forefoot, middle forefoot, lateral forefoot, hallux and the lesser toes) using a percentage mask.

RESULTS

In rearfoot, medial forefoot, middle forefoot and lateral forefoot areas, shoe 1 showed the smallest max pressure and an increasing trend was found from shoe 1 to shoe 4. In the medial midfoot area, shoe 1 showed a significant higher max pressure than shoe 2 ($p=0.017$) and shoe 4 ($p=0.000$). Besides, shoe 3 showed a significant higher max pressure than shoe 4 ($p=0.001$).

DISCUSSION and CONCLUSIONS

The results showed that the outsole structures of running shoes indeed affect plantar loading and an increasing trend was found from shoe 1 to shoe 4 in the areas of rearfoot, medial forefoot, middle forefoot and lateral forefoot on max pressure. This result might be caused by the arc- shaped outsole of shoe 1 that the arc- shaped outsole was more proper for running as eighty percent runners were rearfoot strikers. Most people strike the land with their rearfoot first and then the midfoot and last the forefoot while the arc- shaped outsole make this process easier as well as change the plantar distribution to a better situation. A potential limitation of this study was the materials of the sole. Besides the different structures, the different materials of the sole would also affect plantar loading so that further study should select shoes with identical sole materials and only different in structures of the midfoot area. In conclusion, the structures of running shoe outsole would affect the plantar loading during running. The results of this study indicate that people should select proper running shoes according to their own situation when running or training.

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Table 1 Max Pressure differences.

Max Pressure[kPa]	Shoe 1	Shoe 2	Shoe 3	Shoe 4
Rearfoot	179.17±49.12	184.02±55.07	224.79±107.31	318.15±169.24
Medial midfoot	126.84±16.89	111.82±19.90	121.05±18.47	99.63±22.26
Lateral midfoot	141.33±21.45	147.52±38.98	129.99±24.24	148.46±52.73
Medial forefoot	221.84±56.58	250.26±63.29	257.54±77.35	277.28±86.54
Middle forefoot	219.10±53.15	242.11±56.25	269.30±59.76	307.01±73.09
Lateral forefoot	148.35±50.67	162.43±41.43	176.00±44.27	184.03±56.08
Hallux	176.61±55.72	211.21±78.39	207.83±83.10	273.45±77.37
Lesser toes	136.17±29.95	121.74±33.28	130.33±33.90	148.71±52.45

Shoe1
Shoe2
Shoe 3

Figure 1 Tested Shoes

A NEW APPROACH TO COMPUTE LOWER LIMB MUSCLE VOLUME AND LENGTH USING 3D FREEHAND ULTRASOUND

F. Cenni (1,2), D. Monari (1,2), S.H. Schless (2,3), E. Aertbeliën (1), H. Bruyninckx (1), K. Desloovere (2,3)
(1) KU Leuven, Department of Mechanical Engineering, Leuven, Belgium
(2) Clinical Motion Analysis Laboratory, University Hospital Pellenberg, Belgium
(3) KU Leuven, Department of Rehabilitation Sciences, Belgium
Main topics: musculoskeletal imaging, technical developments in movement science.

INTRODUCTION and AIM

Ultrasound (US) systems are largely used to collect medical images for visualizing subcutaneous body structures. Enhancing the US systems results not only with 3D data acquisition, but also with the spatial information in a large field of view. This approach, called 3D freehand US, combines images and the corresponding position and orientation (pose) of the US transducer with the aim of reconstructing the 3D morphology for large anatomical parts [1]. In particular, morphological properties of muscle are useful to quantify clinical features and to evaluate medical treatments. Thus far, 3D freehand US has only limited clinical use as the procedure is not widely accessible, and the segmentation process required to extract relevant clinical features is very time consuming [2]. This study reports preliminary results on the reliability of a clinically-applied 3D freehand US acquisition and the processing technique for quantifying muscle length and volume. A methodology to quickly generate muscle reconstruction is introduced, and the reliability of the extracted features is examined in a group of typically developing children.

PATIENTS/MATERIALS and METHODS

The medial gastrocnemius muscle was imaged in 5 typically developing children (8.6±3.8 years) while lying in prone position. Using an US scanner and a linear transducer with a 60mm field of view (Telemed, Lithuania), a stack of 2D B-mode US images were acquired by manually moving the US transducer over the length of the muscle in a transverse orientation at a steady speed. Three scans of the medial gastrocnemius were performed for each subject. To simultaneously record the pose of the US transducer, 4 reflective markers rigidly attached to it were tracked by a portable optical motion analysis system, with 3-integrated cameras at 120Hz (Optitrack NaturalPoint, USA). An in- house developed Python package, based on established procedure [1], was used for the 3D reconstruction of the scanned volume. This was then processed in MeVisLab (www.mevislab.de) for clinical feature extraction by sequentially applying: A) semi-automatic segmentation, B) interpolation of the all relevant outlined borders, and C) creation of the 3D muscle model (Figure 1). The corresponding muscle volume and length was computed per scan and the reliability investigated by means of intra-class correlation coefficients (ICC), single measures.

RESULTS

The average muscle volume and length of all subjects and scans were 65.9 ± 29.4 mL and 159.9 ± 26.8 mm, respectively. The corresponding ICC values for comparing muscle volume and length during three scans with 3D freehand US were 0.98 and 0.95 with intra-scan variability of 2.5 mL and 5.7 mm, respectively.

DISCUSSION and CONCLUSIONS

These preliminary results showed that this novel method for image reconstruction and segmentation has reliability and efficiency in retrieving clinically-applicable data of muscle morphology in children comparable to the literature [2]. In addition, the easy and quick approach for computing volume and length (80% computational time less than a complete manual segmentation) will thus allow for analysis in large patient populations. Further validation of the technique will be to seek a comparison to a gold-standard method, such as MRI.

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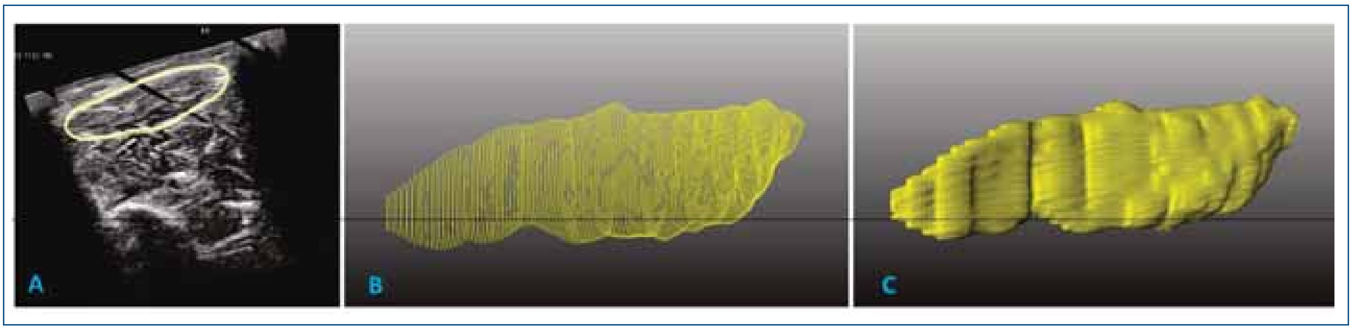

Figure 1: A) semi-automatic segmentation on US image, B) all relevant outlined borders C) 3D muscle model in MeVisLab.

THE GENDER EFFECT ON PLANTAR PRESSURE DISTRUBUTION OF ADOLESCENTS

İlkşan Demirbüken (1), Bahar Özgül (1), Eren Timurtaş (1), Mine Gülden Polat (1), Emir Şahin (1), Murat Dinçer Çekin (2), Saadet Ufuk Yurdalan (1)

(1) Marmara University Health Sciences Faculty, Department of Physiotherapy and Rehabilitation, İstanbul, Turkey
(2) Marmara University Health Sciences Faculty, Department of Health Management, İstanbul, Turkey

INTRODUCTION and AIM

Gender differences of adult population in anthropometric characteristics and anatomical structures have been reported to cause differences in lower extremity kinematics and kinetics (1, 2) and in dynamic plantar pressure during walking (3). However, the plantar pressure distribution of adolescents has not been investigated sufficiently. The purpose of this study was to describe the pedobarographic profiles of normal adolescents across gender and explore gender-related differences in foot pressure patterns.

PATIENTS/MATERIALS and METHODS

43 female and 88 male totally 131 adolescents (age range between 10-15years) were included in the study. Dynamic pedobarography system (EMED-M, 38 × 42 cm, four sensors per square centimeter, 50 Hz; Novel GmbH., Munich, Germany) was performed to retrieve walking patterns at self-selected speed after recording physical characteristics of subjects (gender, body weight, height) and analysis of foot segments was performed using EMED Scientific Software (Novel GmbH., Munich, Germany). Maximum pressure (N and %BW), peak pressure (kPa), contact area (mm) and contact time (sec) were obtained across four foot segments (toes, forefoot, midfoot and hindfoot) and whole foot. Independent T test was used to compare pedobarographic data of groups of females and males and the level of significance was determined as $p<0,05$.

RESULTS

There was no significant difference between gender groups in body weight ($p=0,104$) whereas the average age and height of males were higher than the females ($p=0,001$, $p=0,002$). There was no gender difference between pedobarographic parameters (maximum pressure (N), peak pressure, contact area and contact time) in all foot segments expect segment of toes ($p>0,05$). In females maximum pressure (%BW) was higher than males in the segment of toes ($p=0,011$).

DISCUSSION and CONCLUSIONS

The results showed that most of the pedobarographic parameters did not differ between female and male adolescents in foot regions and whole foot. However, difference in maximum pressure (%BW) for the toe regions may be indicative of different plantar pressure distribution segmentally by gender in adolescent age group. In addition, this difference detected for the toe regions may be due to the difference between the average age and height of males and females. The studies examining the gender effects on pedobarographic parameters in the same age group were not detected yet. The studies related to dynamic plantar pressure during walking especially focused on adults and showed different findings compared to results of our study (3). Meng-Jung Chungand and Mao-JiunWang showed that male adults had higher peak pressure, peak force and normalized peak force in the medial toes and forefoot, greater contact area in the central forefoot and heel regions than females. Furthermore, female adults showed higher normalized peak force and contact area in the midfoot (3). The various findings of the studies that have investigated gender effect on plantar pressure distribution in different age groups arises the idea of gender effect on plantar pressure distribution changes according to developmental stages of life. More studies examining the gender effects on plantar pressure distribution of adolescents by using similar methods are required.

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TURNING IN AMPUTEES - FUNCTIONAL EFFECTS OF A TORSION ADAPTER

D.W.W. Heitzmann, J. Block, M. Alimusaj, S. I. Wolf,
Department of Orthopedics and Trauma Surgery, University Hospital Heidelberg, Germany

INTRODUCTION and AIM

The residual limb structures of individuals with trans-tibial amputation (TTA) are not well suited for weight bearing and its accompanying loads. To protect these structures from harm, any unnecessary stress should be avoided, like. However shear stress may be induced by transverse plane angular motion of the residual limb with respect to the prosthetic socket [1]. Such movements are induced by transverse plane moments. The objective of this study was therefore to evaluate if TTA benefit from a torsion adapter during 45° turns which aim to reduce transverse plane moments.

PATIENTS/MATERIALS and METHODS

Repeated measurements of 10 TTA (45±17.4y; 179±8cm; 77±12.4kg) walking with two prosthetic feet (Variflex XC Rotate, Össur, Iceland) similar in appearance and alignment except for a torsion adapter ([REAL] = Foot with working adapter, [FAKE] = foot with blocked placebo adapter) were conducted to identify differences. Kinematics and kinetics during turns were collected by means of conventional instrumented gait analysis using Plugin-Gait model (Vicon, UK). A visual cue indicated randomly in which direction the subject should turn. A starting line was set such that subjects involved limb landed on a force platform (Kistler, CH) during the turn. Landing on the involved side and turning towards the involved side corresponds to a spin turn, and landing on the involved side and turning away from that side matches a step turn, respectively [2]. TTA were blinded for the foot investigated and the sequence of measurements for REAL and FAKE was randomized. Data of 10 unimpaired subjects (33±10y; 179±9cm; 72±17kg; non-dominant side) served as a reference. Differences between feet were identified by two tailed Wilcoxon Signed-Rank Tests for paired samples.

RESULTS

During spin turns TTA using REAL show a significantly higher ankle moment for external rotation in comparison to FAKE. In level walking TTA using REAL shows higher peak moments for knee and ankle internal rotation. When compared to reference TTA show a pronounced internal rotation during step turns and a pronounced and significant external rotation during spin turns.

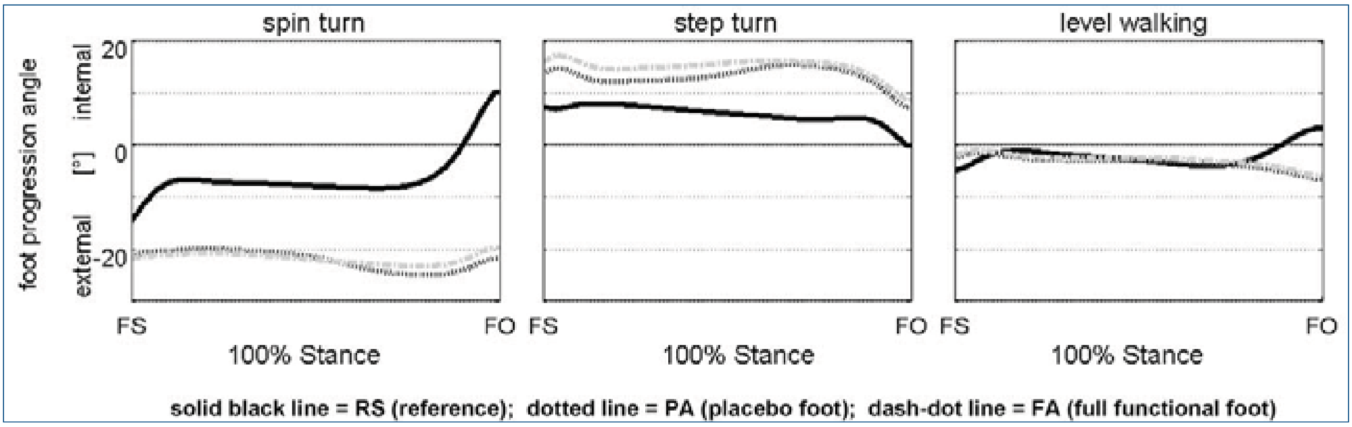

Figure 1: Figure 1: Foot progression angle in stance for turns and level walking (solid black line = Reference; dotted line = FAKE; dash-dot line = REAL; FS = foot-strike FO = foot-off)

DISCUSSION and CONCLUSIONS

Although significant differences in transversal moments were found between feet for peak moments of knee and ankle in level walking, and for the ankle in spin turns it still remains unclear if these differences are of clinical relevance. In general, each TTA showed distinct transversal moment characteristics, but no clear inter-individual patter could be extracted. However, all TTA showed similar changes in foot progression angle during turns with both prosthetic feet, when compared to reference. Alteration of foot progression angle may be a compensation mechanism to reduce transverse plane moments. Consequently the full potential of REAL to reduce transverse plane moments was left unused. A gait education of TTA with special regards to such compensation is probably advisable and should be combined with the prescription of torsion adapters in order to benefit from such devices.

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THE RELATIONSHIP BETWEEN TRUNK CONTROL IN SITTING AND DURING GAIT IN CHILDREN AND ADOLECENTS WITH CEREBRAL PALSY

RANNEI SAETHER,[1,2] JORUNN L HELBOSTAD,[3,4] LARS ADDE,[1,4] SIRI BRÆNDVIK,[3,4] STIAN LYDERSEN,[2,5] TORSTEIN VIK [1,2]

1. Department of Laboratory Medicine, Children's and Women's Health, Norwegian University of Science and Technology, Trondheim, Norway
2. Department of Pediatrics, St. Olavs Hospital, University Hospital of Trondheim, Trondheim, Norway
3. Department of Neuroscience, Norwegian University of Science and Technology, Trondheim, Norway
4. Clinic for Clinical Services, St. Olavs University Hospital, Trondheim, Norway
5. Regional Centre for Child and Youth Mental Health and Child Welfare – Central Norway, Norwegian University of Science and Technology, Trondheim, Norway

Main topics: Movement analysis in clinical practice, clinical decision making processes

INTRODUCTION and AIM

Control of the trunk during gait is especially important for balance, since two-thirds of the body mass (head, arms and trunk) is located at the upper two-thirds of the body height, making the body unstable.(1) Poor trunk control is a primary impairment in children, adolescents and adults with cerebral palsy,(2) and assessment of trunk control is thus important in the decision process leading to 'gait interventions' like orthopedic surgery, botulinum toxin injections and/or application of orthoses. None the less, in the decision process leading to such interventions the focus is mainly on the lower extremities,(3) even in 3-diemnsional gait analyses.

Since trunk control in sitting is less influenced by impairments in the lower extremities, assessment of trunk control in sitting may be used as a first step to identify primary impairments. Even though the two tasks are clearly different, trunk control in sitting may be assessed as an indicator of impaired (primary) trunk control during gait, if there is a relationship between trunk control in sitting and during gait. If such a relationship can be documented, the implementation of a short test of trunk control in sitting may provide information about primary impairments in trunk control and thus may lead to improved decision processes regarding the choice of gait interventions. Moreover, the results of such a sitting assessment might be used to select children who need a thorough assessment of the relationship between the trunk and lower limbs, including full-body 3D gait analysis, before a treatment option is chosen.

Our aim was to assess the relationship between trunk control in sitting and trunk control during gait, using two tests of trunk control in sitting and a trunk worn accelerometer during gait.

PATIENTS/MATERIALS and METHODS

Trunk control in sitting and trunk control during gait was assessed in 26 children (17 males) at a mean age of 11.7 years (range: 8-18 years) with spastic cerebral palsy (CP) and gross motor function corresponding to Gross Motor Classification System (GMFCS) I–III. Trunk control in sitting was assessed with the Trunk Impairment Scale (TIS) and Trunk Control Measurement Scale (TCMS), and trunk control during gait by a tri-axial accelerometer worn on the lower back, when the children walked back and forth a 5-m pathway at preferred speed. Gait variables representing trunk control were trunk accelerations and interstride regularity in anterioposterior (AP), mediolateral (ML), and vertical (V) directions.

RESULTS

Trunk control in sitting assessed with the TCMS and the TIS total scores both correlated with trunk accelerations during gait (R_p= 0.67 and 0.60, respectively). Moreover, some subscale scores correlated equally well with trunk control during gait (the TCMS dynamic sitting balance reaching subscale score (DSB-R); R_p= 0.61) or even higher (TIS dynamic sitting balance subscale (DSB); R_p= 0.66).

DISCUSSION and CONCLUSIONS

Trunk control in sitting is moderate to good correlated with trunk control during gait. Our results suggest that two subscales of these tools, being less time consuming, may be applied in the clinical assessment of trunk control. Future studies are needed to explore how this information may be applied in the planning of 'gait interventions' in children with CP.

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MUSCLE FUNCTION INVESTIGATION: AN INNOVATIVE APPROACH COMBINING THE USE OF SURFACE EMG, US IMAGING AND 3D KINEMATICS

M.C. Bisi (1), A. Botter (2), R. Stagni (1,3), T.M. Vieira (2,4)
(1) DEI, University of Bologna, Bologna, Italy
(2) LISiN, Politecnico di Torino, Torino, Italy
(3) HST – ICIR, University of Bologna, Bologna, Italy
(4) EEFD, Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil

Main topics: Musculoskeletal imaging, Technical developments in movement science.

INTRODUCTION AND AIM

The integration of grids of electrodes, US imaging and 3D kinematics can provide novel spatio-temporal information regarding electromechanical function of muscle, relevant both for improving basic knowledge and for clinical applications [1,2]. The aim of the present study was to analyse how much muscle architectural changes, induced by changes in joint positions, can influence the amplitude distribution of surface EMGs.

PATIENTS/MATERIALS AND METHODS

While provided with EMG visual-feedback, a participant [age 33 years; height 1.78 m; body mass 75.1 kg] was asked to recruit a single motor unit [3] of the right tibialis anterior (TA) at two ankle positions: i) neutral and ii) full plantar-flexion. Surface EMGs, kinematic data and ultrasound images (US) were acquired (Fig. 1a). The spatial distribution of the root mean square amplitude of motor unit action potentials was assessed from collected EMGs [4]. 3D position of the US image plane in the laboratory reference frame was calibrated through the acquisition of a plate and two edges both with US system (with markers attached) and with a marker stick (as reference) [2]. A flowchart of the 3D reconstruction of the muscle surface is shown in Figure 1b-d. Muscle volume positioned under the electrode matrix was analysed: width and thickness variations between the two positions were measured.

RESULTS

TA width increased of 6 mm at neutral position in respect to full plantar-flexion (Tab.1). During contractions at neutral position the RMS amplitude of action potentials was twice greater than that obtained with the ankle at plantar flexion position. Relatively larger RMS amplitudes were observed over a wider skin region for the ankle at neutral position.

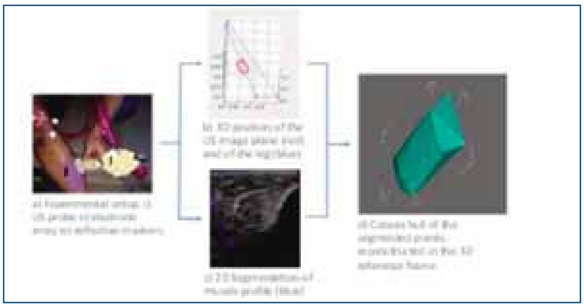

Fig. 1. a) Experimental setup. b), c) and d) Flowchart of the procedure for 3D muscle surface reconstruction

Tab 1. TA variations in width and thickness from plantar-flexed position B) to a neutral position A).

	Δwidth	Δthickness
mean (mm)	6,3	-0,9
std (mm)	1,1	0,5
mean (%)	11,6	-1,4
std (%)	1,6	1,4

DISCUSSION AND CONCLUSIONS

When moving the foot from plantar flexion to a neutral position TA width, RMS amplitude and its spatial distribution increased. Presuming the same motor unit was recruited for both ankle positions (cf. similarities in the shape of action potentials), the changes in EMG amplitude were predominantly due to TA architectural changes. If these findings hold for a sample of subjects, then, the effect of muscle anatomical factors on the surface EMGs may be more expressive than previously appreciated.

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SPINE MOTION MEASUREMENT DURING GAIT, A REPRODUCIBILITY STUDY

D. North (1,2), A. Kranzl (2),
(1) UAS Technikum Wien, Vienna, Austria
(2) Orthopedic Hospital Speising, Laboratory for Gait and Movement Analysis, Vienna, Austria

Main topics: Analysis of clinical movement data, Reliability and service development, Experimental studies in human movement science

INTRODUCTION and AIM

It is hard to represent the motion of the relevant subpart of the thorax because it consists of many different small joints. However, "also for the analysis of the locomotor system, i.e. the lower limb, kinematic measurements of the upper part of the body have been found essential" [2]. In order to measure the spine kinematic data, a new model was defined. In using this new model, it should be possible to measure the thoracic kyphosis and the lumbar lordosis. Moreover, the movements of the cervical, the thoracic and the lumbar spine should be recordable. Due to the fact that this was a new model and nobody had known the influence of the correct marker placement on the results, a study of reproducibility needed to be done.

PATIENTS/MATERIALS and METHODS

In order to guarantee that all the needed data can be measured with the new model, a combination of two existing models had been used for the measurements [1], [2]. For calculating the reproducibility during gait, a group of five healthy test persons had been examined twice, each within a week. The markers were recorded with a 3D camera system (Vicon Nexus). The absolute and relative movements of the Head, Thorax and Pelvis were calculated (Euler Angles). To calculate the spine movements, the trajectories of the spine markers were transformed into the local Pelvis system. Afterwards, a vector between each two successive markers had been calculated. The angle between two vectors described the movement of the spine segment. Table 1 illustrates the definition of all spine angles and the plane they were calculated. In order to evaluate the reproducibility of the kinematic data, the calculated angles were displayed on graphs and the absolute Root-Mean-Square Error (RMSE) was calculated.

RESULTS

Table 2 illustrates the mean and standard deviation of the absolute RMSE for all calculated spine angles. All angles, except T2 in the sagittal plane, show a good repeatability. The self-selected walking speed was not significant different between both test sessions.

DISCUSSION and CONCLUSIONS

The results showed a very high repeatability of the spine kinematic data during gait. However, if the test persons would make other movements, like lateral flexion of the upper body, the repeatability would decrease. The reason for this is the huge skin movement on the back during movements with a high range of motion. When using this model, only kinematic data for the frontal and sagittal plane can be measured. If the movements on the transversal plane are required, additional marker needed to be placed laterally to the spine. It is hard to find the anatomical landmarks for the marker placement at the spine, especially when the person is overweight or has strong back muscles. However, the reproducibility increases with the test persons which had been examined later on. In order to find the right anatomical landmarks, more practice need to be done. Consequently, this leads to better results.

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Table 1: definition of the spine angles

spine angles	angle between the markers:	plane
L3	L5-L3 & L3-L1	front, sag
L1	L3-L1 & L1-Th10	front, sag
T10	L1-Th10 & Th10-Th6	front, sag
T6	Th10-Th6 & Th6-Th2	front, sag
T2	Th6-Th2 & Th2-C7	front, sag
kyphosis	L1-Th10 & Th2-Th6	sag
lordosis	L5-L3 & L3-L1	sag

Table 2: mean absolute RMSE of 5 test persons, left gait Cycle

spine angles	frontal plane [°]	sagittal plane [°]
L3	1.40 ± 2.07	1.07 ± 1.58
L1	0.90 ± 1.31	1.19 ± 1.88
T10	0.67 ± 1.30	0.55 ± 0.96
T6	0.70 ± 0.98	0.33 ± 0.58
T2	0.77 ± 1.22	1.75 ± 3.32
kyphosis		0.48 ± 0.81
lordosis		1.07 ± 1.58

GAIT PHASES DETERMINATION USING MARKOV MODELS APPLIED TO THE RECORDINGS OF A SHANK-WORN GYROSCOPE

A. Mannini (1), D. Trojaniello (2), U. Della Croce (2), A.M. Sabatini (1)
(1) The BioRobotics Institute, Scuola Superiore Sant'Anna, Pisa, Italy
(2) Information Engineering Unit, POLCOMING Department, University of Sassari, Italy

Main topics: Technical developments in movement science; Analysis of gait and motor disorders.

INTRODUCTION and AIM

Gait phases determination has been investigated using inertial measurement units (IMU) attached to different placement sites of the human body, including trunk [1]. Recently, foot-worn sensors were also considered in association with a method based on hidden Markov models (HMM) [2]. Pathologic gait has not been tested yet with that statistical method. In this work, we placed the IMU to the shank, a site for which previous studies pointed out lower signal variability across subjects [3] and lower dependency on pathologic foot postures [4]. We performed preliminary tests to verify if the use of HMM based methods for gait phases determination could be extended to the signals from a shank attached IMU, by evaluating the results from five subjects with abnormal gait.

PATIENTS/MATERIALS and METHODS

Five healthy (H) and five patients (P), including three traumatic brain injury, one Parkinson's disease and one polyneuropathy patient, were enrolled from the outpatient Neurologic Clinic of Sassari, Italy. The P-subjects were included if they (1) showed a reduced walking speed and/or symmetry and (2) could walk independently over a distance of 20 m with or without walking aids. Two IMUs (Opal, APDM, Inc.) were attached to the subjects' shanks about 20 mm above the lateral malleolus. A six-camera stereophotogrammetric (SP) system (Vicon T20) was also used to acquire reference data. Three retro-reflective markers were placed on each foot (toe, heel and malleolus). The IMUs and the SP system were synchronized. Subjects were asked to walk for about a minute at a self-selected, comfortable speed (V1) and higher speed (V2) along a pre-designed loop in the SP calibrated volume ($8 \times 4 \times 1.8$ m^3). Three trials were recorded for each subject. Subjects wore their shoes. Four gait events (GEs), foot strike (FS), flat foot (FF), heel off (HO), and toe off (TO) were extracted [5,6]. A HMM was considered for the extraction of gait phases using the recordings of the medio-lateral (ML) component of the IMU angular velocity. The method, validated in our previous work, is based on a left-right four states HMM, where the gait phases identified by the four GEs are paired to model states [2]. The HMM input is the ML angular velocity and models the emissions from each state as a bivariate Gaussian mixture model with three modes. The HMMs were validated using a Leave-One-Subject-Out (LOSO) cross-validation approach. Moreover, the method was trained using the H-subjects data and tested on the P-subjects (H-training P-test).

RESULTS, DISCUSSION and CONCLUSIONS

GEs timing differences between the SP and the HMM estimates are reported in Table 1. Running LOSO validation on H- or P-subjects data separately, the above mentioned differences were on average lower than 20 ms. The observed variability, especially in determining FF and HO, was due to the lower angular velocity in proximity of those events, which results in a higher level of uncertainty. Even if the study is still at a preliminary stage, the results obtained make us to believe that the HMM method for determining gait phases can be applied to data from an IMU placed on the shank on both healthy and abnormal gait.

Table 1: Difference between SP and HMM estimates of GEs timing (mean value ± standard deviation)

SP-HMM estimates [ms]	FS	FF	HO	TO
LOSO validation, H subjects (710 strides per side)	16 ± 24	17 ± 70	-21 ± 69	-13 ± 30
LOSO validation, P subjects (295 strides per side)	15 ± 52	19 ± 160	-5 ± 107	-2 ± 79
H-training P-test (295 strides per side)	18 ± 47	109 ± 143	-65 ± 91	8 ± 77

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OVER GROUND VS. TREADMILL WALKING: DIFFERENCES IN MOMENTS ARE DUE TO DIFFERENCES IN GROUND REACTION FORCES

Adam Rozumalski, M.S. (1), Tom F. Novacheck, M.D. (1,2), Chad Griffith, M.D. (2), Katie Walt, P.T. (1), and Michael H. Schwartz, Ph.D. (1,2)
(1) Gillette Children's Specialty Healthcare, St. Paul, USA
(2) University of Minnesota – Dept. of Orthopaedic Surgery, Minneapolis, USA

INTRODUCTION
Instrumented treadmills have a great potential to augment current gait analysis techniques. Several studies using adult subjects have been conducted comparing the kinematics and kinetics observed while walking on a treadmill to those observed over level ground [1-2]. These studies found slight, but not meaningful, differences between the two conditions. The current study analyzes a group of typically developing children to see if these results can be extended to the pediatric population.

METHODS
Twenty four typically developing children walked at a comfortable speed through the gait lab while kinematics and kinetics were collected. The children then walked on an instrumented treadmill at a speed determined from their self-selected over ground speed while kinematics and kinetics were collected. All of the children wore their own shoes.

RESULTS
Differences were found in the sagittal plane moments at the hip, knee and ankle during the first half of stance. This was due to an increase in moment arm of the ground reaction force at the foot in the treadmill condition. The center of pressure was found to be further forward on the foot during treadmill walking. There is also a slight increase in the initial peak of the vertical ground reaction force, which is maintained through mid-stance, that helps contribute to the plantarflexion moment [Figure 1]. Walking speeds were closely matched between the treadmill and over ground conditions.

DISCUSSION
Previous studies have concluded that there is little difference in the kinematics and kinetics between over ground and treadmill walking in adults [1-2]. Our study, however, shows that there are significant differences for children walking at a self-selected speed. These differences are important to recognize when developing clinical services. For example, the early rise in platarflexion moment could be misinterpreted as gastrocnemius spasticity in children with cerebral palsy. Treadmill studies hold great promise, but directly comparing the results to over ground data may not be appropriate.

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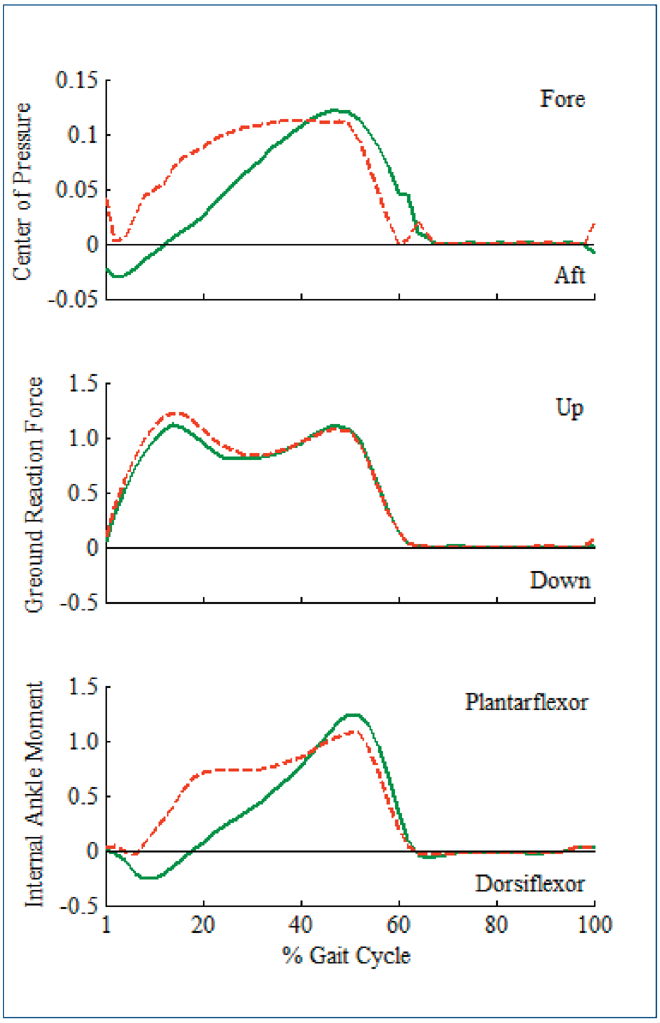

Figure 1. Differences in treadmill (red dashed lines) vs. overground (green solid lines) walking. Center of pressure is expressed as a fraction of leg length and is the fore/aft distance from the ankle center. The vertical ground reaction force is expressed as a fraction of body weight. The internal ankle moment is expressed in the units Nm/kg.

LOWER LIMB ALIGNMENT AND THREE DIMENSIONAL MOVEMENT ANALYSIS IN DROP VERTICAL JUMP IN FEMALE HANDBALL PLAYERS

Carolina Ericson (1), Katarina Hjältman (2), Jacques Riad (1,3)
(1) Skaraborg Gait Laboratory
(2) Dept. Orthotics and Prosthetic
(3) Dept. Orthopaedics, Skaraborg Hospital Skövde, Sweden

INTRODUCTION and AIM

In sport activities normal knee motion can be exceeded and cause anterior cruciate ligament injury, frequently reported in female athletes (1). Increased knee valgus motion and loading during landing in the drop vertical jump is associated with anterior cruciate ligament injury (2). Neuromuscular control deficits, hormonal and anatomical factors have been stated as possible risk factors for knee injuries (2). Thigh and tibial length, lower limb alignment and femoral notch width are examples of anatomical variables reported. We found no reports on anatomical alignment assessed by physical examination and the relation to kinematic findings in the coronal and transverse plane in jumping. In addition we lack information on hip joint kinematics in relation to the forces commonly causing knee injury, knee valgus and external rotational moments during jumping.

The aim was to study hip and knee alignment assessed by physical examination and relate to three dimensional motion analysis with kinematics and kinetics of the knee and hip in jumping.

MATERIALS and METHODS

Forty three consecutive female handball players mean age 18,1 years (range 14,3-32,2 years) participated. Mean weight was 63,8 kg and height 169,2 cm. All but one was right foot dominant (preferable foot to kick a ball with). Individuals with previous serious injury or surgery or any disease/condition influencing the lower limb were excluded.

A physical examination including passive range of motion of the hip, knee and ankle, using a goniometer and standardized positions was performed (3). A three dimensional motion analysis system incorporating 62 retroflective markers and 12 digital cameras (Oqus 400 Qualisys medical AB, Gothenburg, Sweden) was used. The participants performed 3 drop vertical jumps (DVJ) (4) with shoes and the highest jump was chosen for calculation.

RESULTS

We found a correlation between knee external rotation moment during jumping and hip internal rotation from the physical examination, correlation coefficient 0.222 (p=0.040). The more hip internal rotation there is the higher the external rotation moment of the knee. No correlation between physical examination findings and knee valgus moment was noted.

Knee external rotation moment correlated to external rotation of the hip, calculated from three dimensional movement analysis, during jumping, correlation coefficient 0.302 (p=0.005).

Knee valgus moment was associated with both hip external rotation correlation coefficient 0.247 (p=0.022) and knee extension correlation coefficient 0.301 (p=0.002). The more external rotation and extension of the hip the higher the knee valgus moment.

The height of the jump correlated to knee external rotation moment, correlation coefficient 0.371 (p<0.000).

DISCUSSION and CONCLUSION

We found influence from the hip joint on both knee valgus and rotational moments in female handball players that could have implication on risk of knee injury. Seldom the transverse moments are reported although there are some reports indicating an association with rotational moments in the knee and not only by valgus loading, causing anterior cruciate ligament tear (5).

Interestingly in these high performing athletes the moment in the coronal plane is controlled and kept to a minimum during landing and take-off when jumping, as opposed to the external rotational moment which is directly correlated to the jump height. The higher the jump the higher the rotational moment.

We conclude from our results that hip joint motion, both passive and during jumping, has an association with knee moments and should be considered in the overall assessment in this population.Rational prophylactic muscle coordination and strengthening training programs could possibly be developed with comprehensive assessments after further studies.

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ASSESSMENT OF THE EFFECT OF A UNILATERAL TORSION SPLINT IN A 5 YEARS OLD YOUNG HEMIPLEGIC BY A NEW KINEMATIC MODEL ASSOCIATING FUNCTIONAL CALIBRATION AND INVERSE KINEMATIC

E. Desailly (1), F. Hareb (1), M. Jarrige(1), E. Kéroulé (1), L. Lejeune (1), D. Bouchakour (1), N. Khouri (1)

(1) Fondation Ellen Poidatz, Saint-Fargeau-Ponthierry, France

Main topics: Orthotics, Technical developments in movement science, Outcomes after clinical intervention.

INTRODUCTION and AIM

The child, has a left hemiplegia resulting of a prenatal stroke. At 4 years, her varus-equinus is reduced from -50° to -10° by toxin and casts, then to +5° by a gastrocnemius fasciotomy. During this treatment a hip external rotation and stiff knee gait appeared. At 5 years, the transverse disorders are confirmed by Clinical Gait Analysis (CGA) and a unilateral Torsion Splint (TS) is prescribed in a therapeutic test purpose in order to determine whether or not this TS is effective and if an early surgical treatment could be beneficial. Assessing the effect of orthotic is always difficult as the reflective markers used in CGA can be in conflict with the splint structure or may be displaced between both conditions.

PATIENTS/MATERIALS and METHODS

The child BMI is 21 which is considered obese for this age. The torsion splint is an orthotic device with two polypropylene parts linked by a torsion cable, the proximal one is a large polypropylene pelvic section (widely covering iliac spines) and the distal one is an AFO (making it impossible to place knee markers on the skin). Considering all this limitations, a 52 markers model was used with 6 markers for the pelvis 5 for the thigh and 4 for the shank. After functional identification of the joint centres and axes (1,2), specific anatomical segment frames where defined and a weighted inverse kinematic (3) procedure was achieved to compute gait kinematics. Three gait trials are recorded in both conditions with and without the pelvis part and the torsion cable.

RESULTS

Functional identifications performances are evaluated by segments lengths differences in both conditions (Table 1) and concerning hip location by SCoRE residuals (without r_R=0.0055 r_L=0.0167 –with r_R=0.0187 r_L=0.0305). The kinematic assessment of the effect of the torsional splint shows that external foot progression is corrected (-22 °) by a decrease in external hip rotation (-12 °) and a correction of the pelvis external rotation (-10 °). Right knee flexion has improved (+15 °). Left foot progression improves from 0 ° to +15 °.

Table 1: Comparison of the segments lengths resulting from the functional identifications with and without the torsion splint.

Torsion splint	Inter hip dist. (mm)	R thigh (mm)	L thigh (mm)	R shank (mm)	L shank (mm)
without	142,4	244,9	265,5	216,8	220
with	146,2	246,1	266,2	215	229,7
difference	-3,8	-1,2	-0,7	1,8	-9,7

DISCUSSION and CONCLUSIONS

The quality indicators give a good confidence in the comparison between the conditions. The expected splint effect is validated. Meanwhile, unexpected improvements effects on the knee and contralateral foot are measured. Paradoxically, the right external rotation of the pelvis is corrected despite the opposite torque transmitted by the cable. An improved presentation of the foot might insure a compensation of this potentially disturbing torque. These effects are incorporated into the decision process of a possible femoral osteotomy.

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GAIT CHARACTERISTICS IN PATIENTS WITH KNEE OSTEOARTHRITIS AND ITS CHANGE FOLLOWING TOTAL KNEE ARTHROPLASTY

JH Lee(1), SH Lee(2), SS Eun(3)
(1) Dep. of physical medicine and rehabilitation, Wooridul spine hospital, Seoul, Rep of Korea
(2) Dep. of Neurosurgery, Wooridul spine hospital, Seoul, Rep of Korea
(3) Dep. Of Orthopedic surgery, Wooridul spine hospital, Seoul, Rep of Korea

INTRODUCTION and AIM : Knee osteoarthritis (OA) is one of the most prevalent musculoskeletal diseases among the elderly and it is a major source of pain and functional disability. This study aimed to assess the gait characteristics of patients with knee OA compared to that of normal subjects and assess changes in these characteristics following total knee arthroplasty(TKA) using three-dimensional gait analysis.

PATIENTS/MATERIALS and METHODS : Patients with knee OA underwent gait analysis before TKA(pre-TKA) as well as 4 weeks after TKA(post-TKA). The gait analysis data of pre-TKA, post-TKA, and normal subjects (controls) were compared to identify gait characteristics of patients with knee OA as well as compared with control and change following TKA.

RESULTS : Maximum anterior pelvic tilt, in addition to internal and external pelvic rotation angles was greater before TKA as compared to the control subjects. Pre-TKA maximum hip flexion angle was larger than that of control, and pre-TKA knee flexion angles were larger than those of control throughout the gait cycle. Pre-TKA maximum knee extension moment was significantly larger than that of the control. Pre-TKA maximum knee varus angle and valgus moment was larger than those of control but they significantly declined after TKA. Pre-TKA maximum knee external rotation moment was lower than that of control(Table 1).

DISCUSSION and CONCLUSIONS : Three dimensional gait analysis of patients with knee OA exhibited extensive abnormal gait patterns throughout pelvis, hip joint and knee joint. Gait deviations were observed in linear parameters such as decreased gait velocity and step length, and increased double support time, in kinematics such as increased pelvic rotation, hip flexion, knee flexion and knee varus angle, and consequently, in kinetics such as increased knee extension moment and valgus moment. TKA fulfilled the improvement of knee varus angle and valgus moment to near normal status.

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Table 1. Comparison of knee kinematic and kinetic data among prearthroplasty, postarthroplasty in patients with knee osteoarthritis, and normal control

	Preoperation	Post operation	Control	p			
				Total	Pre-post	Pre-cont	Post-cont
Knee flexion at stage 1	14.11±6.44	17.99±6.89	3.63±5.29	<0.001	0.171	<0.001	<0.001
Knee flexion at stage 2	22.54±6.58	25.1±6.61	14.85±5.8	<0.001	0.476	<0.001	<0.001
Knee flexion at stage 3	19.03±5.62	19.88±7.05	4.94±5.72	<0.001	0.916	<0.001	<0.001
Knee flexion at stage 4	55.52±16.77	64.74±6.29	64.01±5.09	0.010	0.023	0.015	0.966
Maximal knee IR	2.5±11.57	5.78±8.77	8.92±10.39	0.136	0.644	0.119	0.591
Maximal knee varus	11±6.36	6.99±5.47	5.97±3.45	0.006	0.06	0.004	0.78
Maximal knee ER MOM	0.01±0.01	0.02±0.01	0.14±0.09	<0.001	0.947	<0.001	<0.001
Maximal knee valgus MOM	0.47±0.24	0.21±0.14	0.38±0.24	0.004	0.004	0.42	0.034
Maximal knee ext MOM	0.33±0.21	0.33±0.2	0.19±0.12	0.008	0.999	0.026	0.03

Stage 1 : maximal knee flexion angle at initial contact, stage 2 : maximal knee flexion angle at loading response phase, stage 3 : maximal knee extension angle at midstance phase, stage 4 : maximal knee flexion angle during swing phase, IR : internal rotation, ER : external rotation, MOM : moment,

Relationship between Weight-bearing Ratio on Affected Lower Extremity and Gait Ability Using Portable Electronic Foot Sensor Shoes (Step Aid®) in Hemiplegic Stroke Patients

J. Kato [1], M. Iwamoto [2], K.Itotani [3], M.Murakami [3], Y.Imabori [4], K.Fujimoto [4], M. Tanaka [4]

(1) Department of Internal Medicine, Hyogo rehabilitation Center at Nishi-Harima, Tatsuno City, Japan
(2) Faculty of Physical Therapy, Hyogo rehabilitation Center at Nishi-Harima, Tatsuno City, Japan
(3) Faculty of Physical Therapy, Department of Rehabilitation, Kobe International University, Kobe City, Japan
(4) Faculty of Health Care Group, KKIMAC, Moriyama City, Japan

Main topics: Analysis of gait and motor disorders, Rehabilitation

INTRODUCTION and AIM

To improve the weight-bearing ratio (WBR) of a paretic lower limb while walking in cerebrovascular disorder patients, it is important to perform gait training in consideration of motor and sensory disturbances and the balance ability. A shoe-type load-measuring apparatus (Step Aid®, KKIMAC, Japan) was recently developed. It is equipped with an insole-type pressure load sensor and capable of providing feedback on whether the lower limb weight-bearing while walking is appropriate, excessive, or insufficient through an optic sensor and sound. In this study, using this apparatus, we investigated the association between WBR of a paretic lower limb and the gait ability in patients with cerebrovascular disorder-associated hemiplegia.

PATIENTS/MATERIALS and METHODS

The subjects were 17 patients with cerebrovascular disorder-associated hemiplegia who were admitted to our hospital for rehabilitation (61±11 years). The patients were divided into 2 groups: 8 patients who could walk independently (using a cane and lower limb orthosis), and 9 patients who required assistance for gait (using a wheelchair). Paretic lower limb weight-bearing was evaluated by wearing Step Aid® on the paretic foot. The 10-m walking time in- and outside parallel bars was measured, and the balance was evaluated using the Berg Balance Scale (BBS). WBR of the paretic lower limb was measured on static standing and while walking in- and outside parallel bars, and CV (%) was calculated.

RESULTS

The walking time in the independent gait group was significantly shorter than that in the gait-assisted group in- and outside parallel bars (9.8±1.3 vs. 28.7±14.5 seconds and 8.1±0.8 vs. 34.9±28.1 seconds, respectively; inside parallel bars: $p<0.01$, outside parallel bars: $p<0.05$), and BBS was significantly higher (53.2±2.6 vs. 40.2±6.4, respectively; $p<0.001$). WBR of the paretic lower limb on static standing was significantly higher in the independent gait group (97.7±2.5 vs. 71.3±12.1%, respectively; $p<0.001$), and similar findings were obtained while walking in- and outside parallel bars. Regarding the CV value, no significant difference was noted between the 2 groups in walking inside parallel bars, but it was significantly higher in the gait-assisted group while walking outside parallel bars (1.1±0.1 vs. 3.3±1.4, respectively; $p<0.001$).

DISCUSSION and CONCLUSIONS

It has occasionally been reported that paretic lower limb weight-bearing serves as an index to predict the independent gait of patients with cerebrovascular disorder accompanied by motor paralysis. In our study, WBR of paretic lower limbs on static standing and gait in- and outside parallel bars was significantly higher in the independent gait than in the gait-assisted group, confirming that WBR of the paretic lower limb is an important index to achieve independent gait. In addition, the CV value of WBR of paretic lower limbs while walking outside parallel bars was significantly higher in the gait-assisted than in the independent gait group, showing the variation of paretic lower limb weight-bearing.
In conclusion, WBR on the paretic side while walking is an important index to achieve independent gait in patients with cerebrovascular disorder-associated hemiplegia, and follow-up of the course of lower limb WBR using Step Aid® may be useful for gait rehabilitation in patients with cerebrovascular disorder-associated hemiplegia and diseases requiring weight-bearing training after orthopedic treatment.

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BOTULINUM TOXIN AND REHABILITATION PROGRAM IN THE TREATMENT OF CAMPTOCORMIA IN PARKINSON'S DISEASE

M. Bacchini (1), G. Chiari (1) , M. Rossi (1)
Don Carlo Gnocchi Foundation - Onlus - S. Maria ai Servi Center – Parma- Italy

Main Topics: Movement analysis in clinical practice and Clinical decision making processes

INTRODUCTION and AIM

The flexion of at the least 45° of the thoraco-lumbar spine in idiopathic Parkinson's disease, that increases during walking and disappears in the supine position or when patients push their hands lean against a wall is referred to as camptocormia [1]. As camptocormia is an axial dystonia and often responds poorly to medical therapy, it remains one of the most disabling features in Parkinson's disease [2]. The principal aim of this study was to evaluate with clinical, radiological and gait analysis patterns the effect of botulinum toxin type A (BTX–A) injection and a specific rehabilitation in camptocormia in Parkinson's disease.

PATIENTS/MATERIALS and METHODS

5 patients with camptocormia (4 females and 1 female; the average age was 61 years) participated in this study. A total of 9 trials each patients were carried out using the EL.I.TE. 3-D SMART opto-electronic system (BTS, Milan, Italy) following DAVIS protocol. EMG (Pocket EMG, BTS, Milan, Italy) signals from dorso-lumbar paravertebral muscles (DLP**)**, rectus abdominis superior (RAS), rectus abdominis inferior (RAI), obliquus externus (OE), obliquus internus (OI), ileo-psoas (IP), gluteus medius (MG) were recorded. Two dynamometric platforms permitted the measurement of the joint moments and the mechanical energy produced.

All patients underwent clinical investigation (Trunk Dystonia Disability Scale: TDDS) , X-rays and gait analysis on two occasions: at inclusion and 1 month after botulinum toxin injection. The measurements were performed in "on" conditions 1 h after the regular morning antiparkinsonian drug administration.

Dynamic EMG showed a pattern of abnormal tonic hyperactivity of the abdominal muscles, whereas no continous activity was in dorso-lumbar paravertebral muscles (Fig. 1). Using electromyographic guidance, we injected botulinum toxin (Dysport, 500 U in 2,5 mL physiologic solution) into the rectus inferior abdominis, obliquus internus and ileo-psoas muscles bilaterally in six sites using 125 U per site. Patients underwent a rehabilitation programme consisting of individual 90-minute daily sessions, 5 days a week for 4 weeks.

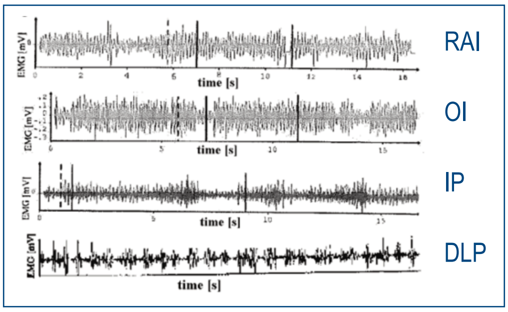

Figure 1: Dynamic EMG

RESULTS

After the treatment, TDDS score showed a mean improvement of 6 points. Significant decrease of X-ray degree of thoracic kyphosis (46.9° ± 7.2° vs. 58.2° ± 9.3°) associated with an increase in back spine strength was observed. Kinematic: resumption of the pelvic sinusoidal trend in sagittal plane with reduction of retroversion of the pelvis (Fig. 2) and of flexion of the hips and knees. Kinetics: increase of the hip extensor moment peak, at the terminal stance, with an average value of 1.2 Newton x meter/kg, against 0.7 of the pre-treatment controls.

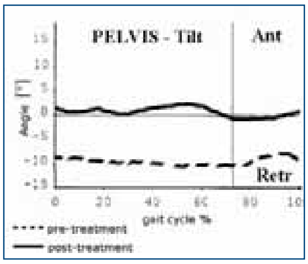

Figure 2: Pelvic tilt

DISCUSSION and CONCLUSIONS

We suggest that perhaps a combination of botulinum toxin injection and specific physiotherapy would have yielded more significant results regarding the functional benefit of the therapy in camptocormia in Parkinson's disease. These patients showing axial rigidity, gait disorder, postural instability, and poor L-dopa responsiveness are probably affected by a selective form of Parkinson's disease [3], who would benefit greatly from an additional, non pharmacological, treatment strategy.

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EFFECT OF HIP FLEXOR WEAKNESS ON GENERATING STIFF KNEE GAIT PATTERN: SIX CASES PILOT STUDY

Akalan NE[1], Apti A[2], Kuchimov S[3], Temelli Y[4], Nene A.[5]
(1) Istanbul University, Faculty of Health Science, Physiotherapy and Rehabilitation Division, Istanbul, Turkey
(2) Bogaziçi University, Institute of Biomedical Engineering, Istanbul, Turkey
(3) Istanbul University, Faculty of Health Science, Physiotherapy and Rehabilitation Div., Istanbul, Turkey
(4) Istanbul University, Istanbul Faculty of Medicine, Orthopedics and Traumatology Div, Istanbul, Turkey
(5) Roessingh Rehabilitation Center, Enschede, Netherland.

Main topics: stiff knee gait, hip flexor weakness, hip and knee flexor velocity.

INTRODUCTION and AIM

Stiff knee gait (SKG) is one of the most common gait abnormalities in subjects with stroke and cerebral palsy (CP)[1]. Diminished knee flexion velocities at toe-off and increased knee extension moments during double support are strongly believed to cause SKG [2]. Especially for children with CP, because of the hip flexor contracture, stretching exercise or for more severe cases, myofacial muscle lengthening of psoas or ilio-psoas lengthening is commonly performed. Muscle weakness is a serious problem in CP and these procedures causes them even weaker. The purpose of the study was to determine what, if any, association exists between ilio-psoas muscle weakness and stiff knee gait on typically developed individuals.

PATIENTS/MATERIALS and METHODS

Figure 2: Representing significant SKG parameters.Six able bodied healthy participants (Av. Age: 22.4±0.81) were included in the study. For each participants after obtaining gait acquisition, isolate manually, passive 30 min (135 sec x13) [3] cyclical stretching for ilio-psoas muscle was performed on non-dominant side while a load (5% of the body weight) firmly placed on front-distal thigh (Fig. 1). Researcher verbally acknowledged that the stretched was under the pain threshold in every 30 seconds. After first stretching, the drop of the strength level was checked from 5/5 to 3+/5 was determined by manual muscle test, if it was not desirably dropped 11 min (5x135 sec) additional cyclical stretch was applied. Computerised gait analysis was then performed in self-selected speed within 40 sec after the last stretching session. The load and stretching were used to increase affect of ilio-psoas weakness relative to thigh in order to simulate hip flexor weakness. If three or four Goldberg parameters were completed it is considered as SKG. Paired t-test was used for the statistical comparison ($p<0.05$).

Figure 1: Stretching iliopsoas (a), weight placement (b)

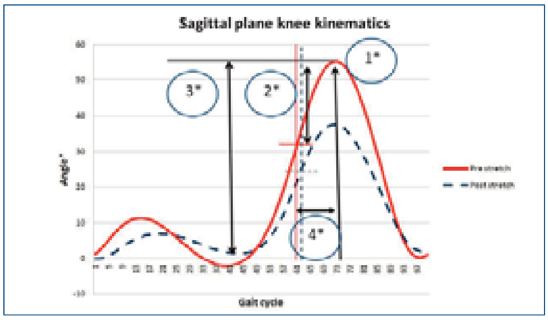

Figure 2: Representing significant SKG parameters.

RESULTS

After stretching with the load maximum hip flexion and knee flexion velocity between mid-stance (mean-difference in percentage; -31%, -23% respectively). Peak knee flexion (PKF) (-31%), total knee range in sagittal plane (-29%), duration of time (-27%) and the range between toe-off to PKF (-49%), cadence (-19%), and mean velocity (-31%) significantly reduced. Stride and stance time significantly increased ($p<0.05$).

DISCUSSION and CONCLUSIONS

Our pilot study showed that, hip flexor weakness completed the 4 Goldberg parameters [2], except significantly shorten the duration between toe-off to PKF time, which was expected to see, delayed. Any treatment such as ilio-psoas muscle lengthening and/or radical stretching exercises which reduces the hip flexor strength and/or hip flexion velocity may increase rectus-femoris activation demand and cause SKG pattern. The surgical procedures, which reduce hip flexor strength, may contribute SKG pattern although reducing risk of hip dislocation.

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A SUCCESSFUL CASE OF BIOLOGICALLY RECONSTRUCTED FEMUR AFTER OSTEOSARCOMA: WHAT IS THE LONG-TERM BIOMECHANICAL ADAPTATION?

G. Valente (1), L. Pitto (1), A. Roncari (1), S. Piroddi (1), A. Leardini (2), M. Manfrini (3), F. Taddei (1)
(1) Medical Technology Laboratory, Rizzoli Orthopaedic Institute, Bologna, Italy
(2) Movement Analysis Laboratory, Rizzoli Orthopaedic Institute, Bologna, Italy
(3) Musculoskeletal Oncology, Rizzoli Orthopaedic Institute, Bologna, Italy

Main topics: Musculoskeletal modelling, Outcomes after clinical interventions, Orthopaedics.

INTRODUCTION and AIM

Biological reconstruction of the femur using massive bone allograft (MBA) is a worldwide solution for limb-salvage surgery after osteosarcoma. Because of the risk of MBA mechanical failure and size limitations of vascularised fibula autografts (VFA), a combination of VFA placed inside a MBA represents an original solution [1]. However, the remodelling and long-term survival of the reconstruction are not consistent [2]. The aim of this study is to analyze the long-term biomechanical adaptation of a single successful case, given the evolution of bone morphology and density, by using a subject-specific musculoskeletal modelling approach.

PATIENTS/MATERIALS and METHODS

The patient (male, 8 years old) underwent a biological reconstruction of the proximal right femur, and was then continuously disease free. CT scans of the lower limbs were acquired post-operatively and during follow-ups at every 6 months for routine controls. The evolution of bone morphology and density was quantitatively evaluated (Figure 1). After 6.5 years, the patient underwent gait analysis and CT scanning after being instrumented with the same reflective marker setup [3]. A 9-body segment, 12 degree-of-freedom articulated 3D linkage actuated by 84 musculotendon actuators was created from these images (Figure 1), and a typical inverse dynamics and static optimization approach was used to calculate muscle and joint contact forces during each motor task.

RESULTS

The morphological and densitometric analysis showed an intense remodelling process involving both VFA and MBA with concentric remodelling fronts (Figure 1), and a comparable growth of the two femurs, although an increase in valgus angle at the operated femur resulted in a 1 cm limb dismetry. Preliminary musculoskeletal modelling outcomes showed significant differences in joint kinematics and kinetics between the two legs during motor tasks. The analysis is being extended to calculation of muscle and joint contact forces of the lower limbs.

DISCUSSION and CONCLUSIONS

This study shows a successful biomechanical adaptation in presence of an outstanding remodelling between the massive bone allograft and the vascularised fibular autograft in a biological reconstruction of the femur. Future investigation will analyze the stress conditions of the reconstruction during each motor task.

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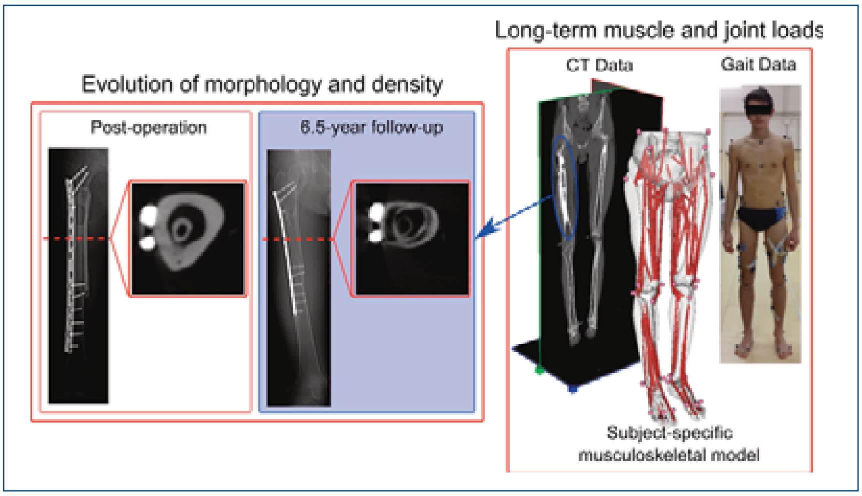

Figure 1: Workflow of the analysis. Left panel: CT-based morphological and densitometric measurements of the reconstructed femur. Right panel: simulations of daily activities using a subject-specific musculoskeletal model built from CT and gait data to evaluate long-term biomechanical adaptation.

LATISSIMUS DORSI TENDON TRANSFER IN PATIENTS WITH POSTEROSUPERIOR ROTATOR CUFF TEARS AND THE ABILITY TO PERFORM ADLS: 3D VIDEO MOTION ANALYSIS STUDY

M.W. Maier, S. Erhard, P. Raiss, D. Spranz, S. van Drongelen, S.I. Wolf, F.Zeifang
Clinic for Orthopedics and Trauma Surgery, Heidelberg University Hospital, Heidelberg, Germany

INTRODUCTION

Most of the patients with posterosuperior rotator cuff tears lose their ability to perform acitivities of daily living (ADL), especially when it comes to ADL where it is necessary to exorotate and elevate the upper extremity. In such patients a latissimus dorsi tendon transfer (LDTT) can be performed to restore the ability of exorotation [1]. For postoperative assessment shoulder surgeons measure parameters like range of motion (ROM), pain, satisfaction and strength. The Constant score (CS) is a commonly used to assess ROM and ADL [3], but till to date there is no objective data if a LDTT can restore the ROM especially in performing ADLs. Therefore, the purpose of this study was a 3D measurement of patients with LDTT to evaluate their abilities in maximum values, especially endo- and exorotation, and ADLs.

METHODS

This retrospective study included 26 patients (19 men, 7 women), who received a LDTT between 2004 and 2012 for posterosuperior rotator cuff tears. Mean age on operation date was 53 years (35 – 66 years) and mean time after surgery was 4.2 years (1- 9 years). All patients were assessed concerning their revision status. Additionally in 13 patients a 3D motion analysis using the Heidelberg Upper Extremity (HUX) model [2] was performed, clinical evaluation was performed with the CS. The non operated side was measured as a control group in 8 of the 13 patients. Active maximum values were measured for flexion/ extension, abduction/adduction, endo-/exorotation in 0°flexion, 90° flexion, 90° abduction. Also the seven ADLs (toilet hygiene, combing hair, washing armpit, eating with a spoon, drinking, taking a book from a shelf and using a phone) were recorded. In order to have valuable data patients needed to repeat the tasks 5 times, patients data were excluded if the patient was not able to repeat the task at least 3 times.

RESULTS

5 out of 26 patients (19.2%) were lost to follow up, 2 patients needed revision not associated to the transfer (tenotomy of the long biceps tendon due to tendinitis, T2 nail for humerus spiral shaft fracture after fall and LC DC plate osteosynthesis after second fall). One patient was diagnosed with a tear-out of the transferred tendon eight months after LDTT, but no revision was done. Three patients needed revision for postoperative wound healing deficits. On latest follow up none of the patients needed a revision surgery with reversed shoulder arthroplasty. 4.2 years (1-9 years) after LDTT the patients reached an average CS of 56.2 points, with sub-scores showoff 11.5 in pain, 12.2 in daily competences, 12.2 in motility and 7.2 in strength.

During motion analysis it came clear that most of the patients had difficulties in performing the task "take a book from a shelf", in repeating the task patients reported loss of strength; 2 patients were not able to perform the task. 3D motion analysis showed differences between operated and non operated side in the task "take a book from a shelf". Patients were instructed to grab a standing book, look at the titel and place it in standing position back on the shelf. During the task, retraction of the shoulder girdle and abduction in the shoulder was higher, but it showed less exorotation. Results are demonstrated in following graphics.

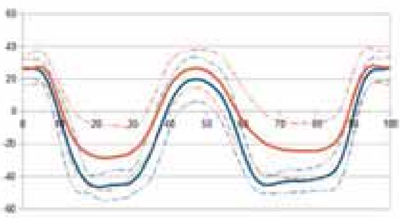

Figure. 1: Exo-/endorotation

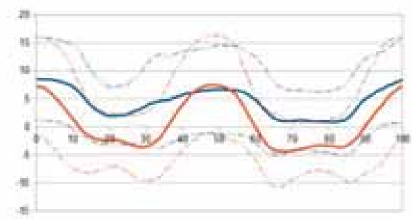

Figure. 2: Pro-/Retraction

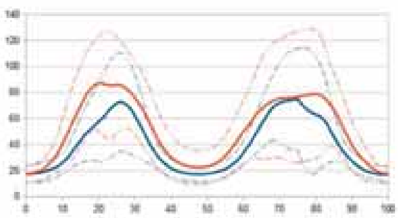

Figure. 3: Abduction/Adduction

Red: operated side Blue: non-operated side; Straight lines: mean, dotted lines: standard deviation

Table1 and figures 4 - 6 show measurement of mean maximum values of the operated side.

	Flexion	Extension	Abduction	Adduction	Exo0°	Endo0°	Exo90°abd	Endo90°abd	Exo90°flex	Endo90°flex
Mean (°)	120	60	122	30	12	50	34	60	39	42

Table 1: mean maximum values of the operated side

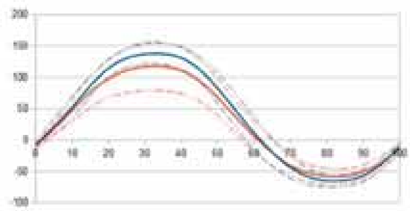

Figure 4: Flexion/ extension

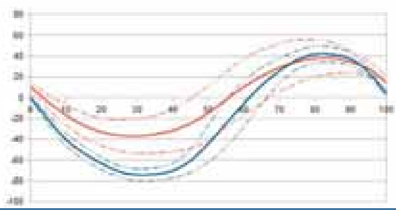

Figure 5: Exo-/endorotation 90° flexion

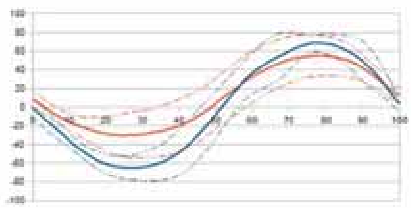

Figure 6: Exo-/ endorotation 90° abduction

Red: operated side, blue: non-operated side; straight lines: mean, dotted lines: standard deviation

CONCLUSION

After LDTT the active ROM for flexion, extension, abduction and adduction showed nearly the same ROM as the non-operated side. In mean maximum values for endo- and exorotation there was still a difference to the non-operated side but the study showed that most of the patients were able to exorotate the shoulder in 0°, 90° flexion and 90° abduction.

After LDTT the patients were able to perform ADLs, but as demonstrated with the task "take a book from a shelf" the motion sequence can be different from the motion sequence of non operated side. There was a difference in means, but also a relatively high standard deviation, which could mean that, despite same instruction, every patient had their own way to perform the task.

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SPASTICITY EVALUATION OF THE CALF MUSCLES IN CHILDREN WITH CEREBRAL PALSY

M. Witjes[1], K. Roeleveld[1], S.M. Brændvik[1,2]
[1]Department of neuroscience, NTNU, Trondheim, Norway
[2] Clinical Services, St. Olavs University Hospital, Trondheim, Norway

Main topics: analysis of clinical movement data, analysis of motor disorders

INTRODUCTION and AIM

Spasticity is a prominent symptom in Cerebral palsy (CP) and may lead to development of secondary musculoskeletal problems and impaired function (1). The management of spasticity aims to prevent these secondary problems and to improve function. However, the assessment of spasticity remains a controversial topic in research and clinical settings (2). Clinical scales are often used to assess spasticity, but the subjective character restricts their validity. The aim of this study is to evaluate the EMG response during the Tardieu test (3) and to evaluate the consistency of this response with the Tardieu scale.

PATIENTS/MATERIALS and METHODS

The Tardieu test was performed in supine position with the knee in 90˚ and 180˚ flexion in 7 children with CP aged from 6-17 years. Children with diplegic CP (N=3) were measured bilaterally and children with hemiplegic CP (N=4) unilaterally. A catch or clonus was assessed by the examiner during the fast passive dorsiflexion. Concurrent EMG activity of the gastrocnemius and soleus muscles was measured and also the ankle angle was measured with an eight camera Vicon system throughout the movement in order to select the right part of the movement for further analysis.

RESULTS

In total 20 tests were performed (2 positions, 3 bilateral and 4 unilateral). Two tests were excluded, because there was too much noise in the EMG signal. A catch or clonus was identified in 100% (67% catch and 33% clonus) of the tests. In 75% of the tests identified with a catch, this catch was observed in the EMG signal of the gastrocnemius and/or soleus as a burst preceding the catch (figure 1A). In 67% of the tests identified with a clonus, this clonus was observed in the EMG signal as repetitive bursts (figure 1B). In the other tests no burst was observed in the EMG signal (10%, figure 1C) or the EMG response showed a continuous increase in EMG activity (10%, figure 1D). A different EMG response was observed between the gastrocnemius and soleus in 56% of the included tests.

DISCUSSION and CONSLUSIONS

In most cases the appearance of a catch or clonus in the calf muscles can be seen in the EMG signal as one or more bursts in EMG activity. This is in accordance with the results of van den Noort, et al. (4). In addition, four different EMG patterns were observed. Different response patterns have been observed in stroke patients (5), but have not yet been studied in CP children. Future research should point out whether these different EMG patterns are clinically relevant for improving the function in children with spastic CP.

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The study is funded by The Norwegian Fund for Post-graduate Training in physiotherapy awarded SMB and Erasmus mobility grant provided by the European Commission awarded MW.

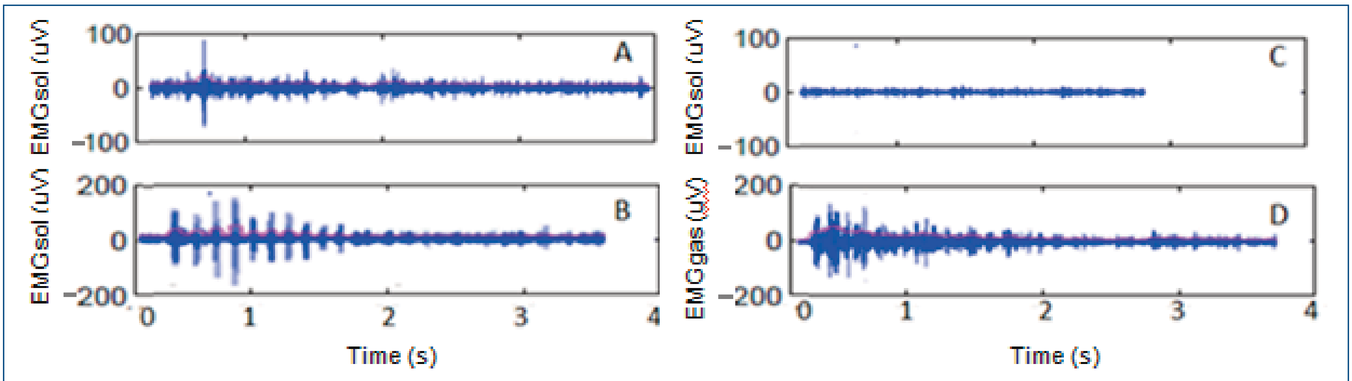

Figure 1: Different EMG responses during the first 4 seconds of fast passive dorsiflexion. A) Burst in muscle activity of the soleus muscle. B) Repetitive bursts in muscle activity of the soleus muscle. C) No change in soleus muscle activity. D) Increase in muscle activity of the gastrocnemius muscle.

IN VIVO EXPLORATION OF AN ANATOMICAL CALIBRATION TECHNIQUE FOR WEARABLE SENSORS

Alessio Caroselli (1), Rita Stagni (1)
(1) Dept. of Electrical and Information Engineering – Gugliemo Marconi, University of Bologna, Bologna, Italy.

Main topics: Movement analysis in clinical practice, Experimental studies in human movement science.

INTRODUCTION and AIM

Wearable sensors (WSs) have become widely accepted for the assessment of human movement analysis. Since clinical information is inferred from joint kinematics, several studies have proposed functional methods to evaluate mechanical rotation axes and define, for each bone segment, a relationship between the bone segment and the measurements of the WS operating on it. These approaches are affected by the quality of the movement performed by the subject, who is usually affected by movement impairment in clinical application, heading to data with a limited inter-subject comparability. This limitation is overcome by traditional anatomical calibration approaches, but their use with WSs represents a big challenge, since bone anatomical landmarks (ALs) must be expressed in the WS reference frame. A previous work from the authors proposed a novel anatomical calibration technique, named VCAST [1], exploiting an off-the-shelf camera as measurement device to calibrated palpable ALs in the WSs reference frames. This method, tested in-silico, resulted in negligible errors superimposed to those committed by operators in the ALs identification, and in an estimate of anatomical segmental pose comparable to the one obtained using stereo photogrammetry. The present study aims at bringing VCAST to the next level, testing it on a real subject and making a step closer to real clinical applications. The work also overcomes one of the limitations encountered in the previous work, implementing an accurate method for the joint centers functional calibration (here applied to the hip but applicable to the gleno-humeral joint) with WSs.

MATERIALS and METHODS

The knee joint kinematics estimation is a simple and representative experimental setup to test the in vivo accuracy of the proposed technique. The accuracy is obtain using the stereo photogrammetry as reference. Two inertial measurement units (IMUs) are fixed on the shank and thigh segments of a healthy young subject. Both IMUs are secured on stereo photogrammetry clusters and reflective markers are glued on the VCAST calibration device. According to the International Society of Biomechanics, the anatomical calibration of the lower limb segments is performed using five palpable ALs (LM, MM, TT, ME, LE) and the HJC.
Palpable ALs calibration: The palpable ALs are expressed, with the same manual procedure, in the IMUs reference frame, using the VCAST calibration device, and in the SP reference frame.
HJC calibration: The HJC is calibrated with a calibration trial where the subject performs small movements with the leg. During the trial, the IMU and the cluster fixed on the thigh lays on sphere surfaces centred in the HJC. With this in mind, the AL is calibrated in the IMU reference frame processing accelerations and angular velocities [2] and in the SP reference frame processing the position of the reflective markers.
After the anatomical calibration, the subject is asked to perform two motor task: a series of squat and few steps. For each motor task the knee joint kinematics obtained through IMUs is compared with those obtained using the stereo photogrammetry.

RESULTS

Preliminary results suggest that the knee joint kinematics accuracy is really close to the dynamic accuracy limit of the IMUs used. The experimental setup is still ongoing and final results will be ready for the conference date.

DISCUSSION and CONCLUSIONS

Previous works indicate that the presented approach introduces calibration errors of *0.6 ± 0.5 mm* for the palpable ALs and of *3 mm* for the HJC. Since knee joint kinematics shows errors that can be mostly ascribe to the IMUs dynamic accuracy, the presented approach could extend the usability of commercial WSs in those applications where anatomical calibrations are required. Clinical applications, that desire an accurate motor task estimation to discern motor disorders, can point at this anatomical calibration technique, characterized by low time consuming, high portability, ease of use, usability outside laboratory and cheapness.

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FUNCTIONAL ASSESSMENT TOOLS ARE ASSOCIATED WITH RECURRENT FALLS IN STROKE PATIENTS WHO HAVE LEFT A REHABILITATION HOSPITAL 6 MONTHS PREVIOUSLY

Naoki Matsumoto (1) (2), Yu Kawaishi (1), Mika Tani (1), Shuhei Mizuno (1), Satoko Waki (1), Kazue Noda (2)
(1) Kobe Rehabilitation Hospital, Kobe, Hyogo, Japan
(2) Graduate School of Health Sciences, Kobe University, Kobe, Hyogo, Japan

Main topics: recurrent falls, stroke, FIM, BBS, 10-m gait

INTRODUCTION and AIM

Falls cause fractures and injuries in humans. Older persons reporting only a single fall in the past year and reporting or demonstrating no difficulty or unsteadiness during the evaluation do not require a fall risk assessment.[1] This is mainly applicable to stroke patients. After leaving the hospital, stroke patients should consider changing physical functions because recurrent falls increase the risk of injuries. However, studies evaluating stroke patients who have left the hospital are limited. The aim of this study was to investigate the relationship of functional assessment tools with recurrent falls using a non-fallers group (fell ≤1 time) and recurrent fallers group (fell ≥2 times) including patients who left the hospital 6 months previously.

PATIENTS and METHODS

Subjects were 31 stroke patients (mean age, 66.87 years; SD, 12.55; age range, 41–84; 14 men and 17 women) who left Kobe Rehabilitation Hospital. The patients were evaluated 6 months after leaving the hospital. The assessment variables were age, sex, Berg Balance Scale (BBS), Mini-Mental State Examination (MMSE), Trail Making Test A (TMT-A), Functional Independence Measure (FIM), Rivermead Behavioural Memory Test (RBMT), comfortable gait speed (10 m), dual task (serial-7s), error in estimated reach distance, lesion side, history of falls in the hospital, and number of medicines used. The data on falls were collected every month by telephone interview for 6 months after the patients left the hospital. The evaluations at 6 months after leaving the hospital were performed at the patient's home or the hospital. A fall was defined as follows: an event which results in a person coming to rest inadvertently on the ground or other lower level and other than as a consequence of the following.[2]

RESULTS

Of the 31 stroke patients, 5 (16.13%) experienced ≥2 falls and 26 (83.87%) experienced ≤1 fall 6 months after leaving the hospital. Sex ($P = 0.029$), BBS ($P = 0.0095$), FIM-motor ($P = 0.018$), and comfortable gait speed (10 m) ($P = 0.018$) were significantly different between the non-fallers and recurrent fallers groups. Patients in the recurrent fallers group tended to be female, have lower BBS and FIM-motor scores, and walk slower compared with those in the non-fallers group.

DISCUSSION and CONCLUSIONS

Only sex and assessment tools involving motor function (BBS, FIM-motor, and comfortable gait speed) were significantly different between the 2 groups. Assessment tools involving cognitive function showed no significant difference. We suggest that motor function is associated with recurrent falls in stroke patients after leaving the hospital. In other studies, cognitive function was associated with recurrent falls; however, this was not observed in the present study. We believe that one of the reasons for this difference is the smaller sample size in this study.

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LONG TERM EFFECTS OF PRETERM BIRTHS: ASSOCIATIONS BETWEEN UPPER-LIMB KINEMATICS, BRAIN VOLUMS AND COGNITIVE FUNCTIONS

Louise Rönnqvist[1], Erik Domellöf [1, 2], Anna-Maria Johansson[1], Katrine Riklund[3], Thomas Lindqvist[3], & Richard Birgander[3]
[1]Department of Psychology, Umeå University, SE- 901 87 Umeå, Sweden, [2]Kolbäcken Child Rehabilitation Centre, SE-907 33 Umeå, Sweden, [3]Department of Radiation Sciences, Umeå University SE- 901 87 Umeå, Sweden

Main topics: Analysis of clinical movement data, motor control and motor learning

INTRODUCTION and AIM

Studies of long-term outcomes linked to a preterm birth have generally found increasing amount of neurodevelopmental and cognitive disabilities and delays (PI: Rönnqvist). Still, few have addressed the upper-limb performance by means of kinematic outcomes and in associations with cognitive functions and brain volumes. Thus, the main aim of this study was to investigate such possible relationships within school age preterm born children and in relation to their gestational age (GA) at birth.

PATIENTS/MATERIALS and METHODS

The present study is part of a longitudinal, ongoing multidisciplinary project with the goal to discover possible long-term effects of a preterm birth. In this sub-study 7-9-years-old children born preterm (PT) without early sign of neuropathology (N= 24, Mean GA=32, range 22-35) in comparison to age matched term born children (N=31) was included. Kinematics was measured by ProReflex, 3D-registration during task specific, bi- and uni-manual upper-limb movement performance. Additionally, functional brain volumes were investigated by 3-Tesla (T) magnetic resonance imaging (MRI) and cognitive functions by the Wechsler Intelligence Scale for Children, 4th edition (WISC-IV).

RESULTS

Our preliminary results showed significant poorer upper-limb kinematics with more segmented and longer movement paths in the PT-born children in comparison to the term born, this was particular evident for thus children born very- and extremely PT (<32 GA). In agreement with this finding, a decreased total brain volume and regional gray matter reduction were significantly correlated with more segmented arm and head movement trajectories, with poorer general IQ outcomes, as well as with lower gestational ages.

DISCUSSION and CONCLUSIONS

The findings from the present study show that a preterm birth, and especially a very- and extremely preterm birth, may cause long-term effects on the development of neurophysiology mechanism involved in the goal-directed upper-limb movements. Additionally, it shows that the development of the neuro-motor mechanisms also are associated with both cognitive functions and the general brain development. Thus, indicating that a very- /extremely preterm birth may still associate to neuro-developmental related sequels when children reach the school age.

GAIT ANALYSIS AND FUNCTIONAL OUTCOME AFTER CALCANEAL FRACTURES

S. van Hoeve[1], J. de Vos[1], J.P.A.M. Verbruggen[1], P. Willems[2,3], K. Meijer[2,3], M. Poeze[1,3]
1Department of Surgery, division of Trauma surgery, Maastricht University Medical, Maastricht, The Netherlands,[2]Department of Movement Sciences, Maastricht University, Maastricht, The Netherlands, [3]NUTRIM School for Nutrition, Toxicology and Metabolism, Maastricht University, Maastricht, The Netherlands

INTRODUCTION

Calcaneal fractures are associated with significant morbidity and socio-economic impact, frequently leading to limited functional outcome and high costs. To evaluate this outcome questionnaires, physical examination and radiographic findings are used regularly, although the relationship between radiographic parameters and functional outcome is inconsistent. Gait analysis after calcaneal fractures may provide the link between radiographic parameters and functional outcome. The Oxford foot model (OFM) has been reported as a valid and reproducible addition to the biomechanical examination of the foot.
AIM to evaluate gait analyses in patients after operative repair of calcaneal fractures in relationship with functional outcome and radiographic findings.

PATIENTS/MATERIALS

Thirteen patients with calcaneal fractures (>6 months after surgical fixation) underwent gait analysis Results were compared with healthy subjects (n=9) and patients after subtalar arthrodesis (n=8).
METHODS Intersegment joint angles were measured to evaluate range of motion (ROM) during gait using the VICON-MX3-system, making use of the OFM. Patient reported outcome questionnaires (FADI, VAS, SF-36) and radiographic images (including CT scans) were evaluated before and after surgery. Correlations were measured using SPSS.

RESULTS

Hindfoot inversion/eversion ROM in the ankle/subtalar joint after calcaneal fractures was significantly correlated with functional outcome parameters (R^2=0.5, P<0.05). Also the fracture step-off (>2 mm) in the subtalar joint (R^2=0.7,P<0.004) and the sagittal subtalar joint axis (R^2=0.6,P<0.02) after surgery were significantly correlated with the ROM in the hindfoot.

CONCLUSIONS

Gait analysis after calcaneal fractures provides the link between the anatomic reconstruction and functional outcome and may be used to monitor patients after surgery.

EFFECT OF POSTURAL INSOLES ON STATIC BALANCE IN INDIVIDUALS WITH STROKE: RANDOMIZED CONTROLLED TRIAL

Luiz Alfredo Braun Ferreira (1), Roberta Delasta Lazzari (1), Renata Calhes Franco de Moura (1), Veronica Cimolin (2) Manuela Galli (2) e Claudia Santos Oliveira (1)
(1) Doctoral and Master's Program in Rehabilitation Sciences, Nove de Julho University, Brazil
(2) Department of Electronics, Information and Bioengineering, Politecnico di Milano, Milano, Italy

Main topics: Movement analysis in clinical practice / Central and peripheral resources for the movement

INTRODUCTION and AIM

Posture and balance are key to the successful rehabilitation of patients after stroke. Postural insoles seek to reorganize the tone of the muscle groups and influence the body through reflex posture correction. Act in muscle proprioception and lead the changes in proprioceptive ascending chains. Thus, this study aims one stabilometric analysis of static balance in hemiplegic individuals vascular post-accident brain using postural insoles.

PATIENTS/MATERIALS and METHODS

Once you know the legal aspects and the eligibility criteria, 14 post-stroke subjects, mean age 58.4 years, were randomly divided into a control group (n = 6) and experimental group (n = 8) and instructed to use postural insoles for 3 months. The control group used a placebo insoles and the experimental group used postural insoles correcting dysfunction of equine varus foot. Evaluation consisted of stabilometric analysis through a force platform Kistler 9286BA, with the barefoot.

RESULTS

Analyzing the effect of postural insoles on balance in individuals post-stroke, can observe significant differences in the experimental group compared to the control group.

Table 1: Stabilometric values of individuals post stroke before and after 3 months of use of postural insoles. Experimental Group (EG) and Control Group (CG). Legend: *p ≤ 0.05 (intra-group analysis – repeated-measure ANOVA); # p ≤ 0.05 (inter-group analysis – independent t-test).

	PRE EVALUATION				POST EVALUATION			
	OPEN EYES		CLOSED EYES		OPEN EYES		CLOSED EYES	
	GE	GC	GE	GC	GE	GC	GE	GC
Max oscillation from barycenter (mm)	29,42 (29,66)	9,95(3,13)	24,01(21,98)	13,50 (4,43)	13,12(2,30)*#	44,08 (61,83)	18,52 (6,64)#	40,86 (50,61)
Min oscillation from barycenter (mm)	0,33 (0,39)	0,21 (0,07)	0,33(0,12)	0,23 (0,13)	0,34 (0,26)	0,53 (0,47)	0,30 (0,19)	0,32 (0,11)
ROM Ant/Post (mm)	33,73 (33,27)	16,82 (5,61)	31,03(27,30)	21,29 (8,18)	18,33(3,47)*#	46,18 (63,02)	28,70(11,29)#	49,03 (50,51)
ROM Med/Lat (mm)	38,40 (35,60)	11,33 (3,73)	32,42(24,85)	14,09 (7,19)	17,19(4,48)*#	44,35 (54,29)	22,93(12,72)*#	32,16 (45,10)
Trace Length (mm)	501,57 (282,00)	388,04 (136,01)	521,85 (266,02)	488,48 (210,19)	363,32 (102,08)*#	531,16 (444,58)	578,54 (391,16)	541,87 (337,48)
Speed (mm/s)	15,78 (8,74)	12,13 (4,35)	16,21(7,63)	15,01 (6,86)	11,82 (3,26)	15,31 (11,14)	18,68 (12,57)	16,28 (8,07)
Equivalent Area (mmq)	2875,85 (4209,35)	684,72 (379,10)	2466,54 (2440,99)	1010,47 (789,30)	863,59 (292,75)*#	5748,02 (9740,70)	2258,20 (2273,02)	2303,37 (3065,21)

DISCUSSION and CONCLUSIONS

Ankle-foot orthoses are often provided to improve gait and balance in patients with stroke, although the evidence of effects on walking and balance control is still inconsistent. According to Tyson and Kent (2013) orthoses can improve gait and balance after stroke, but only the immediate effects were examined. In the present study we can observe significant improvements in static balance of the individuals using postural insoles for 3 months compared to the control group.

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VARIABILITY OF CENTRE OF PRESSURE MOVEMENT DURING GAIT ON PREFERRED AND NONPREFERRED LIMBS IN YOUNG AND MIDDLE-AGED WOMEN

Z. Svoboda (1), L. Bizovska (1), Z. Kovacikova (1), P. Kutilek (2), R. Cuberek (1), M. Janura (1)
(1) Faculty of Physical Culture, Palacky University Olomouc, Olomouc, Czech Republic
(2) Faculty of Biomedical Engineering, Czech Technical University in Prague, Kladno, Czech Republic

Main topics: Natural history of movement and ability, Motor control and motor learning

INTRODUCTION and AIM

While there are many evidences for greater variability of kinematic parameters during gait caused by aging, however relatively simple measurable the centre of pressure (COP) movement variability as indicator of changes in movement behaviour during gait have not been sufficiently observed yet. We hypothesised that the COP movement variability is influenced by age and laterality and would be different among the specific subphases of a stance phase The aim of this study was to investigate changes in COP movement during the stance phase of gait caused by both aging and lower limb preference.

PATIENTS/MATERIALS and METHODS

Two groups of females participated in this study: a younger (n=25, age 22.2±1.8 years), older (n=25, age 56.6±4.9 years). The preferred limb was determined before the measurement start by asking a question: “What leg would you kick a ball with? COP movement and ground reaction forces during gait at self-selected speed were recorded using two force platforms. Participants walked at self-selected speeds. The standard deviations of the medial-lateral, anterior-posterior and total COP displacements in four subphases: loading response (LR), midstance (MSt), terminal stance (TSt) and pre-swing (PS) were assessed. Two-way ANOVA and Bonferroni’s post-hoc test were used to identify the differences between preferred and nonpreferred limbs within groups and to identify the age-related differences for both limbs separately.

RESULTS

The observed variables indicated significantly higher mean values ($p < 0.05$) in all cases in subphases LR and PS in comparison with MSt and TSt. Higher variability of COP movement in medial-lateral direction in LR and PW was found for the nonpreferred limb in comparison with preferred limb in the younger group, whereas the opposite effect was present in the older group (higher variability for the preferred limb) (table 1).

DISCUSSION and CONCLUSIONS

Significant differences between limbs were found mostly in subphases of loading response and pre-swing in both groups. These results indicate that only in phases of double support is functional asymmetry manifested. This finding suggests that functional asymmetry during gait is influenced by age. Bilateral asymmetry of lower limbs was apparent in the younger group and suppressed in the middle-aged group.

ACKNOWLEDGEMENT

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Table 1: Observed COP movement variables in different subphases of a stance phase

Subphase	Variable	Younger group (n = 25)		Elder group (n = 25)	
		Preferred	Nonpreferred	Preferred	Nonpreferred
Loading Response	SD*x* [mm]	0.67 (0.38)	1.02 (0.48)*	1.92 (0.73)#	1.27 (0.57)*
	SD*y* [mm]	2.13 (1.06)	1.36 (0.66)*	2.04 (0.94)	1.67 (0.79)
MidStance	SD*x* [mm]	0.12 (0.04)	0.10 (0.05)	0.18 (0.10)#	0.12 (0.06)*
	SD*y* [mm]	0.49 (0.15)	0.52 (0.13)	0.59 (0.22)	0.57 (0.22)
Terminal Stance	SD*x* [mm]	0.10 (0.03)	0.10 (0.03)	0.10 (0.03)	0.11 (0.04)
	SD*y* [mm]	0.51 (0.22)	0.47 (0.17)	0.63 (0.26)	0.55 (0.28)
PreSwing	SD*x* [mm]	0.58 (0.35)	0.90 (0.43)*	1.65 (0.69)#	1.02 (0.40)*
	SD*y* [mm]	1.35 (0.60)	2.50 (1.15)*	2.36 (1.12)#	3.34 (1.61)*&

Legend: SDx(y) – standard deviation of COP displacement in medial-lateral (anterior-posterior) direction, * – $p < 0.05$ when comparing preferred vs. nonpreferred limb within groups, # – $p < 0.05$ when comparing preferred limb between groups, & – $p < 0.05$ when comparing nonpreferred limb between groups.

IS GAIT PATTERN INFLUENCED BY OBESITY IN PATIENTS WITH DOWN SYNDROME?

V. Cimolin(1), M. Galli (1, 2), C. Rigoldi (1), N. Cau (1), C. Condoluci (2), G. Albertini (2)
(1) Department of Electronics, Information and Bioengineering. Politecnico di Milano, Milano, Italy
(2) IRCCS "San Raffaele Pisana", San Raffaele SpA, Roma, Italy
Main topics: Analysis of clinical movement data.

INTRODUCTION and AIM

There is a high prevalence of obesity in Down syndrome (DS) [1]; however, there are no studies, which evaluated the effect of obesity on gait strategy in participants with DS. The aim of this study is to assess the clinical gait analysis of a group of obese individuals with DS and a group of non-obese individuals with DS, to evidence if the obesity influenced gait pattern in these participants; then, the presence of differences between females and males inside the two DS groups was investigated.

PATIENTS/MATERIALS and METHODS

Seventy-eight young subjects with DS and 20 normal weight participants (range 5-18 years) were evaluated using 3D Gait Analysis. Among individuals with DS, 40 were obese (obese DS group), while 38 were normal weight (non-obese DS groups). 3D Gait Analysis was conducted using an optoelectronic system, force platforms and video recording. Spatio-temporal, kinematic and kinetic parameters were identified and calculated for each participants. The considered groups were compared with with Kruskal-Wallis test followed by post-hoc comparison.

RESULTS

Most of parameters were similar in the two groups of patients with DS; the only differences were in terms of stance duration, longer in obese DS group (obese DS group: 63.7% vs. non-obese DS group: 59%; controls: 59.6%), and dorsiflexion ability during swing phase, which was limited in obese DS group (obese DS group: 4.6° vs non-obese DS group: 8.9°; controls: 8.6°). The two DS groups were significantly different in terms of ankle stiffness, directly connected with muscle hypotonia and ligament laxity (Figure 1) [2]: both groups were characterised by reduced values as compared to controls, but the obese DS group presented lower values respect to non-obese DS participants. As concerns the presence of differences between males and females, females were characterised by significant modifications of the gait pattern respect to males in both groups, at hip and pelvis.

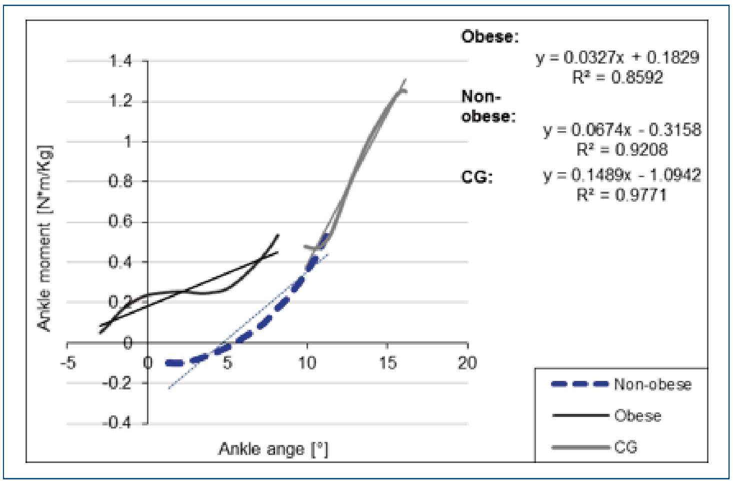

Figure 1: An example of ankle angle–moment plot cycle during second rocker for an obese DS participant, for a non-obese DS participant and one healthy individual is reported. The slope of the joint moment plotted as a function of joint angle during second rocker represents ankle joint stiffness.

DISCUSSION and CONCLUSIONS

Our results show that the presence of obesity has effects on gait pattern in individuals with DS, and in particular, on ankle joint stiffness. The obtained values showed that Obese DS Group was characterised by higher hypotonia and ligament laxity, than the non-obese group. In addition, our results also showed that the gait alterations induced by obesity are gender-moderated. These results could have special clinical relevance; the biomechanical comparison of gait in obese and non-obese young individuals with DS may provide a basis for developing either specific or common rehabilitative strategies.

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VIDEO-BASED MOTION-SEGMENTATION FOR CLINICAL USE

H. Rahmati (1), O. M. Aamo (1), R. Støen (2), L. Adde (3)
Department of Engineering Cybernetics, NTNU, Trondheim, Norway
Department of Pediatrics, St. Olavs University Hospital AND Department of Laboratory Medicine, Women's and Children's Health, NTNU, Trondheim, Norway
Department of Laboratory Medicine, Women's and Children's Health, NTNU, Trondheim, Norway AND Clinics of Clinical Service, St. Olavs University Hospital, Trondheim, Norway

Main topics: Movement analysis in clinical practice, Technical developments in movement science.

INTRODUCTION and AIM

Motion is an important cue for the clinical diagnosis of, for instance, cerebral palsy (CP), or for gait analysis. Conventional motion capture systems need laboratory facilities and expert personnel to set up experiments that could be intrusive for the motion patterns. In this study, we propose a method for capturing and segmenting the motions of individual body parts separately based on a single monocular video camera. The performance of our method is studied in two experiments. First, the segmentation results are compared to the ground-truth (manually segmented) data. Second, the precision in predicting CP based on video is compared with results obtained by electromagnetic sensor data.

PATIENTS/MATERIALS and METHODS

The data set we studied consisted of 78 infants assessed at an age of 10-18 weeks post-term, of which 14 had a confirmed diagnosis of CP at two years of age. Two sets of data were captured from each infant: The first data set was produced by 6 electromagnetic sensors placed on the body to measure the infant's movements. The second data set consisted of video films taken of the infants by a standard video camera simultaneously with the collection of the sensor data. That is, the two data sets are measures of the same motions.

Our method obtains a trajectory for an object from a video in three phases. First, from optical flow fields a dense set of motion trajectories is computed for the whole image. Second, a graph-based segmentation algorithm is applied to the set of trajectories in order to separate them into groups representing the individual body parts (Fig. 1). Third, a tracker is applied to each group to compute a single trajectory for each group (Fig. 2). In the present study, six groups were used, representing the right hand and arm, the left hand and arm, the right foot and leg, the left foot and leg, the head, and the trunk.

RESULTS

As our first experiment, the segmentation accuracy of our method is compared to the ground-truth data. The ground-truth data is provided for 10 out of 78 videos by manually segmenting some of the frames by a user. The comparison result showed 95% segmentation accuracy. As the second experiment, the tracking results of our method are compared with those of sensors by measuring their accuracy in predicting CP. To do so, a set of features is extracted, a SVM classifier is designed, and finally, the prediction accuracy is calculated. The result was 87% for our method and 85% for the sensor data.

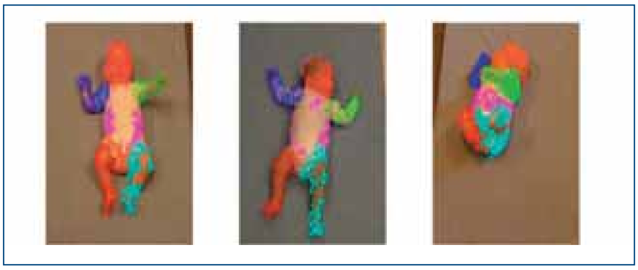

Figure 1: Segmentation results for 3 subjects. Each segment is shown with different color and marker.

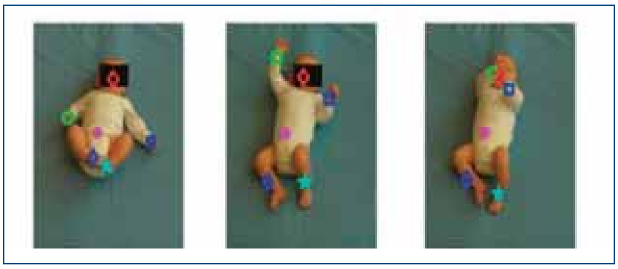

Figure 2: Tracking results for different frames of the same infant. Track of different body parts are shown with different color and marker.

DISCUSSION and CONCLUSIONS

In this paper, we proposed a new video-based motion capture approach. Since our method is based on a single camera, not only it is an economically cheap replacement for conventional motion-capture systems, but it also reduces the need for experts for installation. The segmentation accuracy of our method indicated promising performance. In addition, since the primary goal of this paper was to extract motion data out of a video for early CP detection, the data provided by our method is compared with those of electromagnetic sensors in their prediction accuracy. The results showed that our method is able to provide data as rich as state-of-the-art motion-capture systems. The facts that our method doesn't need any installation on the infant's body, it is based on a single video camera, and doesn't need experts' interaction, make our method potentially profitable to be widespread for clinical use.

WHAT DOES GAIT DEVIATION INDEX ADD TO DESCRIPTION OF GAIT IN CHILDREN WITH ARTHROGRYPOSIS?

M Eriksson (1), Å Bartonek (1), E M Gutierrez-Farewik (1, 2, 3)
(1) Dept of Women's and Children's Health, Karolinska Institutet, Stockholm, Sweden
(2) Dept of Mechanics, Royal Institute of Technology, Stockholm, Sweden
(3) BioMEx Center, Royal Institute of Technology, Stockholm, Sweden

Main topics: Orthotics, Movement deviation indexes

INTRODUCTION and AIM

Arthrogryposis Multiplex Congenita (AMC) is characterized by presence at birth of multiple joint contractures [1]. Greater movements in trunk and pelvis during walking have been observed in children with AMC who used orthoses compared to children who used only shoes [2]. The gait deviation index (GDI) summarizes pelvis and lower limb parameters from 3-D gait analysis into a multivariate measure of overall gait deviations, wherein 100 indicate a normal walking and less than 100 indicate deviant walking [3]. The aim of this study was to describe gait with the GDI, also adding trunk kinematics, spatiotemporal parameters, and kinetics in a group of children with AMC.

PATIENTS/MATERIALS and METHODS

28 children with AMC (median age 10.3, min 5.0, max 17.8 years) participated in the study. 3-D gait analysis was performed with an eight-camera motion analysis system (Vicon®, Oxford, UK). The children walked at a self-selected comfortable pace along a 10m walkway with two embedded force plates (Kistler®, Switzerland). Joint angles, joint moments, joint work done (time integral of power), and GDI were computed. Children with AMC were divided into three subgroups based on orthosis use; AMC1 used knee-ankle-foot orthoses (KAFO) with locked knee joints (n=5), AMC2 used KAFOs with open knee joints or ankle-foot orthoses (AFO) (n=11), and AMC3 used shoes (n=12). The Wilcoxon signed ranks test was used to test for differences between the left and right sides. The Kruskal-Wallis test and the Mann-Whitney U post hoc test were used to compare results between the AMC groups.

RESULTS

There was no difference in the GDI between the limbs. The side with the lowest GDI was chosen for further analysis. AMC1 had lower median GDI (51.0) than AMC2 (75.6) and AMC3 (75.3). AMC1 had lower dimensionless median cadence (24.3) than AMC2 (33.3) and AMC3 (34.0). There were no differences between the groups in the other spatiotemporal parameters. Trunk lateral sway and trunk rotation were greater in AMC1 (median 16.4º and 20.6º respectively) and AMC2 (8.9º and 13.2º respectively) than in AMC3 (4.8º and 6.3º respectively). Kinetic analysis demonstrated a proximal work shift on AMC wherein the hip accounted for a larger portion of lower extremity positive work than the ankle or knee in all AMC groups, primarily in AMC1.

DISCUSSION and CONCLUSIONS

The children with AMC had a deviant gait represented by a GDI lower than 100. The lowest GDI was found in children walking with locked KAFOs (AMC1), whereas children with open KAFOs or AFOs (AMC2) had similar GDI as children walking with only shoes (AMC3). The GDI describes gait deviations of pelvis and the lower limbs in this patient group, however, in children with AMC excessive trunk movements has been observed. Since the GDI does not include trunk movements, it cannot completely describe the gait characteristics in this patient group. The kinetic work analysis demonstrates the children's high reliance on hip muscles, and based on their gait patterns, presumably trunk muscles, to provide propulsion. A suggestion is to modify the GDI to include trunk kinematics, which could be useful in children requiring compensatory trunk movements during walking.

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TACTILE SENSING FABRIC GLOVE TO PREDICT PEAK PALMAR PRESSURE AND PREVENT EARLY IMPAIRMENTS IN LEPROSY AFFECTED PATIENTS

Sathish Kumar Paul (1), Rekha Vijaya Kumar (2), Sudesh Sivarasu (3)

(1 The Leprosy Mission Trust India, Delhi
(2) School of Bio Sciences and Technology, VIT University, Vellore, Tamil Nadu- 632014, India
(3) 3MRC/MIRU–Division of Biomedical Engineering, Department of Human Biology, Faculty of Health Sciences, University of Cape Town, South Africa 7925, South Africa

Main topics: Rehabilitation, Assistive Devices

INTRODUCTION and AIM

The peripheral nerve damage causes significant impairments if not detected and treated early. The nerve function impairment in leprosy patients leads to the loss of protective sensation and muscle imbalance. Secondary impairments like ulcers and callosities are further developed due to the neglect of the high pressure prone areas caused due to the nerve function impairment.
The study aimed to develop a tactile sensory glove with the sensors embedded in fabrics. The peak pressure threshold levels identified can further predict injury prone areas and prevent new impairments in the anaesthetic hands while carrying out their normal functional activities.

PATIENTS/MATERIALS and METHODS

The signal conditioning and the data acquisition system were designed and developed to trace the pressure distribution patterns of the palm at certain pre defined areas while the patients were involved in their routine activities of daily living like cooking, gardening and riding bikes. The sensor glove developed was used to record the changes in the superficial palmar pressures of the hand while the patients were using the prehensile functions like the grasp and pinch powers in carrying out the specific activities. The study were conducted on (n = 100) patients from different job profile, gender and from different geographical location.

RESULTS

The glove embedded with the tactile sensors helped predict peak palmar pressure changes while the patients were involved in specific hand function activities. The pattern of the result suggests that the pressure were maximal while in the middle of an activity and is minimal at the onset and the end of the activity. The buzzer set along the glove gave an instant auditory feedback to the patient on the activity which causes prolonged high pressures to the skin surface of the hand. Setting the threshold limit depending on the high pressure areas for each activity in every individual patients will help in predicting and preventing new ulcers and calluses.

DISCUSSION and CONCLUSIONS

The robust tactile sensor glove provided to individual patients with peripheral nerve damage irrespective of their profession will help predict their pressure threshold while doing specific functional activity using impaired hands. The cost effective device also will help predict the ulcer prone areas in the anesthetic hands and feet on the leprosy affected patients if modified and provided on their initial visit to the hospital. The portable, water resistant device can be used for any kind of activity and anywhere in the community. The sensors will help the clinicians and the therapists in prescribing appropriate orthosis and adaptive tools and appliances for the patients and help prevent ulcers and further disabling impairments.

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AN OPEN LOW-COST EMG ACQUISITION SYSTEM FOR ANALYSIS AND ROBOT COTNROL

H. Hajimirzaalian (1), M. Caimmi (1), M. Malosio (1), L. Molinari Tosatti (1)
(1) Inst. of Industrial Technologies and Automation, National Research Council of Italy, Milan, Italy

Main topics: Technical developments in movement science, Biofeedback

INTRODUCTION AND AIM

Surface electromyography SEMG is increasingly used in combination with assistive and rehabilitation devices for control, biofeedback, customizing the intervention and monitoring the results in neurological patients [1,2]. Accurate SEMG signal acquisition requires amplifiers, electrodes, filters and graphic software, often leading to relatively expensive solutions. Because of the costs, using SEMG for analysis and control of rehabilitation devices is still limited in the academic and laboratory ambient. In this study, a low-cost easily interfaceable EMG signal acquisition system, based on an open software and hardware architecture, is proposed for data acquisition and control of rehabilitation devices.

MATERIALS AND METHODS

The proposed SEMG signal acquisition system is compared with the professional BTS FREEEMG system. Two surface electrodes were placed on the biceps of a healthy subject at the distance of about 1cm; the reference electrode was placed on the wrist. Data were acquired without modifying the position of the electrodes for both systems. The subject performed 5 maximal voluntary elbow flexion contractions and SEMG was acquired in sequence with the two systems.

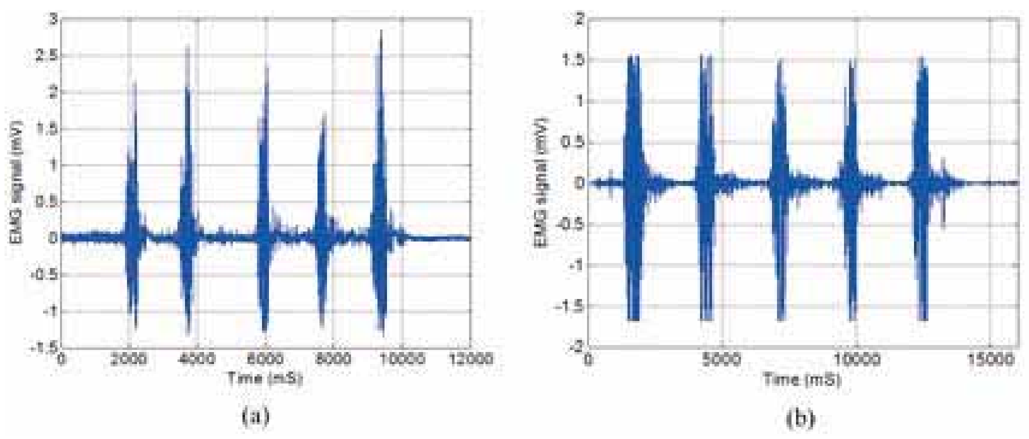

Figure 1. The acquired EMG signal by both systems; the low-cost designed system (a) and the BTS professional system (b)

RESULTS AND DISCUSSION

In Fig. 1 signals acquired by both systems are depicted. As it can be observed the result of the low-cost system is comparable with the BTS system and it is acceptable to use in the control process of rehabilitation robots. While the cost of producing the designed system is 1% of the price of the BTS FEEEMG system.

CONCLUSION

In this study, a 6 channels low-cost EMG acquisition system was realized. The acquired results by the designed system represented a good signal quality and reliability of the system, to use in clinical applications especially in the control process of rehabilitation robots. Moreover, the totall cost to produce the system is much less than the price of the other commercial systems.

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DETERMINING OF RESULTANT MUSCLE TORQUES IN LOWER EXTREMITY JOINTS, GENERATED DURING PARTICULAR MODERN DANCE ELEMENTS

J. Gorwa [1], R. Michnik [2], J. Jurkojć [2], L.B. Dworak[1]
[1]Department of Biomechanics, University School of Physical Education in Poznan, Poland
[2]Biomechatronics Department, Silesian University of Technology, Zabrze, Poland

1. INTRODUCTION

The evolution of modern dance relishes the extremism. Each element described in classical dance, will be performed further, deeper and in a more exaggerated manner in modern dance.
Modern style choreographers often propose very dangerous dancing movements from the point of view of biomechanics of the locomotive system. These dangerous situations created by "movement designers" are often the result of absence of basic knowledge about the capabilities and limitations of the human locomotive apparatus [1].
The aim of this study was to analyze the most important parameters determining the quality of the motion structure of the particular modern dance jumps – including grand jeté.

2. MATERIAL AND METHODS

This paper consists of a case study of two professional male modern ballet dancers. The dancers are employed full time in a theater ballet dance team. The artists were asked to perform three times a particular modern dance jumps. The measurements were performed in the Biomechanical Laboratory of the Department of Biomechanics at the University School of Physical Education in Poznan. Examined dancer performed all the movements barefoot. Motion was recorded by four Basler digital cameras with the frequency of 200 Hz. Data were processed by means of the APAS motion analysis system to determine kinematic parameters. GRF were measured with the use of the Kistler dynamometric platforms. On the basis of momentary GRF and values of momentary kinematic parameters, using the inverse dynamic problem, resultant torques of muscle forces in the lower limb were calculated for the particular modern elements. The calculations were performed with the use of a proprietary software developed in the Matlab environment. Each try of the modern grand jeté jump was analyzed kinematically and dynamically and its technique was evaluated. Analysis began the moment the foot came in contact with the ground and ended the moment it left the ground.

3. RESULTS AND DISCUSSION

During the landing phase, the contact of the foot with the ground is characterized by application of ground reaction force in the toe region (forefoot), as the foot is lowered, the point of application of force travels toward the long axis of the dancers. While reaching max. value of GRF the foot contact with the ground falls on forefoot (dancer no.1) and midfoot (dancer no.2). Along with the increase in horizontal components, there is a change in the angle between the ground reaction force application line and plane of support. During GJ jump dancer no.2 experiences much more loads acting on the lower limb segments with the exception of ankle torque (moment of force) which value for dancer no.1 was bigger than the one for dancer no.2. For a dancer no.1 the lowest value of torque appears in knee joint. The jump of dancer no.2 characterizes the biggest load on the hip joint and the lowest on the ankle joint (fig.1).

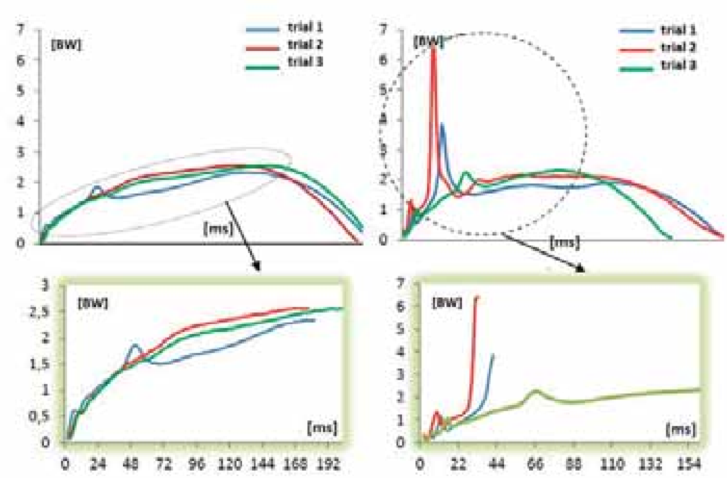

Figure.1. Line graph of ground reaction during the performance of grand jete jump (of modern dance)
The results of this research article prove the appearance of technical differences between artists during performing of dance elements.

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ABNORMAL MUSCLE SYNERGIES SIGNIFICANTLY ALTER ENDPOINT STIFFNESS AND VIRTUAL TRAJECTORY WHILE DRAWING IN A HORIZONTAL PLANE

T. Oku (1), K. Uno (1), T. Nishi (2), M. Kageyama (2), P. Phatiwuttipat (1), K. Koba (1), Y. Yamashita (1), M. Uemura (1), H. Hirai (1), F. Miyazaki (1), and H. Naritomi (2)
(1) Dept. of Mechanical Science and Bioengineering, Graduate School of Engineering Science, Osaka University, Toyonaka, Osaka 560-8531, Japan
(2) Dept. of Rehabilitation, Senri Chuo Hospital, Toyonaka, Osaka 560-0082, Japan

Main topics: Analysis of clinical movement data, Movement deviation indexes

INTRODUCTION and AIM

Mechanical impedance and virtual trajectories are principal indexes for understanding the control strategies underlying voluntary and involuntary movements. The attractive phenomenon of muscle synergies — coordination of co-activation of multiple muscles— may be explained as composites of mechanical impedance [1]. We discuss the balance/imbalance of muscle activities in the context of muscle synergies, endpoint stiffness, and a virtual trajectory.

PATIENTS/MATERIALS and METHODS

A healthy subject (61-year-old male, right-hand dominant) and a subject who suffered a stroke (74-year-old male, right-hand dominant, mild-to-moderate right hemiplegia) traced a circle of radius 0.1 m on a table, in the counter-clockwise direction, at a slow speed. The electromyography (EMG) signals of six muscles in the right upper limb and the positions of the shoulder, elbow, and wrist joints were recorded to investigate the endpoint stiffness and virtual trajectory obtained from the novel method for muscle synergy analysis [2].

RESULTS

The muscle synergies, which represent the balance in co-activation of agonist-antagonist muscle pairs, showed different patterns in healthy and post-stroke subjects. The altered muscle synergies resulted in the distortion of endpoint stiffness and virtual trajectory.

DISCUSSION and CONCLUSIONS

The EMG analysis from the perspective of muscle synergies, endpoint stiffness and the virtual trajectory revealed clear differences in motor strategy between healthy and post-stroke subjects. The abnormal muscle synergies caused by spasticity or rigidity seemingly lead to the elongation of the endpoint stiffness ellipse and the rotation of the orientation of its major axis. The concomitant virtual trajectory was also affected by the alteration, and the virtual trajectory tended to move in the fixed direction of the minor axis of the endpoint stiffness ellipse. Thus, our approach has the potential to quantitatively evaluate tacit motor commands for movements, and may have practical uses in rehabilitation, for the assessment, diagnosis, and treatment of motor impairment.

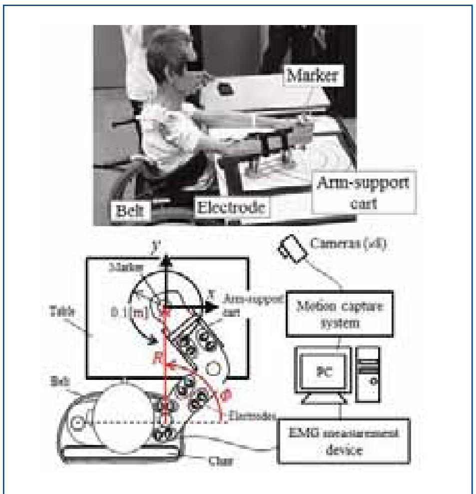

Figure 1: Experimental setup. Each subject traced a circle in a horizontal plane. The gravity effect of the upper limb was compensated using an arm-support cart. During the task, EMG signals and limb kinematics were measured.

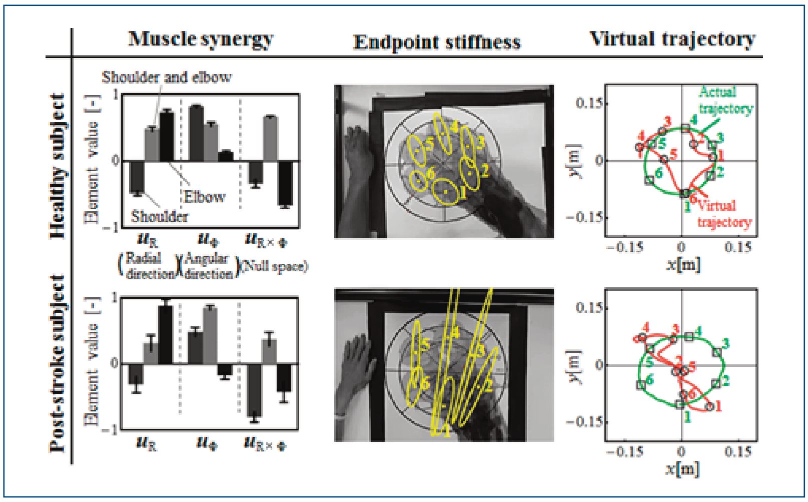

Figure 2: Muscle synergies, endpoint stiffness, and virtual trajectory during circle tracing in healthy and post-stroke subjects. Each muscle synergy vector u_R, u_ϕ, and $u_{(R\times\phi)}$ is determined by the balance in the co-activation of agonist-antagonist muscle pairs, and respectively represents the bases for the radial, angular, and null movements of the virtual trajectory in the polar coordinates centered on the shoulder. The alteration of muscle synergies results in significant distortion of endpoint stiffness and virtual trajectory. Note that actual trajectories were very similar between healthy subject and patient post-stroke.

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THE EFFECT OF FUR INSOLE ON PLANTAR PRESSURE DISTRIBUTION OF YOUNG LADIES DURING NORMAL WALKING

Shiyang Yan (1,2), Luming Yang (1,2), Suofang Li (1), Jun Zhou(1)
(1) National Engineering Laboratory for Clean Technology of Leather Manufacture, Chengdu, 610065, China
(2) Key Laboratory of Leather Chemistry and Engineering (Sichuan University), Chengdu, 610065, China

Main topics:
Analysis of clinical movement data
Experimental studies in human movement science
Reliability and service development

INTRODUCTION and AIM

As we all know, fur derived from thousands of years ago, which is the first covering of human beings to keep warm and protect themselves. With the time-based development, fur has been evolved into many aspects, such as clothing, rug, shoe, even cosmetic and health-care equipment. Fur is used in shoe-making for beauty and warm, especially in snow boot. According to the experiment with respect to snow boot before, we have supposed that the fur insole has the pressure dispersing effect on the plantar pressure. So the purpose of this study is to demonstrate our hypothesis with scientific research. The aim of this study is to support the improvement of fur product and applications of fur to health-care field.

PATIENTS/MATERIALS and METHODS

The data of plantar dynamic pressures were collected from 17 women (21 ± 3 years) without pathology; they were recruited from Sichuan University. Each participant was required to walk at custom speed by wearing normal insoles and fur insoles respectively. Pedar-X system (Novel GmbH, Munich, Germany) was used to collect data; eight anatomical masks were defined by an available toolbox. All data were statistically analysed by SPSS 17.0 and Microsoft Excel.

RESULTS

The result shows that the max pressures in condition 1 greater than condition 2 in all anatomical areas, except for the values of medial heel and lateral heel, although they are found to be very close in conditions 1 and 2, the values are still a little greater in condition 2. According to the paired t-test result, comparison of two conditions has significant differences in toe 2-5, midmeta, lateralmeta and midfoot areas.

DISCUSSION and CONCLUSIONS

Although the max pressures of wearing fur soles in medial heel and lateral heel areas were greater than wearing normal insoles, no significant differences were found in two conditions, which could be explained by the fact that the midmeta, medial heel and lateral heel are the most pressure distributed areas, which is based on domestic researches [1-2]. However, in previous researches, Kernozek et al. [3] showed that the maximum toe beared the most pressure of the body in young adults, which may due to the different life style and walking habits in different continents [1]. So it is noted that this study is applying for Chinese only. As a result, when participants wore fur insole, it gave a obvious pressure relief in midmeta and lateralmeta. But due to the data deficiency, more samples are needed in the further research.

Table 1: Comparison of max pressure (KPa) in two conditions

Mask	Max pressure (KPa) Condition A	B	P-value
toe1	177.21 ± 63.21	175.45 ± 90.46	0.902
toe2-5	100.15 ± 41.12	90.11 ± 30.90	0.024
medialmeta	158.24 ± 39.20	151.52 ± 32.68	0.329
midmeta	221.06 ± 51.22	208.21 ± 44.29	0.033
lateralmeta	172.47 ± 30.82	151.78 ± 31.90	0.007
midfoot	67.53 ± 9.38	59.74 ± 8.57	0.000
medial heel	220.26 ± 41.86	221.02 ± 42.03	0.899
lateral heel	193.65 ± 35.12	201.47 ± 38.91	0.406

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STATIC AND DYNAMIC PARAMETERS IN PATIENTS WITH DEGENERATIVE FLAT BACK AND ITS CHANGE AFTER CORRECTIVE FUSION SURGERY

JH Lee(1), SH Lee(2),
(1) Dep. of physical medicine and rehabilitation, Wooridul spine hospital, Seoul, Rep of Korea
(2) Dep. of Neurosurgery, Wooridul spine hospital, Seoul, Rep of Korea

INTRODUCTION and AIM

Degenerative flat back shows sagittal imbalance from decreased lumbar lordosis and lead to gait disturbance with stooped posture. This study was to evaluate characteristics of static and dynamic parameters in patients with degenerative flat back(DFB) and their improvement after corrective surgery, to assess correlations between change of static and dynamic parameters, and to compare degree of their improvement between successful and unsuccessful outcome groups.

PATIENTS/MATERIALS and METHODS

Forty-seven patients with DFB were included who conducted whole spine X-ray and three dimensional motion analysis before and 6 month after corrective surgery. Forty-four subjects were selected as control group. As static parameters, thoracic kyphosis (TK), thoracolumbar junction(TLJ), and lumbar lordosis(LL), pelvic incidence (PI), sacral slope(SS), and pelvic tilt(PT) were measured. As dynamic parameters, maximal and minimal angle of pelvic tilt, lower limb joints, and thoracic and lumbar vertebrae column(dynamic TK and LL) in sagittal plane were obtained.

RESULTS

The DFB group showed significantly larger LL, PT and smaller TK, SS. The DFB group showed the smaller maximal and minimal TK, LL, pelvic posterior tilt, hip flexion, knee flexion, and ankle dorsiflexion than the control group. Most of these were corrected by fusion surgery significantly. Dynamic spinal parameters correlated with static spinal parameters. Successful group obtained significantly larger improvement in maximal and minimal dynamic LL than unsuccessful group. Otherwise, no significant difference was found in static parameters(Table 1).

DISCUSSION and CONCLUSIONS

The patients with DFB showed increased thoracic kyphosis and decreased sacral slope in static parameters and increased posterior pelvic tilt, hip flexion, and knee flexion angle in dynamic parameters, which could be reversed by lumbar corrective surgery. Significant correlation between static and dynamic parameters was mainly found in spinal parameters. Surgical outcomes in terms of patients' satisfaction were more related to improvement of dynamic parameters such as maximal and minimal dynamic lumbar lordosis rather than to that of static parameters. Three dimensional motion analysis was clinically useful in evaluation of patients with DFB in that it allowed for assessment of dynamic parameters of spinopelvic and lower limb segment, which was related to daily function or treatment outcomes.

Table 1. Comparison of static and dynamic parameters between successful and unsuccessful surgical group

	Successful(N=30)	Unsuccessful(N=17)	p
ΔLL	-37.64±20.2	-42.95±27.23	0.45
ΔTLJ	7.75±22.17	4.2±19.62	0.586
ΔTK	16.14±10.84	8.93±13.52	0.07
ΔPI	9.21±12.47	13.64±15.78	0.294
ΔPT	-6.32±9.99	-5±15.78	0.726
ΔSS	15.47±12.95	18.63±14.39	0.444
ΔMax_Dynamic TK	-24.69±17	-16.4±11.29	0.081
ΔMax_Dynamic LL	-27.6±12.38	-17.73±9.51	0.007*
ΔMin_Dynamic TK	22.61±16.53	15.79±11.29	0.139
ΔMin_Dynamic LL	-26.51±12.65	-16.02±8.34	0.004*

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WALKING REPEATIBILITY OF MIDDLE-AGED ADULTS AT DIFFERENT SPEEDS

SC Strike, PM. Obici, R Lee
University of Roehampton, London, UK

Main topics: Analysis of clinical movement data; Technical developments in movement science.

INTRODUCTION and AIM

Generally, literature associates increased gait variability with an increased risk of falling however, this remains controversial (Beauchet et al, 2009). Further research is required to develop our understanding of gait variability measures. The purpose of this research was to measure the temporal-spatial characteristics and the inter-step trunk acceleration variability using an accelerometer when walking on a treadmill over a broad span of speeds for mid-aged adults. We hypothesized that the preferred walking speed (PWS) gait pattern would be different depending on whether the previous walking was slower or faster than PWS and that the step and stride length and cadence and trunk acceleration variability would be different when walking at different speeds.

PATIENTS/MATERIALS and METHODS

A total of twelve healthy community dwellings (7 male) aged 54 ± 4.25 years were recruited for the study. Each participant wore their own comfortable walking shoes. A three dimensional accelerometer, recording at 50Hz, was attached to the participant's third lumbar spine (L3). The treadmill was programmed such that all participants started the test at their PWS. Then the treadmill speeded up ($0.5 m \cdot s^{-2}$) to 1.25 or 1.50PWS or slowed down to 0.50 or 0.75PWS. After a period of steady state walking at the new speed, the treadmill returned to PWS. To determine inter-step trunk acceleration variability, 200 data points were extracted from the middle of each steady state phase, and an unbiased autocorrelation coefficient calculated in three dimensions. Repeated measure ANOVA was used to determine the effect of the entry speed on the PWS and to determine any differences over the different speeds.

RESULTS

The PWS pattern was not significantly different depending on the entry walking speed, both for temporal-spatial measures and trunk acceleration variability ($p>0.05$). The walking pattern was significantly different when walking at different speeds for the temporal-spatial measures of cadence and step length ($p<0.05$). The trunk acceleration variability was significantly different only in the vertical direction when walking at 0.5PWS compared to the other speeds ($p<0.05$).

DISCUSSION and CONCLUSIONS

Age can compromise dynamic stability and older people walk more slowly than young people, in part to ensure stability. However, walking slowly has been associated with increased variability and is a predictor of falls. (Shimada et al, 2011). The manner in which speed changes alter the walking pattern is unclear for mid-aged adults. For our mid-aged adults, the walking pattern was independent of entry speed, which suggests that PWS has a consistent walking pattern and that is not influenced by the nature of the walking prior to the PWS. Walking at different speeds involves changes in gait parameters, by modulating the step/stride length, and/or the cadence, but this does not alter the trunk repeatability significantly This suggests over a wide span of speeds, the trunk acceleration patterns are relatively stable for this population.

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AN ACTIVE ORTHOSIS SUPPORTING THE STS MOVEMENT – REACTION OF HEALTHY SUBJECTS

J. Block, S. van Drongelen, S. I. Wolf,
Department of Orthopedics and Trauma Surgery, University Hospital Heidelberg, Germany

Main topics: Orthotics, Assistive devices, Robotic devices in human movement science and rehabilitation

INTRODUCTION and AIM

An external knee torque, provided via an active orthosis should support weak persons in every-day-life. As a first task demanding great knee joint torque [1] the sit to stand movement (STS) is implemented. First tests in healthy subjects should gather information on timing and behaviour of the prototype and control system.

PATIENTS/MATERIALS and METHODS

A group of 5 subjects was tested (4 men, 1 women 27y ± 2.4y; 1.86m ± 0,02m; 87kg ± 3.24 kg) with a knee-ankle-foot-orthosis motorized by a serial elastic actuator [2]. The two test conditions were STS with zero support (c0) and with support (c1). The implemented control algorithm [3] uses input from the orthotic knee and ankle angle sensor as well as force data from sensors integrated in the shoe sole to estimate the required knee torque. Users were provided with a percentage of their estimated knee torque analogue to the servo principle.
Per subject seven STS movements were analysed by 3D movement analysis including EMG of the m. rectus femoris. Additionally a questionnaire regarding orthotic fit, timing and support was answered by the users. In the initial position the user was seated on a bench, each foot freely placed on a force platform. The bench was in contact with a third platform, allowing detection of the point in time where the seat was completely unloaded (seat-off). Filtered and rectified EMG envelopes and sagital knee kinematics and kinetics were compared between the two conditions and in c1 also analyzed in relation to the calculated target- and the real motor torque. Data were subphase normalized to the phase from start to seat-off and the phase from seat-off to end, where the length of the phases equaled the subjects' mean over the conditions.

RESULTS

All users reported an appropriate timing of the active support. Real knee torque and calculated target torque were in time. The motor generated torque seemed to be delayed. The activity of the m. rectus femoris (EMG-RF) was the first signal to detect the user´s intention to stand up. Comparing the different conditions EMG-RF and knee torque peak showed a shallower characteristic in c0. Condition did not influence the knee angle (Fig1.a).

DISCUSSION and CONCLUSIONS

The users reported an appropriate timing of the motor support although motor signals showed a delayed increase of the provided torque (Fig1.b red). This apparent conflict could be explained by the healthy users who are not dependent on assistance to overcome the seat off. Adaption of the control should improve this delay. Detecting muscle activation is a promising way to get early information about user intention. Since EMG isn't feasible in every-day-use, therefore mechanical sensors should be integrated in the orthotic system to detect early muscle activation. Furthermore the active orthosis has to be tested in the target group.

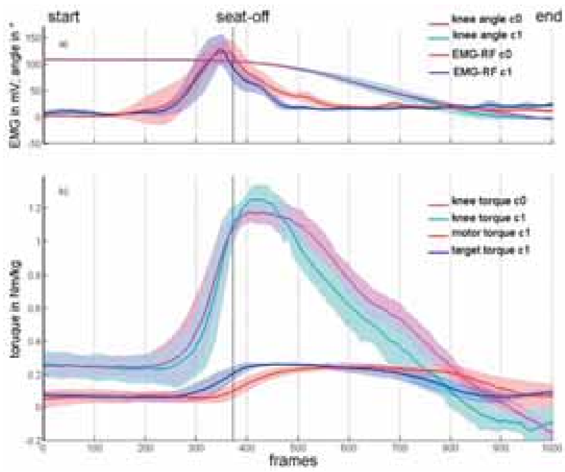

Figure 1: Normalized visualisation of mean motor torques, -EMG, knee angle and knee moment of one subject (right leg only), in supported (c0) and unsupported (c1) condition. Values are mean and SD (shaded).

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Figure 1: Normalized visualisation of mean motor torques, -EMG, knee angle and knee moment of one subject (right leg only), in supported (c0) and unsupported (c1) condition. Values are mean and SD (shaded).

CAN ANATOMIC FEMORAL ANTEVERSION BE CONSIDERED IN GAIT ANALYSES: EXAMPLES OF GAIT PATTERNS IN FAMILIAL DYSAUTONOMIA PATIENTS

Sigal Portnoy, Nurit Hiller, Vlad Goldman, Isabella Schwartz

Department of Physical Medicine and Rehabilitation, Hadassah Medical Center, Jerusalem, Israel

INTRODUCTION and AIM:
Bony torsion may alter kinematic measurements leading to clinical misinterpretation due to faulty assumptions of the models regarding normal femoral and tibial torsion (D'Addesi et al, 1997). Graphing of the kinematic data without correction is likely to be misinterpreted as motions rather than torsions (D'Addesi et al, 1997). Although there is paucity in literature depicting gait kinematics of individuals with bony torsions, it is evident that a very weak correlation between CT-based measurements femoral torsion and motion capture acquired hip rotations is obtained (Radler et al, 2010). We therefore aimed to quantify the effect of alternation in the conventional gait analysis model to account for femoral torsion.

METHODS: The femoral and tibial torsions of seven patients with familial disautonomia were measured using transversal CT scans. The subjects' gait was then captured in a gait laboratory and kinematics of the pelvis, hip, knee and ankle were modeled (Visual 3D, C-Motion) and compared with observational gait analyses in the sagittal and frontal planes.

RESULTS:
An example of the kinematics calculated using the conventional and revised models of a single subject are presented in Figure 1.

CONCLUSIONS:
Our results suggest that a correction to the computational modeling of the lower limbs is warranted when bony torsions are present.

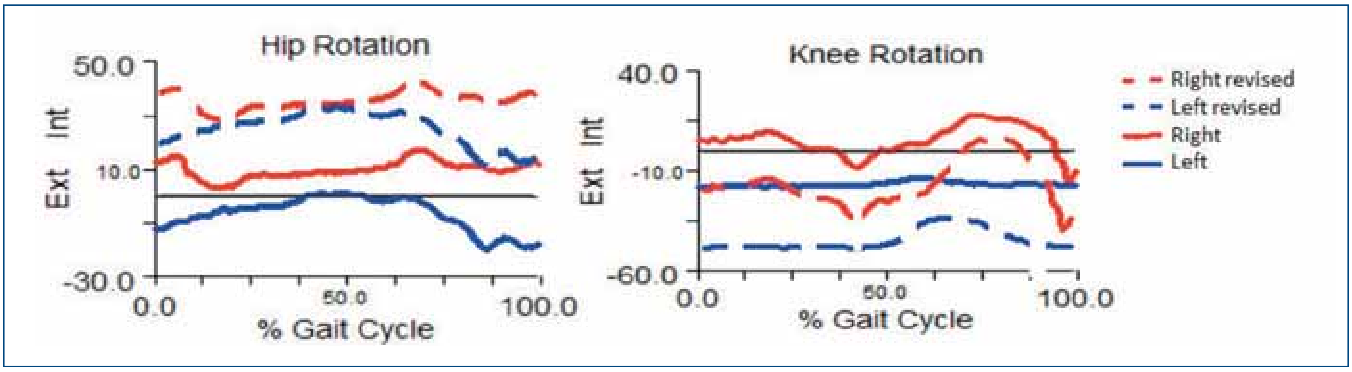

Figure 1: The transversal plane hip and knee kinematics of a familial disautonomia subject, analyzed with the conventional gait model (full line) and the revised model (dashed line).

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THE RETURN TO SPORT ACTIVITIES AFTER METAL ON METAL HIP REPLACEMENT: PRELIMINARY RESULTS OF MOVEMENT ANALYSIS

A. Moroni (1,2), M.T. Miscione (2), G. Micera (1), A. Pasquini (3) S. Fantozzi (4)
(1) Department for Life Quality Studies, University of Bologna, Bologna, Italy
(2) Center of hip resurfacing surgery, San Siro Clinical Institute, Milan, Italy
(3) School of Farmacy, Biotechnology and Sport Science, University of Bologna, Bologna, Italy
(4) Health Sciences and Technologies - CIRI, University of Bologna, Bologna, Italy

Main topics: Outcomes after clinical intervention, Orthopaedics

INTRODUCTION and AIM

Today, younger and more active patients seek hip replacement in an attempt to restore a lifestyle lost to the debilitating effect of hip arthritis; they request high level of activity restored and a low risk of second surgery. Metal on metal hip resurfacing (MOMHR) is largely used for treating symptomatic hip arthritis in young and active patients: the high function is ensured by the large and more anatomically sized components. The aim of this study was to review the clinical and functional results of two athletes operated by MOMHR.

PATIENTS/MATERIALS and METHODS

Two MOMHR patients (males, ex-top level volleyball athletes, BMI 21.3 and 21.6, for patient A and B, respectively) with excellent clinical outcome have been analyzed during walking (3,6 and 12 months of follow-up, 3 trials each) and squat jump (6 and 12 month of follow-up, 3 trials each). Movement analysis was performed using a stereophotogrammetric system (Smart-DX, BTS, Milano, Italy, 10 cameras, 250Hz) and two platforms (9286BA Kistler Instrumente AG, Switzerland). Cluster of 4 markers were attached on the skin of each bony segment, a number of anatomical landmarks were calibrated and segment anatomical frames defined [1].

RESULTS

After 12 months from the hip resurfacing operation, both patients showed a reduction of the differences between the operated and the controlateral side during gait and squat jump trials. The improvement trend, from 3 to 12 months of follow-up, is shown for one kinematic parameter of the hip joint during walking in Table 1 and 2.

DISCUSSION and CONCLUSIONS

Metal on metal hip resurfacing presents a low risk of dislocation, low risk of revision of the implant, excellent survivorship, excellent outcomes and preserves bone stock [2,3]; moreover, the results of this preliminary study show that sport activities can be resumed. In conclusion, MOMHR is a good choice in treating young and active patients affected by symptomatic hip arthritis that ask a high level of activity restored.

Table 1: Range of motion of the flexion/extension angle of the hip for patient A (operated at the left hip) during walking.

Follow-up	Right side (deg)	Left side (deg)
3 months	41.0±1.7	37.3±2.1
6 months	45.4±1.8	42.0±1.7
12 months	42.9±1.5	45.5±1.4

Table 2: Range of motion of the flexion/extension angle of the hip for patient B (operated at the left hip) during walking.

Follow-up	Right side (deg)	Left side (deg)
3 months	51.4±6.7	31.1±4.1
6 months	53.7±3.1	33.1±1.1
12 months	56.4±0.6	39.2±2.5

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CORRELATION BETWEEN GONIOMETRİC MEASUREMENTS OF HIP ROTATIONS IN DIFFERENT POSITIONS AND TRANSVERS PLAN KINEMATICS OF HIP

Pınar. Özkan (1), Sebahat. Aydil (1), Kubilay. Beng (1), Sami. Sökücü (1), Osman. Lapçin (1), Yavuz Selim. Kabukçuoğlu (1)
Baltalimanı Bone Disease and Research Hospital, İstanbul, Türkiye

INTRODUCTION AND AIM

Rotational deformities of hip is a common problem in children with Spastic Cerebral Palsy. Hip rotations are measured by goniometer in prone and supine positions. Computed gait analysis transverse plane kinematics also gives us the data of hip rotations occur during the gait cycle. In this study we researched the correlations between the prone and supine position goniometric measurements of hip rotations and also the correlation between each positions and the transverse plane hip kinematics.

PATIENTS/MATERIALS and METHODS

28 children (6-20 years) with spastic diplegia CP were included in this study. Kinematic data were collected using an eight-camera Vicon Bonita system (Oxford Metrics Ltd., Oxford, England). Goniometric measurements were measured in prone and supine positions. Correlations were calculated with Pearson's correlation coefficient.

RESULTS

A moderate correlation was found between prone and supine positions of hip measurements on right and left internal, external hip rotations. ($r=0{,}54$- $0{,}72$) ($p \leq 0{,}005$)

There was moderate correlation between transverse plane kinematics of right hip and goniometric measurement of right hip in supine poisition($r=0{,}517$, $p \leq 0{,}005$). All goniometric measurement of hip rotations in both positions except supine measurement of right hip external rotation were poor correlated with transverse plane kinematic of hip($r=0{,}01$-$0{,}26$) ($p \geq 0{,}005$).

DISCUSSION AND CONCLUSION

This is the first study investigates the correlation between goniometric measurement of hip rotations in prone and supine positions in CP patients. No significant difference was found in studies with healthy individuals for these parameters (1).

In the literature poor correlation was found between passive hip rotations and transverse plane kinematics of hip. (2,3) The moderate correlation between right supine measurement and right hip kinematics in our study was considerable.

Poor correlation between transverse plane kinematics of hip and goniometric measurements of hip rotations showed us the independency of hip rotations occuring during the gait cycle from the clinical measurements.

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The acute effect for dynamic postural stability of landing movement after different stretching

Noriaki. Maeda (1), Yukio. Urabe (1), Junpei. Sasadai (1), Eri. Fujii (1), Nobuaki. Moriyama (1), Takahiko. Yamamoto (1), Syo. Iwata (1), Dairoku. Kawahara (1)
(1) Graduate School of Biomedical & Health Sciences, Hiroshima University, Hiroshima, Japan

Main topics: •Functional outcome measures in mobility, Experimental studies in human movement science

INTRODUCTION and AIM

Stretching is utilized for the conditioning, rehabilitation, and the injury prevention in many sports as a part of preparation before starting vigorous activities. There are various techniques of stretching, including static stretching (SS) and Cyclic stretching (CS). Previous studies have reported influence for muscle strength and performance by the stretching so far [1]. The effect by SS and CS was shown by range of motion, muscular power and vertical jump performance. But to our knowledge, no research has investigated the effect of SS and CS stretching for postural control after landing. The purpose of this study was to clarify the acute effects of SS and CS for postural control after landing by using Dynamic Postural Stability Index (DPSI) [2].

PATIENTS/MATERIALS and METHODS

Ten subjects were measured ankle-dorsiflextion range of motion (ROM) before and after two stretching interventions and a control condition. Subjects were assigned to 3 randomly ordered experimental conditions, in which all subjects performed by SS, CS, and a control condition (control) and the jump-landing task on the non-dominant limb for unilateral assessment. In the 3 conditions, the positions were maintained for two minutes on standing on original electrical controlled device. Dynamic postural stability was assessed using DPSI by jumping and landing single-legged onto a force platform. DPSI and the individual stability indices were calculated for each condition. Dynamic postural stability was assessed using a single-leg jump landing in the anterior direction. This study also used raw data signals to calculate the GRFmax, which was expressed as the magnitude of the peak force (N) divided by the subject's body weight.

RESULTS

The results of this study indicated a significant effect of SS and CS compared with control for the change volume of ROM and CS produced a significant improvement in the DPSI ($p < 0.05$).

Table 1: Values for the Dynamic Postural Stability Index and Directional Components, GRFmax by Stretching Condition

variable	Condition			p-value
	control	SS	CS	
Dynamic Postural Stability Index	0.28±0.03	0.27±0.03	0.26±0.03	CC > CS†
Anterior-posterior stability index	0.12±0.04	0.13±0.04	0.12±0.04	n.s.
Medial-lateral stability index	0.03±0.01	0.03±0.01	0.03±0.01	n.s.
Vertical stability index	0.25±0.05	0.25±0.03	0.24±0.03	n.s.
GRF max (BW)	1631±83	1591±77	1568±73	n.s.

control : control condition, SS: static stretching, CS : cyclic stretching, GRF max: Grand Reaction Force maximum,
%BW : % Body Weight. †Indicates a significant difference from the soft and semirigid braced conditions ($P < 0.05$).

DISCUSSION and CONCLUSIONS

This study suggest that CS protocol of two minutes hold durations adversely affect dynamic balance of jumping and landing single-legged when using electrical controlled device for which the stretching angle. Furthermore, CS intervention may improve balance performance by increasing postural stability.

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IMPAIRED GAIT AND ENERGY CONSUMPTION IN HEREDITARY SPASTIC PARAPLEGIA

E. Carraro, D. Conte, C. Massaroni, A. Marchesi, E. Trevisi, G. Paparella, A. Martinuzzi
"F. Fabbri" Posture and Motion Analysis Laboratory, "E. Medea" Scientific Institute, Conegliano (TV), Italy

Main topics: Analysis of gait and motor disorders; Rehabilitation.

INTRODUCTION and AIM

Hereditary spastic paraplegias (HSP) are a clinically and genetically determined group of conditions characterized by progressive motor disturbance due to retrograde degeneration of the corticospinal tracts, leading to lower limbs spasticity and weakness, hyper-reflexia, mild sensory impairments, pes cavus. In previous studies, HSP patients gait patterns have been evaluated using gait analysis (GA), highlighting heterogeneous gait alterations related to the pathology, even if no considerations have been made regarding different genotypes [1,2,3]. Besides investigating gait patterns, it could be useful to evaluate metabolic energy cost of walking (EC) in these subjects. Our aim was therefore to investigate the relationship between gait pattern alteration, self-selected walking speed (SWS) and EC of a genetic SPG-4 homogeneous group of HSP patients.

PATIENTS/MATERIALS and METHODS

At the present moment 10 HSP patients with positive SPG-4 genetic test (8 M, 2 F; age 48±13 y, height 173±5 cm) have been recruited. 5 subjects could be evaluated with both GA and EC, 1 with EC only, 4 with GA only. 6 subjects were recruited as control group (CG) for GA only (3 M, 3 F, age 36±8 y, height 172±11 cm). Gait kinematics was evaluated along a 6 m walkway via a 6 cameras motion capture system (BTS smart, Italy) @ 60 Hz. EC was measured with a portable metabolimeter (K4b^2, Cosmed, Italy) in sitting and standing position at rest for 3 minutes; then, patients were asked to walk on a motor-driven treadmill at pre-defined speeds (0.6, 1.2, 1.8, 3.0, 4.2 km/h), allowing them holding lateral bars with hands, until they were able to continue safely. Walking speeds were not normalized to Froude number, since subjects height was similar.

RESULTS

CG mean SWS during GA was 1.02 m/s. The main kinematic angles on sagittal plane are summarized in Fig.1. HSP subjects were divided in 2 groups: those having a SWS during GA similar to CG and those walking at lower speeds, to highlight kinematic differences. EC data from all subjects were fitted with a 2nd order polynomial function, finding a minimum at 1.02 m/s.

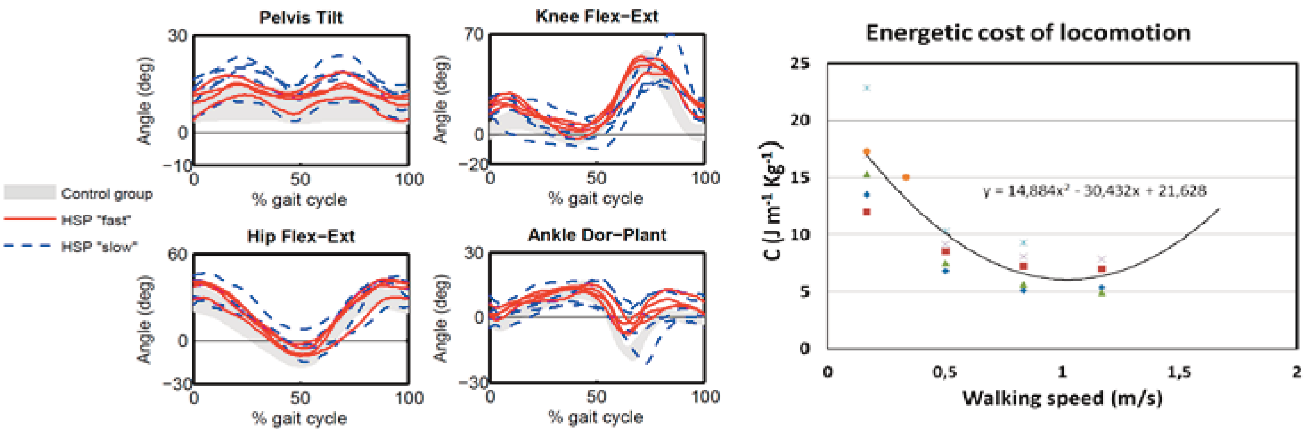

Fig.1. Left: HSP gait kinematics with SWS close to CG and lower SWS. **Right:** EC on a treadmill at different speeds for HSP subjects.

DISCUSSION and CONCLUSIONS

Despite evident limitations of data collected at this stage (small number of subjects, large heterogeneity of data, experimental conditions), we can highlight some interesting findings. Some gait patterns, common in all HSP patients as double bump pelvic tilt, flexed knee at initial contact with reduced flexion at loading response and instability during single support, reduced first and third rockers at the foot, are more evident and variable in subjects with lower SWS. However, EC data seems to suggest that increasing imposed speed on the treadmill drives them towards walking which is metabolically more efficient, with ideal minimum equivalent to CG SWS.

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SUPPORTING THE PROCESS OF REHABILITATION AND DIAGNOSTICS OF PEOPLE AFTER STROKE DURING DRINKING TASK

A. Guzik-Kopyto(1), M. Piecko(1), R.Michnik(1)
(1) Biomechatronics Department of Silesian University of Technology, Zabrze, Poland
Main topics: rehabilitation, analysis of motor disorders, upper extremity

INTRODUCTION and AIM

Many repeated tasks such as drinking task are made every day with the participation of upper extremity. Standardized problems of upper extremity were showed in article of Van Andel [2] which have direct influence on upper extremity functions during daily tasks. It is value to control and analyze the kinematic of a paralyzed upper extremity to quantitatively determine the degree of impairment of hemiplegic people during functional activities of daily living such as a drinking task [1]. It is also helpful to check the progress during rehabilitation. This study was aimed to identify the kinematic differences of upper extremity during drinking between 12 patients and 18 healthy.

PATIENTS/MATERIALS and METHODS

The research was realized on MVN Biomech software from XSENS Company. Experimental investigations within the project have been carried out on 18 healthy men (research group). The participants had no upper extremity symptoms and they could move their upper limb through a normal range of motion. The age of participants was ranged from 19 to 29 (mean 22,72, SD 2,32).They had the following characteristics: (mean, SD) height 180,38 ± 6,98 cm, weight 73,55 ± 9,56 kg and BMI 22,63 ± 2,89. All participants had a dominant right arm. The patient investigated during the project was man with hemiparesis on his left arm after ischemic brain stroke. The patient was 62 years old and had 172 cm of height, 86 kg of weight and BMI about 29,07.

RESULTS

On the basis of studies, courses of joint angles were obtained for each joint of upper extremity during drinking task. The results were compiled and prepared as a standard for making the task. As a part of prepared methodology, 12 patients after stroke with paresis of one upper extremity were analyzed.

DISCUSSION and CONCLUSIONS

During drinking task increased flexion of the shoulder joint is easy to notice. The research group was starting the task with increasing flexion of the shoulder joint from 45degrees to 75degrees and next with increasing extension which means decreasing flexion from 75degrees to about 48degrees at the end of the task. Patient before rehabilitation during task obtained an angle in shoulder joint lower from 40 to 60 degrees than research group. The amount of the angle of flexion in shoulder joint obtained by patient after rehabilitation was more closed to amounts of research group. Prepared methodology is useful and helpful during diagnostics and rehabilitation of people after stroke. It may be a tool used by doctors and physiotherapists to estimate patient’s functions and abilities.

The research was realized as a project N N504 680140 financed from Polish National Science Centre.

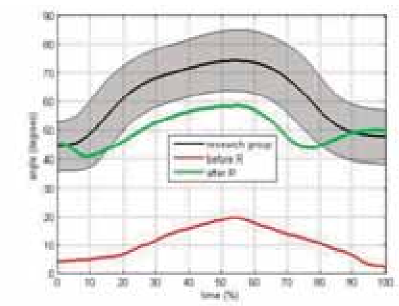

Figure 1: The average course of the joint angle obtained by patient (B1) before and after rehabilitation during flexion and extension in shoulder joint with marked standard for this movement in drinking task

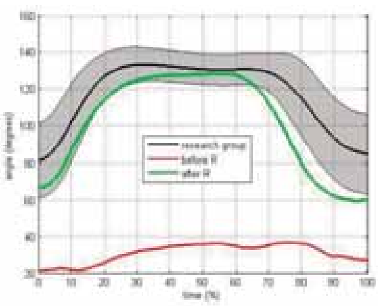

Figure 2: The average course of the joint angle obtained by patient (B1) before and after rehabilitation during flexion and extension in elbow joint with marked standard for this movement in drinking task

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BAYESIAN HIDDEN MARKOV MODELS FOR AUTOMATIC SEGMENTATION OF GAIT DATA

E. Di Lello(1), A. Nieuwenhuys (2), K. Desloovere (3) and T. De Laet(4)
(1,4) KU Leuven, Dept. of Mechanical Engineering, Leuven, Belgium
(2,3) KU Leuven, Dept. of Rehabilitation Sciences , Leuven, Belgium

Main topics: 3DGA data, Cerebral Palsy

INTRODUCTION and AIM

The interpretation of 3DGA data often requires the segmentation of joint angle time-series (e.g. the identification of rockers in the ankle sagittal plane kinematics). We introduce a novel method for the automatic segmentation of joint angle time-series based on a Bayesian time-series model called Hierachical Dirichlet Process Hidden Markov Model (HDP-HMM) [1]. The goal of the method is to segment a joint angle time-series in a set of piece-wise polynomial curves, while at the same time estimating the curve parameters and the time-correlation between the segments. The proposed method is suited for segmentation of a set of time-series, (e.g. , a set of gait cycles exhibiting a specific pattern identified by a clinician) and to learn a probabilistic shape signature that can be used for classification of gait trials. Due to its Bayesian nature, the proposed method is able to incorporate clinical prior knowledge to produce a clinically meaningful segmentation.

PATIENTS/MATERIALS and METHODS

Our method is based on a Bayesian formulation. The goal of is HDP-HMM is to cluster the measurements in a set of possible polynomial segment models. Depending on the selected order of the polynomial, the method will try to split the observations in a number of lines, parabolic curves, etc. All the parameters of the model are defined through probability distributions, including the number of segment models. This means that if prior knowledge about the parameters is available, the HDP-HMM is able to incorporate it and combine with the data in a Bayesian way. To demonstrate the method, we use data of the sagittal plane ankle kinematics during stance, of 107 gait trial of children with CP. The gait trials were classified according to [1], so five different gait patterns are identified.

RESULTS

We used the proposed method to segment a single gait trial or a set of trials, using second order polynomial primitives.
Figure 1 presents a segmented trial belonging to class AStS 0 (minor deviations from normal), while Figure 2 presents an average segmentation of all the 66 trials of the class .
Figure 3 shows a segmented trial belonging to class AStS 1 (horizontal second rocker), while Figure 4 shows an average segmentation of all the 41 trials of the class.

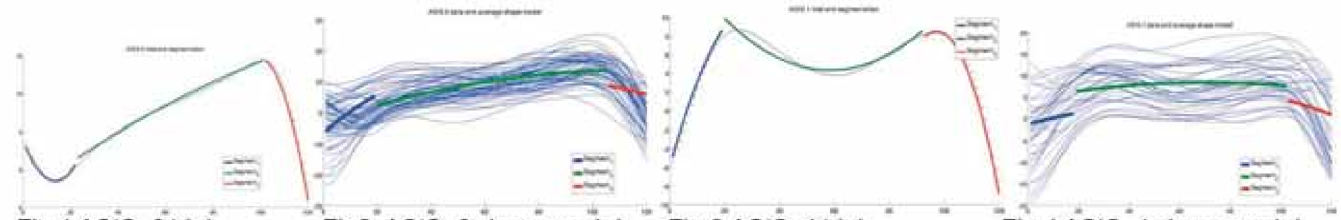

Fig.1 AStS_0 trial   Fig2. AStS_0 shape model   Fig.3 AStS_1 trial   Fig.4 AStS_1 shape model

DISCUSSION and CONCLUSIONS

We showed how the proposed method is able to automatically segment gait trials using polynomial motion primitives. Visual inspection of learned segmentations shows that the HDP-HMM is able to capture the overall shape of a clinically relevant gait pattern, succesfully reducing the data in a set of parametrized curves. In the future, we plan to use these probabilistic shape models for classification of gait trials.

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CORRELATION BETWEEN CLINICAL BALANCE MEASURE AND CONTROL PARAMETER IN FOOT CONTACT OF GAIT USING A TRI-AXIAL ACCELEROMETER IN PATIENTS WITH POST-STROKE HEMIPLEGIA

Yoshitaka Otani (1), Osamu Aoki (2), Tomohiro Hirota (3),
Noriaki Maeda (4), Masahito Murakami (1), Junichi Kato (5)
(1) Faculty of Rehabilitation, Kobe International University, Kobe, Japan
(2) Faculty of Rehabilitation, Shijonawate Gakuen University, Daito, Japan
(3) Department of Rehabilitation, Hyogo Prefectural Rehabilitation Hospital at Nishi-Harima, Tatsuno, Japan
(4) Division of Physical Therapy, Faculty of Medicine, Hiroshima University, Hiroshima, Japan
(5) Department of Internal Medicine, Hyogo Prefectural Rehabilitation Hospital at Nishi-Harima, Tatsuno, Japan

Main topics: Analysis of clinical movement data, Analysis of gait and motor disorders

INTRODUCTION and AIM

The root mean square (i.e. perturbation while walking) and auto-correlation coefficient (i.e. asymmetry while walking) are quantitative methods of assessing acceleration data during gait using a tri-axial accelerometer. The assessment of peak-to-peak fluctuations derived from an acceleration waveform is also useful. This method is simple and used to quantify postural stability during walking. After stroke, patients commonly experience hemiplegia, somatosensory disorder, and disrupted balance. Therefore, we hypothesized that peak-to-peak values and the variations therein might reflect balance ability. We also examined the relationship between Berg Balance Scale (BBS) score and the bilaterally symmetric ratio calculated from step time and stride time.

PATIENTS/MATERIALS and METHODS

Sixteen patients with post-stroke hemiplegia participated in this study (Table 1). The participants were classified into the stable group (BBS score > 45) and unstable group (BBS score < 44). A tri-axial accelerometer was fixed over the L3 spinous process using an elastic belt to measure gait variables (sampling rate, 200 Hz). The subjects were instructed to walk two trials along a 10-m walkway at a comfortable speed. All acceleration data were low-pass filtered (fourth-order zero-lag Butterworth filter at 20 Hz) using Matlab. Gait variables were calculated as acceleration data from five gait cycles (i.e. gait velocity, peak-to-peak amplitude [p-p amplitude], coefficient of variance of peak-to-peak amplitude [p-p CV], step time, stride time) (Fig. 1). The step asymmetry and stride asymmetry ratios were calculated from step time and stride time of paralyzed and non-paralyzed sides. The inter-group difference in gait variables was compared using an independent *t* test. The associations between BBS and gait variables were examined using Pearson's product-moment correlation coefficient. A significance level of $p < 0.05$ was used for all of the statistical analyses.

RESULTS

The stride asymmetry ratio showed that the stable group was significantly smaller than the unstable group ($p < 0.05$). However, none of the other variables were significantly different. The p-p CV of the anterior-posterior component was moderate inversely correlated with the BBS ($r = -0.50$, $p = 0.049$). The stride asymmetry ratio was strongly correlated with the BBS ($r = 0.64$, $p = 0.0007$). The other variables were not significantly correlated with BBS score.

	Stable group	Unstable group
Age (y)	58.3 ± 8.4	66.1 ± 7.6
Stroke type (hemorrhage / infarction)	2/4	5/5
Paralyzed side (R / L)	2/4	2/8
Duration from onset (days)	129.7 ± 23.7	93.2 ± 34.5
BBS (total score = 56)	48.3 ± 3.3	35.5 ± 7.2

Table 1. Subjects' characteristics

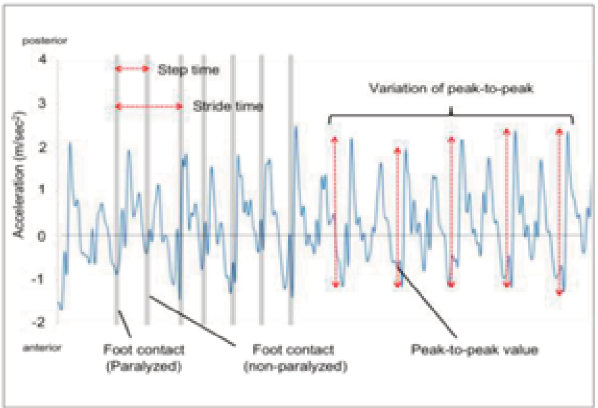

Fig. 1. Acceleration waveform of the anterior-posterio component

DISCUSSION and CONCLUSIONS

This study confirmed that the stable group had a highly regular gait. In addition, BBS was correlated with p-p CV of the anterior-posterior component and the stride asymmetry ratio. Stroke patients with high of balance ability were higher anterior-posterior control of sway than unstable patients during gait.

ESTIMATING CENTER OF PRESSURE AND CENTRE OF MASS PATTERNS IN STROKE SUBJECTS DURING ACTIVITIES OF DAILY LIVING USING FORCE SENSING SHOES

Meulen F.B. van[1], Reenalda J.[1,2*], Nikamp C.D.M.[1,2], Buurke J.H.[1,2], Veltink P.H.[1]
[1] University of Twente, Enschede, the Netherlands
[2] Roessingh Research and Development, Enschede, the Netherlands

INTRODUCTION and AIM

Stroke often is associated with impaired balance control decreasing the performance of activities of daily living (ADL). Insight into the mechanisms underlying balance recovery is necessary to improve rehabilitation for different types of stroke. Up till now, balance control is assessed using standardized clinical tests (like the Berg Balance Scale) or using force plates in a laboratory setting. These tests however provide only limited or no information about the performance of stroke patients during ADL. Recent developments in sensor technology enable the measurement of balance parameters like center of pressure (CoP) and center of mass (CoM) during ADL activities using instrumented shoes" containing force sensors and inertial sensors.
The aim of this study is to evaluate CoP and CoM movement patterns in stroke patients, during activities of daily living while wearing the instrumented.

PATIENTS/MATERIALS and METHODS

Currently, nine stroke survivors have been included. Subjects walked in a straight line over 10 meters and performed a predefined ADL task while wearing the instrumented shoes. The ADL task was defined as a sequence of the following activities: sitting, rising up from a chair, walking to another room, opening a door, manipulating an object while standing and finally returning to the start position.
The instrumented shoes included two force sensors and two inertial sensors per shoe (ForceShoes™ - Xsens, Enschede, the Netherlands). The position of the CoP, relative to the position of both feet (in the frontal plane) was measured at 50 Hz. The position of the CoM was estimated by low-pass filtering the CoP position at a cut-off frequency of 0.4 Hz.

RESULTS

The CoP and CoM patterns vary per individual and per task. During stance and walking in a straight line, individuals generally show a small shift of the mean CoP position and CoM position to their non-affected side. While performing the more difficult predefined ADL task, the mean CoP position and the CoM position shifts more towards the individual's non-affected side.

DISCUSSION and CONCLUSIONS

The use of force shoes enables the measurement of balance parameters during ADL tasks. CoP and CoM movement patterns measured during ADL tasks can give more insight in the recovery of balance control of individuals than current clinical tests or lab measurements. Results indicate that in more demanding tasks, the mean CoP and CoM position shifts more towards the non-affected side compared to walking in a straight line.

ACKNOWLEDGEMENT

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MOULDED INSOLE FABRICATION FOR FOOT DEFORMITIES USING COMPUTER TOMOGRAPHIC IMAGES

Sathish Kumar Paul (1), **Rekha Vijaya Kumar (2), Sudesh Sivarasu (3)**

(1) The Leprosy Mission Trust India, Delhi, India
(2) School of Bio Sciences and Technology, VIT University, Vellore, Tamil Nadu- 632014, India
(3) 3MRC/MIRU–Division of Biomedical Engineering, Department of Human Biology, Faculty of Health Sciences, University of Cape Town, South Africa 7925, South Africa**Main topics:** Musculoskeletal Modelling, Orthotics

INTRODUCTION and AIM

The early prediction and management of plantar ulceration in patients with anesthetic foot such as in leprosy and diabetes have been major challenges in the field of health care all over the world**.** Sensory loss along with the underlying pathomechanics is one of the main causes for plantar ulcers in these patients. With increasing number of diabetic foot cases, the problem requires more surgical interventions.
Clinicians can provide a means to better distribute the pressure around the foot, and can also correct the biomechanics of the foot by using a customized shoe insole. If detected early enough, orthopedic insoles can correct or prevent further complications and deformities in a deformed anesthetic foot. In this study the 3Dimensional (D) model of the foot was used to fabricate a customized orthosis.

PATIENTS/ MATERIALS and METHODS

The Computed Tomography (CT) images of leprosy affected patient's foot with deformities were acquired. The gray intensities corresponding to the bones of the foot from the CT images were 3 dimensionally reconstructed. The 3D model of the foot was then imported into the CAD Software. Boolean operations were carried out in between the 3D foot model and a solid rectangular surface to create a customized foot orthosis.

RESULTS

The results demonstrate that the computerized orthotic fabrication method followed in this study was found to be more reliable in acquiring the anatomical contours of the plantar foot surface for orthotic fabrication. The cost involved in the material used for the moulding processes like the Plaster of Paris Powder (POP), POP rolls and the wastage present in the manual method when we use materials like Ethyl Vinyl Acetate (EVA) and the thermoplastics are reduced by this method.

DISCUSSION and CONCLUSIONS

Orthopedic foot wear plays an important role in the treatment and the prevention of ulcer in the diabetic as well as the leprosy patients. The current work is a novel technique in the fabrication of orthosis. This method reduces the use of more cumbersome techniques to capture the foot images and to take the cast measurements. The simple method used in this study to fabricate a customized orthosis will help in reducing the plantar ulcer and its consequences considerably in a cost efficient way.

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THE USE OF THE GREATER TROCHANTER MARKER IN THE THIGH SEGMENT MODEL: IMPLICATIONS FOR HIP AND KNEE TRANSVERSE PLANE MOTION.

V Graci (1), G Salsich (2)

(1) Department of Neurology, University of Maryland, Baltimore, MD.
(2) Department of Physical Therapy & Athletic Training, Saint Louis University, Saint Louis, MO.

Main topic: Musculoskeletal modelling, Analysis of clinical movement data

INTRODUCTION and AIM

The influence of greater trochanter marker (GT) on hip and knee models is important when quantifying transverse plane hip and knee kinematics, which is particularly relevant in individuals presenting dynamic knee valgus and patellofemoral pain (PFP) or ACL injury. Small differences across hip and knee models could lead to different or misleading clinical conclusions. Hence the scope of this study was to evaluate the effect of including GT in the construction of the thigh segment on hip and knee kinematics during gait in the transverse plane, which is relevant for the investigation of hip and knee injuries and pain problems.

MATERIALS and METHODS

A 3D-motion capture 6 cameras system (120 Hz) was used to collect kinematics on 19 healthy subjects (10 males, age mean ± SD: 27.19 ± 5.66 y) during walking. Hip and knee angles were compared with 1-way-ANOVAs ($p<0.05$) across two thigh segment definitions (with and without greater trochanter) and two shank segment definitions (one with the proximal end defined by the femoral epicondyles and one with the proximal end defined by tibia tuberoses and fibula head) at two time points during stance: peak knee flexion (PKF) and minimum knee flexion (MinKF).

RESULTS

In the thigh model without the greater trochanter the hip was more internally rotated than in the thigh model with the greater trochanter ($P<0.001$). With the thigh model without the greater trochanter, the knee was more externally rotated in the shank model that included tibia tuberosity than in the model that included the femoral epicondyle markers ($P<0.001$).

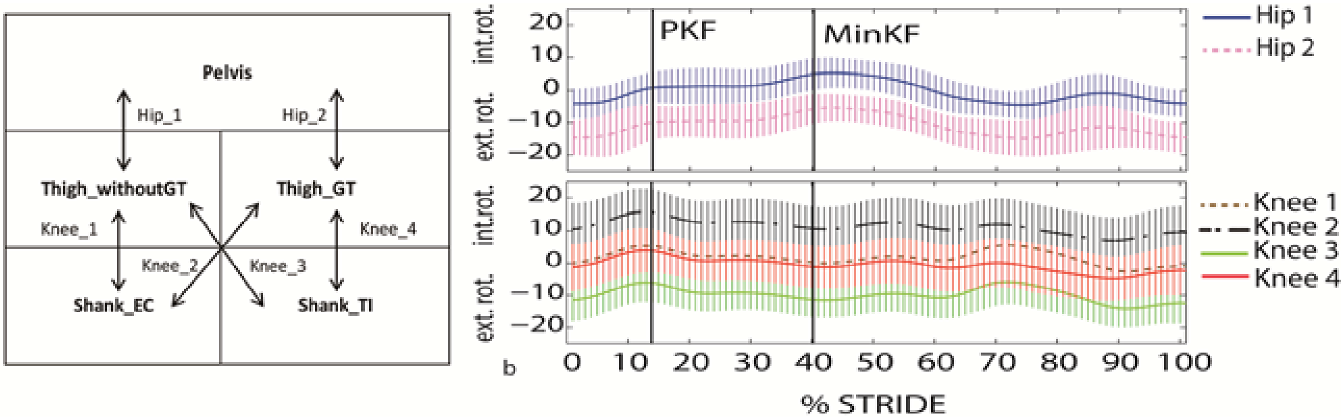

Fig.1 a) Thigh and shank segment definitions and hip and knee models. b) Time series curves of hip and knee transverse plane angles. The black vertical bars represent PKF and MinKF time points. Error bars represent the SD at each time point.

DISCUSSION and CONCLUSIONS

These results can lead to the following hypothetical scenarios: an individual examined by using the Hip 1 (without GT) and Knee 3 might be a false positive for dynamic knee valgus. On the other hand an individual examined by using Hip_2 (with GT) and Knee_2 might be a false negative for dynamic knee valgus. This suggest that when testing individuals at risk of ACL injury or PFP in weight bearing tasks, it is important to have a clear understanding of the limitations of each hip and knee models in use in order to avoid misleading conclusions. When comparing the transverse plane profiles of our results to previous studies in healthy individuals, Hip_1 might be a more advisable hip model to use when assessing gait [1]. If Hip_1 is used, Knee_1 might be a better knee model to employ since it most closely approximates the knee motion found in previous bone-pin studies [2,3].

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TRIDIMENSIONAL ANALISYS OF THE PROPULSION PHASE OF THE SINGLE LEG TRIPLE HOP TEST IN WOMEN WITH PATELLOFEMORAL PAIN SYNDROME

AS. Bley (1), AC. Reis (1), NDA. Rabelo (1), PH. Marquetti, JCF. Correa (1), PRG. Lucareli (1)
(1) Department of Rehabilitation Science, Human Motion Analysis Laboratory, Universidade Nove de Julho, São Paulo, Brazil.
(2) *Universidade Metodista de Piracicaba*, UNIMEP, Piracicaba, São Paulo, Brazil.

Main topics: please, select at least two topics from the long list of the topics of the conference.

INTRODUCTION and AIM

Asymmetry in the alignment of the lower limbs during weight-bearing activities is associated with patellofemoral pain syndrome (PFPS), caused by an increase in patellofemoral (PF) joint stress. High neuromuscular demands are placed on the lower limb during the propulsion phase of the single leg triple hop test (SLTHT) which may influence biomechanical behavior. The aim of the present cross-sectional study was to compare kinematic, kinetic and muscle activity in the trunk and lower limb during propulsion in the SLTHT using women with PFPS and pain free controls.

PATIENTS/MATERIALS and METHODS

The following measurements were made using 20 women with PFPS and 20 controls during propulsion in the SLTHT: kinematics of the trunk, pelvis, hip, and knee; kinetics of the hip, knee and ankle; muscle activation of the gluteus maximus (GM), gluteus medius (GMed), biceps femoris (BF) and vastus lateralis (VL). Differences between groups were calculated using three separate sets of multivariate analysis of variance for kinematics, kinetics, and electromyographic data.

RESULTS

Women with PFPS exhibited: ipsilateral trunk lean; greater trunk flexion; greater contralateral pelvic drop; greater hip adduction and internal rotation; greater ankle pronation; greater internal hip abductor and ankle supinator moments; lower internal hip, knee and ankle extensor moments; greater GM, GMed, BL, and VL muscle activity compared with controls.

DISCUSSION and CONCLUSIONS

The results of the present study are related to abnormal movement patterns in women with PFPS. We speculated that these findings constitute strategies to control a deficient dynamic alignment of the trunk and lower limb and to avoid PF pain. However, the greater BF and VL activity and the extensor pattern found for the hip, knee, and ankle of women with PFPS may contribute to increased PF stress.

Comparison of kinematic data, peak joint angles (°), kinetic data, internal joint moments (Nm/Kg) and EMG data, eccentric phase muscle activation (% MVIC) between patellofemoral pain group and control group during propulsion phase for SLTHT.

	Control Group	Patellofemoral Group	P-value	Effect size
KINEMATIC DATA				
Trunk lean*	6.5 (4.4)	(-)5.6 (4.7)	<0.001	2.6
Trunk flexion	8.8 (3.4)	14.3 (4.7)	<0.001	1.3
Contralateral pelvic drop	7.4 (2.3)	14.8 (3.1)	<0.001	2.7
Hip internal rotation	10.4 (2.0)	18.9 (5.7)	<0.001	1.9
Hip adduction	13.0 (3.9)	19.3 (3.7)	<0.001	1.7
Hip flexion	71.1 (7.3)	80.9 (4.8)	<0.001	1.6
Knee abduction	6.6 (3.6)	7.3 (3.2)	0.518	0.2
Knee flexion	66.0 (3.5)	63.8 (3.4)	0.053	0.6
Ankle pronation	40.4 (4.4)	50.9 (7.4)	<0.001	1.7
Ankle dorsiflexion	40.1 (6.2)	35.6 (4.5)	0.011	0.8

	Control Group	Patellofemoral Group	P value	Effect size
KINETIC DATA				
Hip abductor	1.1 (0.3)	1.7 (0.4)	<0.001	1.7
Hip extensor	3.8 (1.1)	1.8 (0.8)	<0.001	2.1
Knee abductor	1.1 (0.2)	2.6 (0.5)	<0.001	3.9
Knee extensor	1.2 (0.4)	0.9 (0.2)	0.006	0.9
Ankle supinator	0.4 (0.2)	0.7 (0.3)	0.002	1.2
Ankle plantar flexor	2.4 (0.5)	2.0 (0.6)	0.018	0.7
EMG DATA				
Gluteus maximus	10.1 (9.3)	20.4 (11.9)	0.005	1.0
Gluteus medius	10.5 (10.1)	20.9 (10.0)	0.002	1.0
Biceps femoris	8.5 (12.5)	15.9 (7.2)	0.026	0.7
Vatus lateralis	8.6 (6.2)	37.4 (19.3)	<0.001	2.0

Data expressed as mean (standard deviation). *Negative value: ipsilateral trunk lean. Abbreviations: SLTHT = single-leg triple-hop test.

LIFTING TASK: PARAMETERS VARIATION ON STABLE AND UNSTABLE SURFACES

Tafur Diana A. [1]; Grooten Wim [2]; Castillo, JA.[3]
[1] Research assistant / Physical therapist. Health, Cognition, work research group. Medicine and health sciences school. Universidad del Rosario
[2]. Karolinska Institutet. Department for Neurobiology, Caring Science, and Society. Division of Physical Therapy
[3] PhD Cognitive Psychology., MsC Ergonomics,. Health, Cognition, work research group. Medicine and health sciences school. Universidad del Rosario
Mail to: juan.castillom@urosario.edu.co

AIMS

To investigate the biomechanical characteristics (kinematics and kinetics) of a lifting task situation during stable and unstable surfaces.
Studied on kinematic variables the postural responses during lifting during stable and unstable situations as 1) lifting duration, 2) relative phase time, and 3) angular displacement (velocity and acceleration) of joint angles (trunk, pelvis, hip and knee) and the kinetic variables as 4) center of pressure (CoP) velocity 5) CoP area (in relation to the base of support (BoS)).

INTRODUCTION

Following requests from various industries, we assigned Upper Extremity Risk research projects to analyse the number and severity of back, arm and shoulder injuries and illnesses that were the main source of occupational recordable for the facility. Spinal instability has been investigated as a risk factor for LBP and injury. Clinically, spinal stability has been described as the ability of the spine to limit patterns of displacement to prevent damage or irritation of spinal structures and the spinal cord

MATERIALS and METHODS

The load lifting will be done from the ground to the biped position, with the load placed on the median plane of the upper limbs with the trunk, the load return to the initial position, with the indication of the expert. Three different conditions in which subjects were perform the lift: (A) On the floor without any variation of the height; (B) on the surface instable (49.5 x 49.5 x 10 cm). (C) on the surface little unstable (39.5 x 40 x 9 cm) The characteristics of the load to be handled for the execution of the lift is a box (36 x 36 x 25 cm) the grip has side grips for providing grip full hand and avoid awkward postures and external rotation, shoulder abduction and flexion, should facilitate grasping and accommodating load close to the trunk to avoid awkward postures and head, neck and spine.

DISCUSSION and SIGNIFICANCE

The relative phase time showed more time in instable C condition for two phases: down (md=58,3) and up (md=89,6), this could show that at the time of variation the unstable surface anticipatory response in muscular component and speed of response over time is longer, then, if the answer in lifting and back to the anatomical position are higher in comparison to the surfaces A and B. The references to the angular displacement in the segments with significant differences are angles in range Hip left during downward phase, the major values strategy for stable A is differ for instable C, because, in the instable surface C, the strategy not is specific to increase angle hip joint, should use other response system. In this case in instable surface the angles hip joint is less, thereby, it is need more stability without increasing the angles. Spinal instability has been investigated as a risk factor for LBP and injury, providing appropriate ergonomic suggestions based on the biomechanics can improve the tolerance to work in different surfaces.

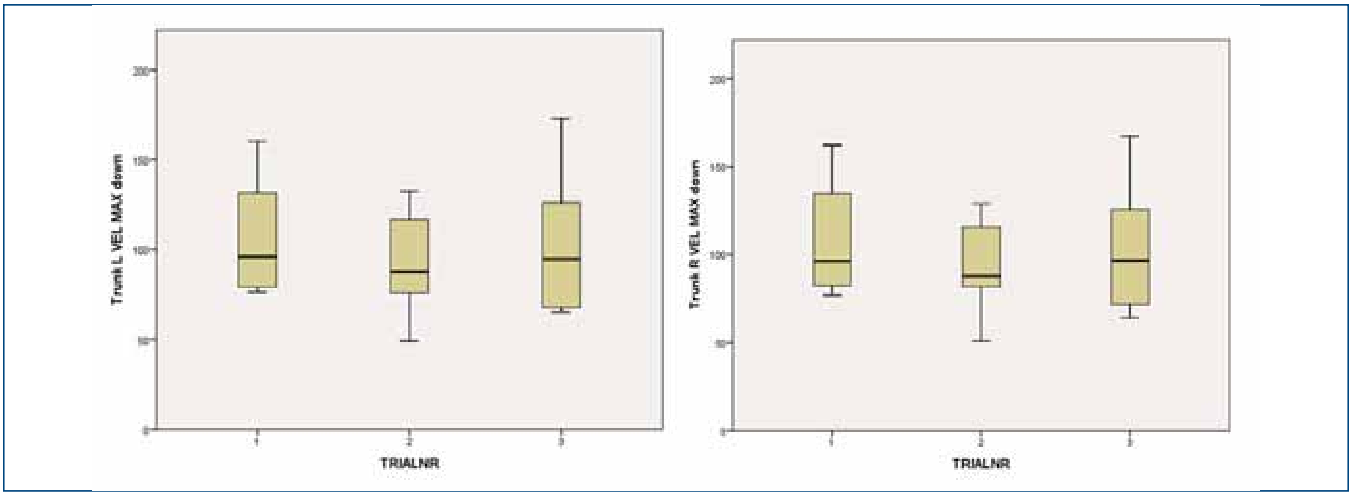

Figure 1 Trunk velocity max down in left (left) and Trunk velocity max down in right (right) for the subjects, in relationship whit the surface (1-2-3) showed differs significant in the three situations

THE CLINICAL EFFECT OF ACUPUNCTURE GUIDED BY GAIT ANALYSIS IN TREATING KNEE OSTEOARTHRITIS

Jing. Li (1),Qi Li,Shuyun. Jiang(2)
(1) Department of Acupuncture & Moxibustion, Yueyang Hospital of Integrated Traditional Chinese and Western Medicine Affiliated to Shanghai University of Traditional Chinese Medicine, Shanghai,China
(2) Department of rehabilitation,Yueyang Hospital of Integrated Traditional Chinese and Western Medicine Affiliated to Shanghai University of Traditional Chinese Medicine, Shanghai,China

Main topics: Knee Osteoarthritis, Gait Analysis, acupuncture therapy

INTRODUCTION and AIM. Osteoarthritis is a common orthopedic disease occurring exclusively in old-aged people.40 percent of people aged between 55 to 64 years'old are suffering from osteoarthritis,which is usually occurring at waist or knee. KOA can cause severe pain ,stiffness ,limitation and even disabled of the knee joint. According to clinical observation,the out articular pain points of KOA is frequently happened in where is different from intra-articular pain caused by inflammation.From the angle of Chinese medicine, these pain points around the knee is corresponding to the knot of tendons.They usually locate at the interface attached tendons,muscles and bones.It is an effective idea and method to puncture in these knots to ease the symptoms of KOA. The acupoints we are chosen based on the results of gait analysis.We are trying to formulate these acupoints to improve the effects of acupuncture in treating KOA. The clinical effects were analyzed by gait analysis, WOMAC and VAS. It is also aimed to promote technology of biomechanics using in region of Chinese medicine.

PATIENTS/MATERIALS and METHODS. 12 patients fitted with the criteria accepted acupuncture therapy and have gait analysis before and after one months' treatment. Acupoints were chosen according to the results of gait analysis. Our gait analysis test included motion analysis,EMG and plantar pressure. The indicators we chose include step length, forward velocity, Swing phase/total support time, knee flexion angle, vertical ground reactive force and amplitude of quadriceps, rectus femoris, tibialis anterior, semitendinosus and semimembranosus. After first test,we punctured in acupoints located at the weak or cramp muscle, abnormal joints and severe pain points. For example, Zu Sanli(ST36), Tiao Kou(ST38), Jie Xi(ST41) could be chosen for tibialis anterior disorders , Bi Guan(ST31), Xue Hai(SP10), Liang Qiu(ST34) for quadriceps disorders, Kun Lun(BL60), Shen Mai(BL62) for strephenopodia, Tai Xi(KI3), Zhao Hai(KI6) for Sufficient evaginate.The acupoints were less than 15.Then we chose 4 to 6 acupoints on weak muscle and pain points to connect electric acupuncture apparatus. After 20 minutes' treatment, we had a retest and observed immediate changes. The treatment were 3 times a week, 4 weeks one course. After 12 times'treatment, we had a retest finally. The results of 3 times' test were compares and evaluated the effects of acupuncture guided by gait analysis in treating KOA.

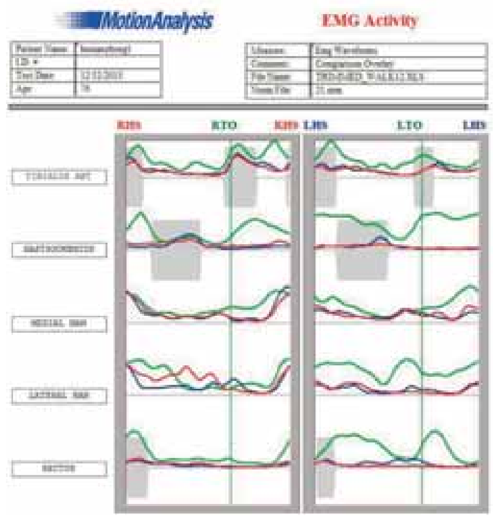

Figure 1. EMG activities of muscles

RESULTS. After one months' treatment,the symptoms of pain ,stiffness and hard to walk were obviously relieved.The results of gait analysis showed a significant progress too. Before treatment, Step length and forward velocity were47.58±11.24and78.01±23.36, after one time treatment the number was up 50.32 ± 10.85 and 85.07 ± 21.89,after 12 times' treatment the final number were 55.12±7.56 and 99.00 ±16.03.Swing phase/total support time showed no statistical significance,but the number was from 0.58±0.09 up to 0.59±0.06 and ended with 0.61 ± 0.05,near the normal level.The knee flexion angle was 54.58±11.45 before treatment, the immediate result was 57.99 ± 11.02 and the final result was 62.01 ± 10.03.The maximum amplitude of quadriceps was 4557.14 ± 3277.85 before treatment, 6103.52±4433.18 for immediate result and the final number was 8247.80 ± 7281.61.The maximum amplitude of hamstring were from 10540.21± 5908.75 to 11138.50 ± 4815.00 and uo to 14091.19 ± 6034.51. The comparison of muscle changes could be seen in figure1. The red curve on behalf of first test, blue one was immediate test and green curve on behalf of final test. Vertical ground force first peak F1 and second peak F2 showed no statistical significance, but bimodal nature of the curve appeared (Figure2).The red curve on behalf of first test, blue one was immediate test and green curve on behalf of final test. Except for Swing phase/total support time and vertical ground reactive force, all the indications showed obvious statistical significance after treatment. Statistical of maximum amplitude of muscles were showed in table1.

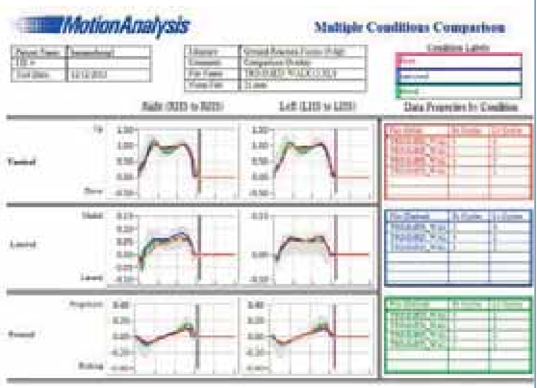

Figure 2. Vertical GRF curves of legs

DISCUSSION and CONCLUSIONS. Gait analysis can provide acupuncturists a more accurate treatment plan within less acupoints , short course and better curative effect. Under the guidance of gait analysis, we can prove scientific nature and effectiveness of acupuncture. We focus on muscle and angle changes of KOA patients, all of the acupoints are located in load-points of abnormal muscle. Though acupuncture treatment, patients' walking efficiency are increasing, both weak muscle and spam muscle are turning to normal. We also notice that the symmetry of two legs in walking is better and all the indicators of two legs are approaching to the other side. According to the results,the clinical effects of treating KOA guided by gait analysis is obvious and curative. The symptoms of pain,stiffness and hard to walk are all relived without side effect, and it can be widely used in clinical treatment.we are trying to promote technology of biomechanics using in region of Chinese medicine and this is our first step.

Table1.Statistical of knee flexion angle and maximum amplitude of muscles

condition	maximum amplitude of hamstring	Maximum amplitude of quadriceps
pre	10540.21± 5908.75	4557.14±3277.85
immediate	11138.50±4815.00	6103.52±4433.18
post	14091.19 ± 6034.51	8247.80±7281.61
P	<0.05	<0.05

ELECTROMYOGRAPHIC AND KINEMATIC EVALUATION OF PATIENTS WITH CERVICAL PATHOLOGY IN A WORK ENVIRONMENT: A PILOT STUDY

F. Anasetti (1), L. Sucarrats Cribillés (1),
(1) Egarsat, Terrassa, Barcelona, España

Main topics: Analysis of clinical movement data, Functional outcome measures in mobility.

INTRODUCTION and AIM

The neck pain is a common condition in a work environment. The literature related neck pain with decreased range of motion (RoM) and an altered pattern of muscle activity but without a clear consensus. This pilot study aims to define a protocol for quantitative evaluation of cervical pathology with surface electromyography (sEMG) system, Mega (Mega Electronics Ltd), and a three-dimensional kinematic craniocervical system, Zebris CMS 70P system (Medizintechnik Gmbh Zebris).

PATIENTS/MATERIALS and METHODS

The study is conducted with 12 women without evidence of asymptomatic cervical pathology with a mean age of 36.0 ± 7.1 years workers. The sEMG is evaluated in muscles: Sternocleidomastoid (ECM), Upper Trapezius (TS) and Cervical Spinal Erectors (ECE). The cranio-cervical flexion-extension, left-right rotation and lateralization are evaluated. Four phases are established in each movement. RoM performed maximum is maintained for three seconds. For the considered values sEMG root mean square (RMS). The values are normalized for each phase from the maximum observed value that in the three muscles is performed during rotation.

RESULTS

Subjects have a RoM in all three planes within normal limits and no significant left-right asymmetries are objectified in electrical activity. For ECM the maximum electrical activity is observed during the contralateral rotation. From the peak value, have a 60% activity during ipsilateral lateralization and 35% during ipsilateral rotation and flexion. ECE is primarily active during the ipsilateral rotation. An activity of 45% was observed during extension, 40% during contralateral rotation and 30% during flexion and lateralization. To the ECM and the electrical activity of ECE less than 20% is observed for the maximum static phases ROM (fig. 1). TS are activated during rotations similarly presenting a minimum difference between the other movements during the static positions and values between 30 % and 50 %.

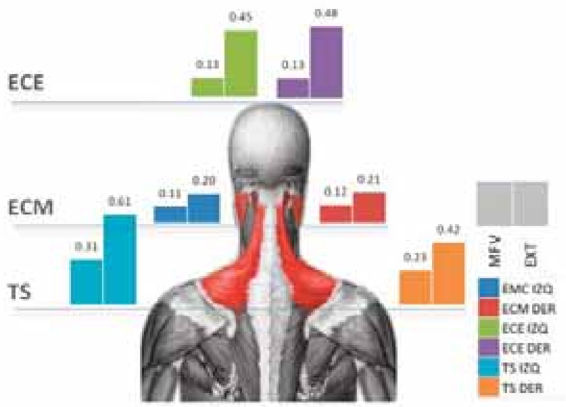

fig. 1 MFV: máxima flexión voluntaria
EXT: extensión

DISCUSSION and CONCLUSIONS

These results confirm the occurrence of the phenomenon of relaxation in the ECE muscles during full flexion. Overall for the observed decreased muscle electrical activity is evident in the static phases of maximum RoM in all three planes.

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GAIT INITIATION IN OBESE SUBJECTS

N. Cau (1), V. Cimolin (1), M. Galli (1, 2), H. Precilios (3), E. Tacchini (3), C. Santovito (3), P. Capodaglio (3)
(1) Department of Electronics, Information and Bioengineering, Politecnico di Milano, Milano, Italy
(2) IRCCS "San Raffaele Pisana", Tosinvest Sanità, Roma, Italy
(3) Orthopaedic Rehabilitation Unit and Clinical Lab for Gait Analysis and Posture, Ospedale San Giuseppe, Istituto Auxologico Italiano, IRCCS, Piancavallo (Verbania), Italy
Main topics: Analysis of clinical movement data.

INTRODUCTION and AIM

Obesity influences balance and gait pattern increasing the risk of fall and injury. In particular, the risk is high during postural transitions. Gait initiation (GI) is a transient procedure between static upright posture and steady-state locomotion [1]; GI requires propulsion and balance control. The aim of this study was to characterise quantitatively the strategy of obese subjects during GI using parameters obtained by the Center of Pressure (CoP) trajectory.

PATIENTS/MATERIALS and METHODS

20 obeses and 15 healthy subjects were assessed using a force platform during GI. CoP plots were divided in different phases, which identified the anticipatory postural adjustments (APA1, APA2a, APA2b) and a movement phase (LOC) (Figure 1) [2, 3]. Duration, length and velocity of the CoP trace in the phases were calculated for the two groups. The Mann-Whitney U test was used for comparing data of obese group and healthy subjects.

RESULTS

Obese participants presented higher excursion in medio-lateral direction (Figure 2); accordingly, longer APA length (APA1: obeses= 0.38 m vs. controls= 0.37 m; APA2: obeses= 0.08 m vs. controls= 0.06 m; $p < 0.05$) and duration (APA1: obeses= 0.32 s vs. controls= 0.28 s; APA2: obeses= 0.29 s vs. controls= 0.25 s; LOC: obeses= 0.59 s vs. controls= 0.53 s; $p < 0.05$) were present in comparison with the control subjects. As concerns velocity, abnormal speed of CoP movement was displayed in all phases; in particular, CoP movements were reduced in antero-posterior direction and faster in medio-lateral direction as compared to the controls.

DISCUSSION and CONCLUSIONS

GI represents a functional related task, which can integrate and complete the functional assessment of obese subjects. Our findings provide novel evidence that may serve for developing exercise programs aimed at specifically improving balance in both the antero-posterior and lateral directions and increasing muscle strength in the lower limbs. GI is less time-consuming than other conventional tests, such standard gait analysis and requires only one force platform which can be fitted in an out-patients department surgery.

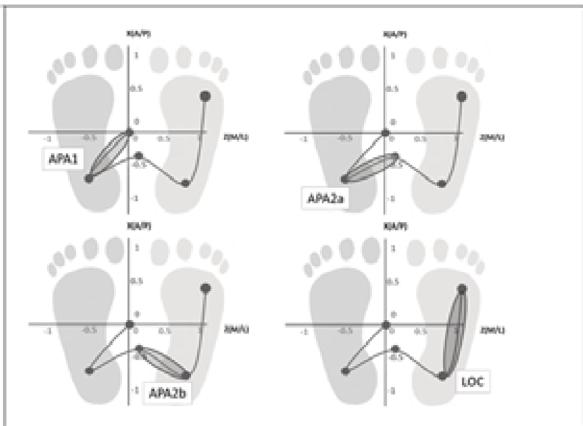

Figure 1: Centre of Pressure (COP) trajectory division for the analysis (APA1, APA2a, APA2b, LOC). The initial foot is the right foot.

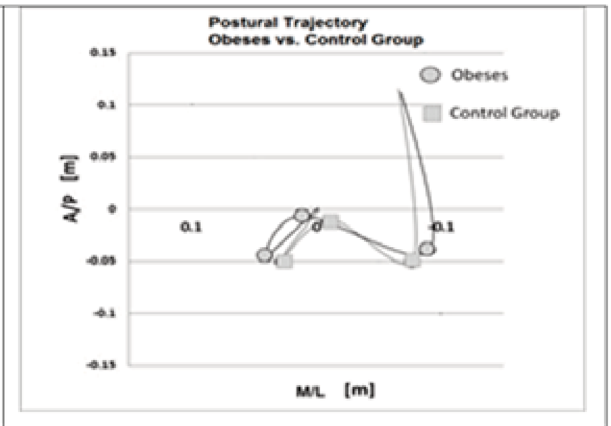

Figure 2: Postural sway comparison between obese and healthy participants

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THE USE OF MATHEMATICAL MODELLING IN EVALUATION OF VOLLEYBALL ATTACK

R. Michnik (1), J. Jurkojć (1), K. Czapla (2)
(1) Biomechatronic Department, Faculty of Biomedical Engineering, Silesian University of Technology, Zabrze, Poland
(2) Sports Center, Silesian University of Technology, Gliwice, Poland

Main topics: volleyball attack , kinematics measurment, modelling of musculoskeletal system

INTRODUCTION and AIM

One of the most common conditions the volleyball players suffer is pain caused by overload in the area of the shoulder complex [1, 2]. It is estimated that a professional volleyball player carries out approximately 40000 attacks during a season. About 85% of shoulder joint injuries is caused by an excessive overload of this joint [1, 2, 4]. Biomechanical testing methods are a useful tool to understand mechanisms which may lead to injuries [3, 4, 5, 6]. This article presents methodology of experimental and model tests which enable the evaluation of kinematics and loads of the upper limb musculoskeletal system during a volleyball attack.

PATIENTS/MATERIALS and METHODS

The tests were conducted in a group of four female volleyball players of the Academic Sports Team 'AZS Politechnika Śląska'. During the tests each player did several repetitions of a volleyball attack from the left wing. The measurements of kinematics were carried out with the use of the measuring system MVN Biomech. In order to simulate the loads of a musculoskeletal system the package of AnyBody programmes was used. Human body was modelled on the basis of a modified Free Posture Model. The model takes into consideration muscles having the greatest impact on the upper limb carrying out the attack and muscles working within the trunk of the body. Calculations were performed at the exact moment of hitting the ball.

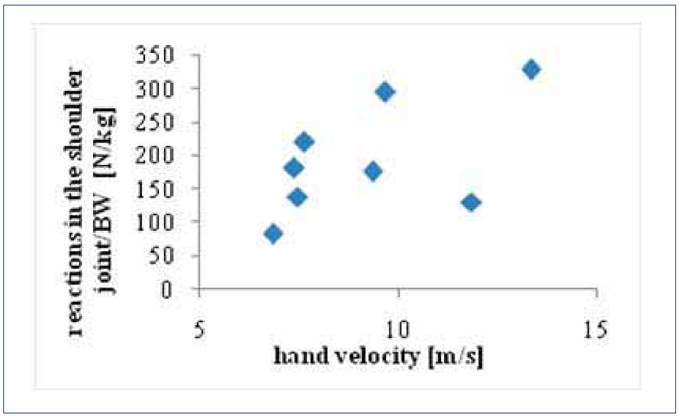
RESULTS

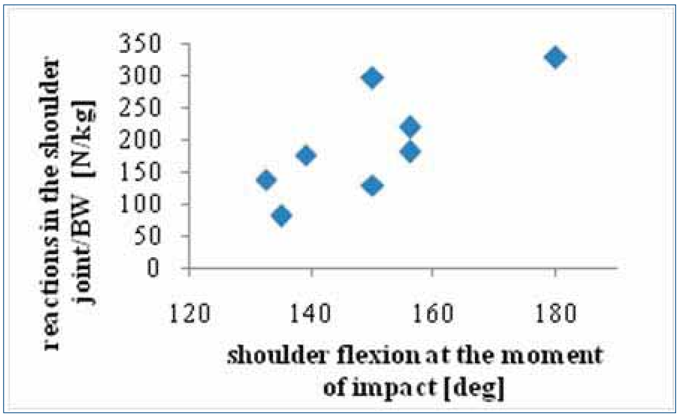
Measurements enabled determination of kinematic quantities describing movement of upper limb during volleyball attack. Model calculations make it possible to evaluate loads in upper limb.

DISCUSSION and CONCLUSIONS

The obtained results made it possible to assess the influence of a position of the upper limb on the speed of the ball at the moment of hitting as well as loads generated in the musculoskeletal system. The conducted research has shown that the technique of a volleyball offensive has an essential influence on the values of reaction forces in the shoulder joint and elbow joint. The application of the proposed methodology of testing in the assessment of a volleyball attack makes it possible to correct and properly develop movement patterns of volleyball players.

The work was realized within the framework of the project no. N N501 043940 financed from National Science Centre.





Relationship between reactions in the shoulder joint at the strike moment and hand velocity and maximal shoulder flexion

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DEVELOPMENT OF A MOVEMENT MONITOR BASED ON ACCELEROMETRY FOR AMBULANT PATIENTS WITH NEUROMUSCULAR DISEASES

AM Seferian (1), AG Le Moing (1,2), A Moraux (1), C Pelegry (1), E Dorvaux (3), JY Hogrel (1), D Vissière (3), L Servais (1)

Institute of Myology, Paris, France
CHU Amiens Neuropediatric Unit, GRAMFC, U1105, Université Jules Verne, Amiens, France
SYSNAV, Vernon, France

Main topics: Analysis of gait and motor disorders; Analysis of clinical movement data

INTRODUCTION and AIM

ActiMyo is an innovative wireless Holter device that continuously records upper limb movement. It has been initially developed in neuromuscular patients to quantify upper limb activity in patients with very restricted movement. Using magneto-inertial sensors placed on the wrist, this system can detect sequence of patterns for lowest movements of upper limbs [1].

Controlled environment and home data recording of non-ambulant DMD patients during a 15 day trial allowed to identify and characterize variables for movements of the upper limbs, but also to quantify the motor and physical activity in their real life (identification of wheelchair use, upper limb immobility, quantification of physical activity...) [2].

We plan to use the same system and adapt it to ambulant patients. A proof-of concept test is ongoing using sensors placed on the wrist, at the waistband at the ankle. The first aim is to determine the most pertinent placement on the body and then to find the most clinically significant parameters to evaluate movement in this population.

PATIENTS/MATERIALS and METHODS

Young ambulant patients older than 4 years with neuromuscular diseases were evaluated at the Institute of Myology and Amiens University Hospital using 3 sensors, each placed on the dominant hand and the homolateral ankle and on the lower posterior median line. Short tests like sitting/standing, walking 10 meters and back at different speeds, climbing 4 steps or the 6-Minute Walk Test are proposed to the patient. The data were analyzed with dedicated software, Actilog, using Matlab to determinate relevant clinical variable.

RESULTS

We recorded 7 patients with a mean age of 7.85 ±3.08. Four patients had DMD and the other one a congenital myopathy. The mean Brooke score was 1.6 and the mean Walton score 4. Most of the patients performed all the tests.

DISCUSSION and CONCLUSIONS

This is a proof of concept study using a new clinical measure based on acccelerometry for ambulant patients with neuromuscular diseases that permits us to find most relevant position of the sensors on the body and calculate pertinent clinical parameters. The final aim is to deliver this new tool for movement monitor at home (lower and upper limb) for this population.

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MULTILIVELLO©ORTHOSE IN A CHILD WITH SPASTIC HEMIPLEGIA

Mario Cerioli
Private practitioner – Cremona (Italy)

Stefania Magri
Azienda Istituti Ospitalieri di Cremona

Introduction: The use of leg - foot orthoses in walking children with cerebral palsy (CP) has been part of current re-educational practice for some time now. Although this experience is used, more or less unconsciously, to satisfy the patient's need to move, it often results in the introduction of external moments that prove, on the contrary, to be a further hindrance to balance (Burtner PA et al, 1999; Buckon CE et al, 2001). Conversely, when suitably customised, leg- foot orthoses have been seen to improve step length, speed, frequency and the physiological cost index when walking in patients with CP. In addition, there are certain conditions, such as flexum of the knee in which, to date, it has only been possible to obtain control using botulinum toxin or a surgical approach. The orthotic solutions proposed thus far have a number of drawbacks: the braces are heavy and cumbersome and restrict the wearer's autonomy and movement potential, thereby reducing the spontaneous functional exercise of walking.

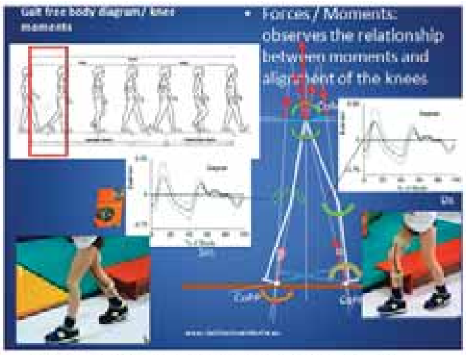
Purpose: Conversely, we propose a lower limb brace in which the connection between the thigh strap and leg strap is constituted by flexible sheets that work in extension. A system of elastic bands connects the hip strap to the thigh strap. This produces a brace that connects the whole of the lower limb and that provides the child with customised compensations that limit deforming thrusts and/or allows the exercising of postural adjustments in a condition of alignment.

Materials and methods: These braces, named Multilivello, were used from two years and six months of life by a child with normal cognitive and social abilities, diagnosed with hemiplegia of unknown origin. Before using the braces, child's gait was characterised by a stable equinus of the right foot diverted internally, with the knee in flexion or recurvatum, according to the requirements of the task and the same kinetic intentionality of the act: when L picks up speed dynamic stabilization occurs in recurvatum, but if he walks slowly or with the intention of stopping soon then prevailing downturn, more useful to control the amount of motion as a function of the arrest.

Results: The Multilevel brace, In the version from the thigh to the foot, has been used quite regularly for about seven hours a day. Even the latest assessment showed that the child has excellent ability to control posture and locomotion (GMFCS, with the cast: level 1), no retraction and no contracture. When, for 19 days, the child is left without brace, the walking characteristics are immediately deteriorated with the increase of equinus, the lower balance and increase knee flexum . The Multilivello brace not significantly interfere with the autonomy of the child. The brace is has been used by 2 ½ years of age to the present day, and its use has not shown any inconvenience.


Without the brace by 19 days


Soon after, with the brace



Watch how change the kinetic needs during step

Discussion and conclusions: The progress achieved in learning motor control can be attributed to the fact that the functional exercise of the changes in position and gait, in the child's natural life, take place thanks to the significant kinetic personalisation of the Multilivello brace, which keeps the tibiotarsal joint and knee dynamically aligned. This allows the wearer to learn an intersegmental, internal stabilisation that is functionally configured, static and dynamic, initially reactive and subsequently anticipatory.
The Multilivello brace would appear to have the qualities required to make it a successful alternative to the types of brace currently available.

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OUTPACING DEATH: SURGERY TO AID WALKING AFTER STROKE

AP Roberts(1), J Riad(2), H Ishwaran(3)
(1) Robert Jones & Agnes Hunt Orthopaedic Hospital, Oswestry, UK
(2) Skaraborgs sjukhus, Skövde, Sweden
(3) University of Miami, Florida, USA

INTRODUCTION and AIM

Slow walking speed is associated with earlier death after stroke. If walking speed can be beneficially influenced by treatment the possibility of a reduction in mortality exists. Analysis of an existing dataset of survival after stroke allows, for each age group and sex, the effect of an improvement in speed to be expressed as a possible reduction in mortality.

PATIENTS/MATERIALS and METHOD

A random forest survival analysis allows the construction of a predictive tree with decision nodes that produce an optimised estimation of outcome (survival)[1]. A hypothetical subject with predefined characteristics can be run through the predictive tree to give an individualised probability of survival. An R program was constructed to run subjects of both sexes; all relevant ages and all walking speeds through the tree to give, for each sex and age a smoothed speed - mortality curve[2]. Once a smooth curve had been derived, mortality reductions can be calculated for each initial speed from the survival data over a range of improved/ worsened speeds. With the assumption that negative walking speeds are not possible (deterioration > initial speed) a heat map of mortality reduction(increase) for each initial walking speed can be produced.

RESULTS

Thirteen patients were identified from gait laboratory records who had received treatment for walking impairment after a stroke. Surgical treatment for stroke consisted of lengthening the heel cord and rebalancing tendons around the foot to enable stability in stance and preposition of the foot at initial contact. A secondary benefit of rebalancing the foot was an improve kinetics at the knee. Modest increases in walking speed were noted along with some patients who could not walk being able to do

CONCLUSION

Surgical management of the lower limb can produce modest improvements in walking speed after stroke. Unbalanced muscle action leading to coronal plane deformity and instability with or without pain renders walking difficult. Equinus contracture renders the foot unstable and may lead to unwanted hyperextension at the knee with secondary hip flexion. If improvements in walking speed enables maintenance of better fitness and metabolic reserve an improvement in mortality may follow. Further work to identify the energy consumption before and after stroke surgery would be needed to explore this possibility.

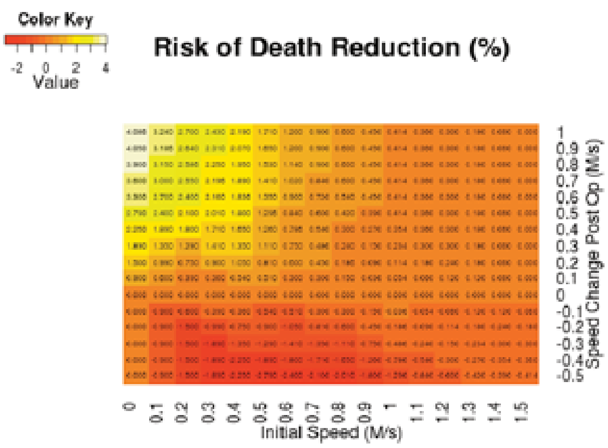

Table 1: Median Increase (SD) of Speed

Sex	Surgery	
F	N	() (0)
	Y	0.182 (0.238)
M	N	0.0300 ()
	Y	0.166 (0.0615)

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QUANTIFICATION OF THE EFFICACY OF LOWER LIMB FUNCTIONAL ELECTRICAL STIMULATION USING 3D MOTION ANALYSIS

M.J. Kerr (1), S.F. Attfield (1)
(1) Derby Gait and Movement Laboratory, Derby Hospitals NHS Foundation Trust, Derby, UK

Main topics: Movement analysis in clinical practice, Assistive devices

INTRODUCTION and AIM

Functional Electrical Stimulation (FES) is an intervention which may be prescribed for patients presenting with drop foot and involves the electrical stimulation of the peroneal nerve via skin mounted electrodes to induce tibialis anterior contraction and therefore, dorsiflexion of the ankle, facilitating ground clearance in the swing phase gait[1]. Control of eversion can also be obtained. Electrodes are most commonly positioned over the fibula head and the tibialis anterior muscle. The efficacy of the device can then be assessed qualitatively by observation of a patient's walking but this does not provide precise information regarding ankle motion or walking speed.

PATIENTS/MATERIALS and METHODS

A 10 camera 3D motion analysis system was used to collect kinematic data from 10 patients seen clinically at Derby Gait and Movement Laboratory with pathologies including multiple sclerosis, stroke and cerebral palsy. Data was collected across 12 FES gait analysis sessions including data on 1 patient, recovering from a stroke, collected at initial assessment, fitting session and again at 3 month review. All patients used an Odstock Drop Foot Stimulator (ODFS) Pace FES unit (Odstock Medical, Salisbury) and marker placement followed the protocol for a 2 segment, 6 degree of freedom model of the shank and foot (fig 1). In each session data was collected while patients walked shod with their FES device switched on and again with the device switched off so that its effect could be evaluated (fig 2). Data was processed in Visual 3d software (C-motion Inc, USA) and the 4 gait parameters investigated were: heel strike angle (angle of foot relative to floor in the sagittal plane), peak ankle dorsiflexion in swing, average eversion in swing and walking speed.

RESULTS

When walking using FES, heel strike angle was seen to increase in 11 of the 12 sessions (91.7%). Peak dorsiflexion in swing, average eversion in swing and walking speed also increased in 11 sessions (91.7%). Instances where parameters did not increase did not all occur in the same session. For the patient analysed on three separate occasions, clear increases were seen in all parameters for each session, with increases in walking speed using FES observed in each consecutive session.

DISCUSSION and CONCLUSIONS

This study demonstrates the use of 3D motion analysis for quantified evaluation of the efficacy of FES and shows a trend for FES to improve the gait of patients with drop foot by increasing heel strike angle, peak dorsiflexion in swing, eversion in swing and walking speed. Factors likely to be affecting sessions in which parameters were not seen to increase included the effect of a patient walking more cautiously at a fitting session while familiarising with the device and also the effect of fatigue from having walked without FES immediately before the trial with FES switched on. Results have also shown an example case of continued, long term improvement in gait with use of FES. This method of quantified analysis allows for the fine tuning of both dorsiflexion and eversion to provide the patient with optimum function.

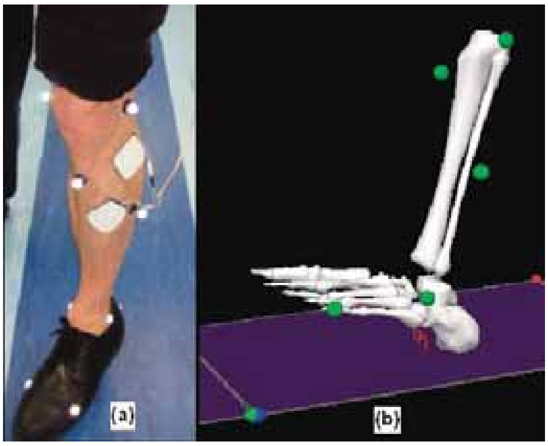

Figure 1: (a) Typical FES electrode placement and (b) 3D reconstruction of shank and foot

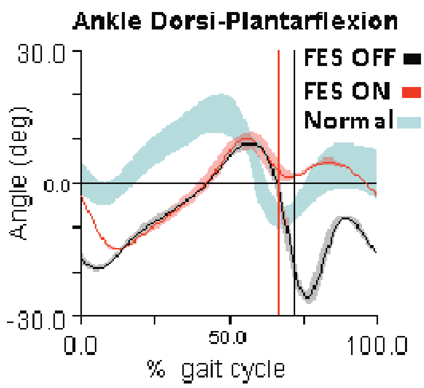

Figure 2: Representative data from 1 session where use of FES can be seen to increase ankle dorsiflexion in swing phase and at initial contact

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IMMEDIATE EFFECTS OF WHOLE BODY VIBRATION ON GAIT STABILITY AND BALANCE IN STROKE PATIENTS WITH HEMIPLEGIA

Masahito Murakami [)], Keisuke Itotani [)], Yoshitaka Otani [)], Junichi Kato [2)]

1) Department of Physical Therapy, Faculty of Rehabilitation, Kobe International University, Kobe City, Japan
2 Department of Internal Medicine, Hyogo Prefectural Rehabilitation Hospital at Nishi-Harima, Tatsuno City, Japan

INTRODUCTION and AIM

Background: Whole body vibration (WBV) exercise may enhance muscle strength adaptations associated with traditional neuromuscular training or rehabilitation. The potentially beneficial effects of WBV are caused by the transmission of mechanical sinusoidal vibrations throughout the body via the feet. **Objectives**: This study was conducted to clarify to investigate immediate effects of WBV training on gait disturbance and balance in stroke patients with hemiplegia .

PATIENTS/MATERIALS and METHODS

Subjects were 18 stroke patients (13males and 5females; 62.7±13.2 years old) in our hospital who were able to walk with themselves. We measured Range of Motion(ROM: SLR and ankle extension), 10m walking time, Timed Up and Go test (TUG) and static standing balance before and after carrying out the 25Hz WBV training with three sets of isometric exercise for 2 min with 2-min rest between sets (Sonic Wave Vibration System, SONIC WORLD Ltd, Korea) on standing position. Evaluation of static standing balance was carried out in the total length in center of the gravity (LNG) and the rectangular are (REC) using force plate MG-1120 (Anima Ltd, Japan).

RESULTS

ROM(both lower limbs), 10m walking time and TUG were significantly improved (SLR: from 61.1±9.9° to 74.7±14.5°; $p<0.01$, ankle extension: 11.6±5.6°to 15.3±5.3°; $p<0.01$, 10m walking time: from 19±9.8 to 17.3±7.7sec ; $p<0.05$, TUG : from 21.2±11.5 to 19.7±8.8sec ; $p<0.05$) after WBV training respectively. The LNG and the REC were not significantly improved.

DISCUSSION and CONCLUSIONS

These results indicated that WBV training might have immediately effects on ROM, gait disturbance and stand up and turn in stroke patients. WBV training was considered to be effective for physical therapy in rehabilitation field.

ARMEO POWER: KINEMATIC ANALYSIS OF THE UPPER LIMB PRE AND POST ROBOTIC TREATMENT IN HEMIPARETIC PATIENTS, PILOT STUDY

S. Filoni*, E. F. Russo*, M. Russo*, L. Russi*, F. Merla*, M.T. Gatta*, P. Sale**
*: Fondazione Centri di Riabilitazione Padre Pio Onlus, San Giovanni Rotondo, Foggia
**:Dipartimento di Neuroriabilitazione IRCCS San Raffaele Pisana Roma.

INTRODUCTION and AIM

The rehabilitation of the upper limb after stroke by functional impairment is a major challenge for rehabilitation. As part of the new techniques of relearning, the use of robotic exoskeletons is proving effective.

PATIENTS/MATERIALS and METHODS

The study aims to investigate the effects of training with a robot-assisted rehabilitation of the upper limb exoskeleton Armeo ® Power for the recovery of motor function of the upper limb in patients after stroke. Patients suffering from hemiparesis in the aftermath of recent stroke cerebri were subjected to training with a robotic exoskeleton duration of 4 weeks.
At inclusion the following rating scales were given: Frenchay Arm Test, the Nine- Hole Peg Test (NHPT) , the modified Ashworth scale ; were subjected to a battery of tests available on Armeo ® Power : reaction time, capture vertical , A- Goals , A- ROM , A- Force; were subjected to an evaluation of motion analysis for upper limb (protocol RAB) in order to study the kinematics of the movement of " pointing " . the parameters of fluidity of movement were considered IC (index of curvature) , NMU (number of peak speed), speed (max and average within the motor task), Delta T (seconds it takes to reach the target) , Normalized Jerk . the angular parameters of the shoulder and elbow were also taken into account.

RESULTS

The rating scales Were again administered and the results were compared with those obtained at the time of recruitment. There have been significant improvements in the clinical scales of assessment. With regard to the present evaluative exercises on Armeo Power, the patients completed the exercises more quickly and with greater precision. There were no significant changes in active ROM. With regard to the task studied with the motion analysis, all the parameters are significantly improved after the training, a clear sign of better accuracy and fluidity of movement after training.

DISCUSSION and CONCLUSIONS

These indices obtained with instrumental Armeo power and with the analysis of the movement could be used to integrate and support the clinical evaluation of the upper limb in patients suffering from outcomes in stroke because they provide information on the deficit and the impairment in the ability of the motor control and are a very accurate monitoring of motor recovery.

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EFFECTS OF ANKLE FOOT ORTHOSES ON BODY FUNCTIONS AND ACTIVITIES: A SYSTEMATIC REVIEW

Dymphy S.A. van der Wilk (1), Pieter U. Dijkstra (1, 2), Klaas Postema (1), Gijsbertus J. Verkerke (1, 3), Juha M. Hijmans (1)

(1) Department of Rehabilitation Medicine, Center for Rehabilitation, University of Groningen, University Medical Center Groningen, The Netherlands
(2) Department of Oral and Maxillofacial Surgery, University of Groningen, University Medical Center Groningen, the Netherlands
(3) Department of Biomechanical Engineering, University of Twente, the Netherlands
Corresponding author: Dymphy van der Wilk; a.s.d.van.der.wilk@umcg.nl

Main topics: Analysis of gait and motor disorders, Rehabilitation, Orthotics

INTRODUCTION and AIM

People with paretic ankle muscles often use an ankle foot orthosis (AFO) to improve walking. However, most AFOs limit ankle range of motion (ROM) introducing problems during activities which require more ROM than allowed for by the AFO. Gaining insight in beneficial and adverse effects of AFOs aids in AFO prescription and developing new AFOs. To structure effects of AFOs, the components body functions and activities[1,2] of the ICF[3] are helpful. The aim of this systematic review is to evaluate studies on effects of AFOs on body functions and activities in people with paretic ankle muscles.

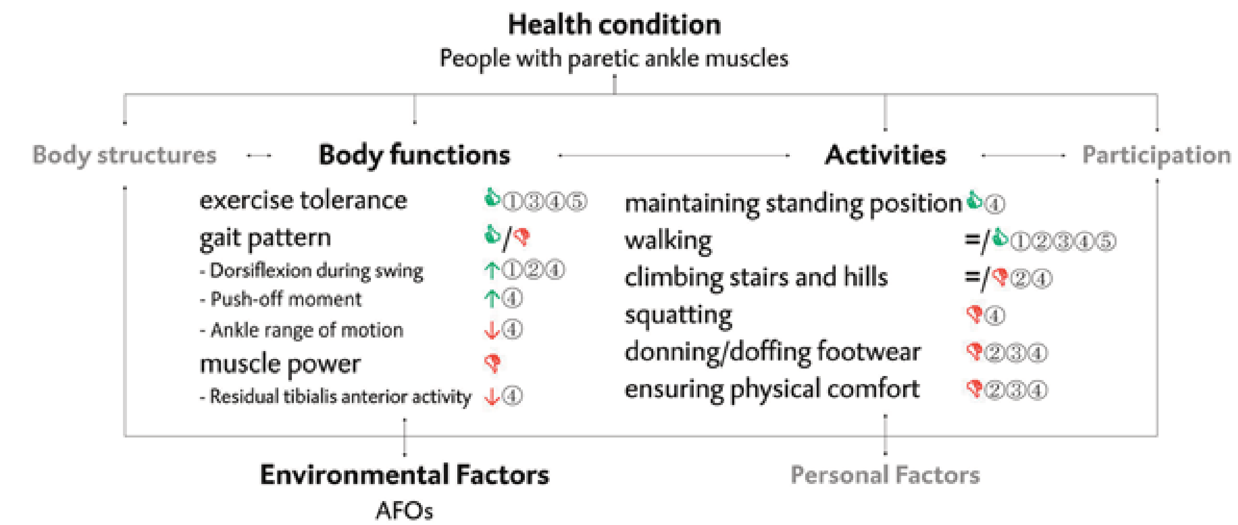
PATIENTS/MATERIALS and METHODS

Search of Pubmed, Cinahl, Embase and Cochrane Library, which ended on February 4th, 2014. Studies solely focusing on people with spasticity were excluded. No language restrictions were applied.

RESULTS

DISCUSSION and CONCLUSIONS

AFOs have both beneficial- and adverse effects on body functions and activities. Beneficial effects of AFOs were found for energy expenditure, dorsiflexion during swing, push-off moment, standing still and walking. Adverse effects of AFOs were found for ankle ROM, residual tibialis anterior muscle activity, difficulty with stair-/ hill locomotion, squatting and donning/doffing, and a decrease in comfort compared to shoes only. Clinicians and developers should be aware of these beneficial and adverse effects of AFOs.



Text box 1: Effects of AFOs on body functions and activities in people with paretic ankle muscles placed in the ICF framework[3]. ① elastic AFOs (rubber band connecting shank and shoe), ②circular AFOs made of fabric, ③circular AFOs made of silicone, ④dorsal AFOs, ⑤ hinged AFOs, beneficial effect, adverse effect, ↑ increase, ↓ decrease, = no effect.

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CENTRE OF PRESSURE MOVEMENT DURING BAREFOOT GAIT IN ELITE PROFESSIONAL BALLET DANCERS

M. Prochazkova, Z. Svoboda, L. Tepla, E. Streskova, M. Janura
Faculty of Physical Culture, Palacky University, Olomouc, Czech Republic

Main topics: Analysis of clinical movement data, Experimental studies in human movement science.

INTRODUCTION and AIM

As well as all sports, the dance has to respect the basic biomechanical rules. The non-acceptance of these rules may lead to injury, especially of the foot and ankle complex [1]. Musculoskeletal injury is an important health issue for dancers at all skill levels. Beneficial information in assessing and detecting foot function and pathology can provide the path of center of pressure (COP) [2]. The aims of the present study were: (1) to compare COP movement in elite ballet dancers between control group, (2) to determine the gender influence on the COP movement.

MATERIALS and METHODS

Thirty-eight elite ballet dancers (15 males, 23 females; age 25.2±5.0 years; height 168.7±7.4 cm; weight 57.2±10.7 kg) of the National Theatre in Brno participated in this study. The dancers were compared to 31 non-dancers (14 males, 17 females; age 23.7±2.2 years; height 172.5±10.0 cm; weight 67.2±12.0 kg). All participants had no history of any acute lower limb injuries at the time of the study or in the preceding six months. For measuring the variables of COP trajectory during the gait was used a 2 m dynamic pressure plate (RSscan International, Olen, Belgium). The displacements of the COP were normalized for subjects' foot length. The normality of the data was verified by Kolmogorov-Smirnov test. For statistical comparison (STATISTICA, Version 12.0, StatSoft, Inc., Tulsa, OK, USA) the two-way (group, gender) analysis of variance (ANOVA) and Fisher's LSD post hoc test were applied. For all tests the significance level was set at $p<0.05$.

RESULTS

Our results showed significantly lower values in medial peak of COP in female ballet dancers compared with male ballet dancers ($p=0.006$). Similarly, the total range of COP was significantly lower in female ballet dancers ($p=0.008$). On the other hand, there were found significantly higher values of the COP variability in anterior-posterior (AP) direction ($p=0.010$) and of the AP COP velocity ($p=0.001$) and total COP velocity ($p=0.001$) in female ballet dancers. In addition to gender differences in ballet group, significant differences were also observed between female groups. We found significantly lower values of the COP variability in medial-lateral direction in women in the control group ($p=0.036$). Likewise, the same significant differences were observed in the AP COP variability ($p=0.001$). No significant differences were observed between male groups.

DISCUSSION and CONCLUSIONS

The results of the present study revealed mainly significant gender differences in dancers group. This may be caused by both different male and female roles during dancing and the fact that primarily female wear the pointe shoes. The smaller COP total excursion may indicate the pronated foot type in female dancers [3, 4]. Furthermore, we found out significantly higher variability of COP movement in both directions in female dancers compared to female controls. This could suggest that there exists gait instability in ballet dancers despite their regular specific balance training. Effects of this training may manifest only during the highly demanding conditions of balance and not in less demanding balance conditions, such as in postural control in daily life activities [5, 6].
Therefore, we can conclude that there is the gender effect on the COP displacement in dancers group that is why for the future research it is important to divide ballet dancers according to gender.

Acknowledgement

This study was supported by the internal grant "Evaluation of postural stability in professional dancers" of Faculty of Physical Culture in Olomouc [grant number FTK_2014:020].

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FEASIBILITY OF TECHNOLOGY SUPPORTED ARM/HAND TRAINING AT HOME AFTER STROKE

SM Nijenhuis (1), GB Prange (2), P Sale (3), A Cesario (3), F Amirabdollahian (4), JS Rietman (2), JH Buurke (5)
(1) Roessingh Research and Development, Enschede, the Netherlands
(2) Roessingh Research and Development, Enschede, the Netherlands; University of Twente, Department of Biomechanical Engineering, Enschede, the Netherlands
(3) IRCCS San Raffaele Pisana, Rome, Italy
(4) Adaptive Systems Research Group, School of Computer Science, University of Hertfordshire, Hatfield, United Kingdom
(5) Roessingh Research and Development, Enschede, the Netherlands; University of Twente, Department of Biomedical Signals and Systems, Enschede, the Netherlands.

INTRODUCTION and AIM
Robotic devices are increasingly used in rehabilitation therapy for the hemiparetic arm after stroke. Only few devices have been designed and tested for training of the wrist and hand in combination with proximal arm movements, even though functional use of the hand is crucial for carrying out activities of daily life. A major advantage of these devices is that they can be utilized at home without a therapist being present. In the present ongoing study, a custom-designed device supporting hand opening is combined with a motivational user interface with gaming environment. The first results about feasibility of technology-supported arm/hand training at home in chronic stroke patients are presented.

Figure 1: (a) Typical FES electrode placement and (b) 3D reconstruction of shank and foot

PATIENTS/MATERIALS and METHODS
So far, 10 of the intended 30 chronic stroke patients with impaired arm/hand function have been included in this pilot clinical trial across the Netherlands and Italy. Subjects were recommended to exercise 180 minutes per week at home with the SCRIPT system (Fig. 1) during 6 weeks. They trained independently using games while they were supervised remotely, off-line, by a therapist. Evaluation of feasibility involved training duration, usability (System Usability Scale, SUS) and motivation (Intrinsic Motivation Inventory, IMI). Arm/hand function (Fugl-Meyer, FM) was assessed before and after six weeks of training.

RESULTS
So far, ten subjects (6 NL, 4 IT) completed training and evaluation sessions. User acceptance was positive (mean SUS 69.3, SD 20.0; mean IMI 5.2, SD 0.8). Compliance with the system was promising: mean training duration per week was 99 minutes (SD 55 minutes). Mean arm/hand function measured with the FM score improved from 34.9 (SD 18.4) pre-training to 37.0 (SD 18.5) post-training (Fig. 2).

DISCUSSION and CONCLUSIONS
So far, results indicate that technology-supported arm/hand training in chronic stroke patients at home is feasible and may be effective. If these results are indicative of the ongoing study, technology-supported arm/hand training may be a promising tool to enable intensive, self-administered practice at home.

ACKNOWLEDGEMENT
This study is part of the SCRIPT project, which is partially funded by the European Commission under the 7th Framework Programme (FP7-ICT-2011-07) Grant Agreement Number: 288698

MOTION ANALYSIS AND THERAPY RESPONSE IN IMMUNE-MEDIATE POLYNEUROPATHIES.

D. Coraci (1), I. Paolasso I (2), E. Di Sipio (2), C. Simbolotti C (2) and L. Padua (2,3)

Board of Physical Medicine and Rehabilitation, Department of Orthopaedic Science, "Sapienza" University, Rome, Italy
Don C. Gnocchi ONLUS Foundation, Rome, Italy
Università Cattolica del Sacro Cuore, Rome, Italy

Main topics: Functional outcome measures in mobility, Rehabilitation

INTRODUCTION and AIM

Human motion analysis (MA) is often used in the diagnosis and follow-up of neuromusculoskeletal diseases. Among polyneuropathies, we have data about gait analysis in CMT but, to the best of our knowledge, no-one about immune-mediated neuropathies. These last are often treated with immune-modulant therapy, in particular intra-venous immunoglobuline (IVIg), but clinical examination is not always able to depict the minimal changes of the movement performance in treated patients. We used MA to study the immunomodulant therapy response in Chronic Inflammatory Demyelinating Polyradiculoneuropathy and Multifocal Motor Neuropathy.

PATIENTS/MATERIALS and METHODS

We enrolled 7 patients with immune-mediate polyneuropathies in IVIg therapy. Motor tasks were recorded using a stereophotogrammetric systems and a piezoelectric force platform. For upper limb, we used a protocol developed by our lab and we evaluated the range of motion (ROM) of finger abd-adduction, flexion-extension and reaching-grasping tasks. For lower limb, we evaluated joint power peak in a linear walking. A clinical evaluation was performed before every MA study.

RESULTS

We obtained improvement in 2 patients, worsening in 2 patients, stability in one patient (for upper limb); improvement in power peak for all patients (for lower limb). These results were not visible in clinical evaluation.

DISCUSSION and CONCLUSIONS

This is a preliminary study but it shows that MA may give useful information about the therapy response. Future studies are necessary to understand if MA is a sensitive outcome measure in immune-mediated neuropathies.

EFFECTIVENESS OF INERTIAL SENSORS AND ANDROID APPLICATION UCSI (Clinical Scale Instrumentation) TO MEASURE TRUNK CONTROL IN PERSONS WITH SPINAL CORD INJURY: PRELIMINARY RESULTS OF AN EXPERIMENTAL STUDY

Valentina D'Alleva[a], Francesca Bettini[a], Paola Paglierani[a], Lorenzo Chiari[bc], Carlo Tacconi[c], Sabato Mellone[b], Federica Guerra[a], Sabrina Cugusi[a], Jacopo Bonavita[a]

[a] UOC Spinal Unit, Montecatone Rehabilitation Institute, Imola

[b] Department of Electrical, Electronic and Information Engineering, University of Bologna, Italy

[c] CIRI - Health Sciences & Technologies, University of Bologna, Italy

INTRODUCTION

For the assessment of trunk control in persons with spinal cord injury, some tests have been proposed in the literature but none of these are currently validated for this category of patients: these are the modified functional reach test and the bilateral reach test.

Inertial sensors have already been applied in many areas of rehabilitation medicine, though they have been scarcely used in the field of spinal cord injury.

So far the instrumental evaluations studied on trunk control of spinal cord injured persons have been carried out using force platforms, dynamometers and electromyography.

OBJECTIVE

The aim of this study is to test the effectiveness of an evaluation system based on wearable inertial sensors measuring trunk control in spinal cord injured people. The wearable sensors integrate an accelerometer, a gyroscope and a triaxial magnetometer. The signals are acquired and processed by a smartphone with an Android application called UCSI (Clinical Scale Instrument), connected with sensors with a Bluetooth connection.

MATERIALS AND METHODS

This is a prospective interventional experimental study with a control group (normal volunteer subjects).

SUBJECT

In the next 12 months we will analyze patients with a clinical diagnosis of SCI with neurological level T1-L1 with any etiology (both traumatic and non-traumatic), ASIA classification A and B , age from 18 years to 70 years old.

Patients will be divided into six groups according to neurological level: D1-D6 (first group), D7 -D10 (second group), D11 -L1 (third group) and according to the onset time of the lesion: acute (less 1 year), admitted in their acute phase at the Spinal Unit of Montecatone, Imola (Bologna, Italy) and chronic (injury from 1 year or more)

Inertial sensors are positioned in correspondence of C7 and L4.

Participants are instructed to perform a series of tests: to maintain sitting posture for 10 seconds, to lean as far as possible with one upper limb at a time in two directions (anterior and lateral direction) and to recover the straight posture from passive mobilization. The trunk stability will be measured during testing in sitting position both in normal and SCI subjects (in control and study group)

At the same time SCIM III scale will be measured in each patient, in relation to the mobility part.

Acceleration and angular velocity, measured by inertial sensor has been recorded and analyzed, to determine the impact of spinal cord injury on the ability to maintain stable sitting posture.

RESULTS

According to preliminary data kinematic variables measured by UCSI are able to value and objectify the differences in trunk control among the different categories of patients and normal subjects and between acute and chronic patients. Acute SCI individuals present an increase of relative angle between cervical and lumbar rachis confronted with normal subjects and chronic patients.

Improvement of trunk control measured by kinematic variables derived by inertial sensors, accords with the progressive increase of the values of outcomes related to SCIM mobility both in term of level of lesion and in term of learning during rehabilitation.

CONCLUSIONS

Preliminary results confirm the instrument's capacity in quantifying trunk stability during a series of test of static and dynamic trunk control.

The use of inertial wearable sensors and of smartphones appears to be extremely practical and fast.

In order to carry out a validation of the instrument in measuring trunk control in spinal cord injury, it will be useful to check the consistency and coherence of the dynamics of the parameters in accordance with clinical evaluation.

LOAD-BEARING VESTS OR UTILITY BELTS- GAIT KINEMATICS IN SWEDISH POLICE

N. Ramstrand (1), R. Zügner, (2), L. B. Larsen (1), R. Tranberg (2),
(1) Department of Rehabilitation, School of Health Sciences, Jönköping University
(2) Department of Orthopedics, Institute of Clinical Sciences, Sahlgrenska Academy, University of Gothenburg, Sahlgrenska University

Main topics: Analysis of clinical movement data; Outcomes after clinical intervention

INTRODUCTION and AIM

As an occupational group police have been reported to experience a high incidence of musculoskeletal injuries with low back pain being the most commonly reported ailment (1,2). The underlying cause of musculoskeletal injury in police is unclear in the literature but has been attributed to use of heavy safety vests and utility belts (3) In order to minimize musculoskeletal injuries sustained from use of heavy utility belts, several countries have introduced load bearing vests which are designed to eliminate the need for a belt and to redistribute the weight borne by police by carrying items in specially designed pockets on the vest itself. To date no studies have investigated the biomechanical effects that load bearing vests may have on the body. The aim of the present study was to compare gait kinematics in active duty police officers wearing load-bearing vests and standard utility belts.

PATIENTS/MATERIALS and METHODS

Twenty-two police were recruited to participate in this study. All were currently serving uniformed police officers. Gait of participants in the study was evaluated while walking at a self-selected velocity on a 10 meter walkway. Each participant was tested under three conditions (a) control condition with no vest or equipment, (b) standard issue utility belt and safety vest, (c) load bearing vest and safety vest. All participants wore their own standard issue police boots throughout testing. Three-dimensional kinematic data was collected for all trials. Nineteen police completed all phases of testing. All police were informed of the aims of the study and gave informed consent prior to their participation.

RESULTS

Friedman analysis of variance revealed significant differences across the three testing conditions. The load bearing vest condition was associated with the greatest kinematic changes. Police wearing the load-bearing vest had a significantly reduced pelvic range of motion in both sagittal and transverse planes ($p<0.05$). They also displayed reduced trunk movement in the frontal plane ($p<0.05$) and less trunk rotation ($p<0.05$). When compared to the control condition the arms assumed a more abducted position in both the belt and the load bearing vest conditions ($p<0.05$).

DISCUSSION and CONCLUSIONS

This study is of great importance to police forces intending to implement load-bearing vests as part of the standard issue uniform. Results indicate that use of a load-bearing vest significantly reduces range of motion at the hips, pelvis and trunk. The consequences of reduced range of motion on potential musculoskeletal injuries must be considered. To date it is not possible to determine if this would have positive or negative effects on the musculoskeletal system. Police in the present study had not been exposed to the load-bearing vest prior to testing and a long-term effects of wear on gait kinematics requires further investigation. The abducted position of the arms in both belt and vest conditions is a potential source of upper back and neck pain.

Load bearing vests had an immediate effect on the kinematics of gait in active duty police officers. Utility belts and safety vests were demonstrated to affect fewer kinematic variables. It is unclear if the observed kinematic changes would have positive or negative effects on the musculoskeletal system or if they would be sustained with prolonged use of the load-bearing vest.

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FUNCTIONAL GAIT ASYMMETRY IN SPEED CONTROL

K. E. Kozlowska (1), M. P. Popek (1), M. Latka (1), B. J. West (2)
(1) Wroclaw University of Technology, Wroclaw, Poland
(2) Information Science Directorate, Army Research Office, Durham, USA

Main topics: analysis of clinical movement data, motor control and motor learning

INTRODUCTION and AIM

The statistics of fluctuations in interstride intervals have been investigated for over two decades. However, there remains one fundamental question: how is speed regulated? To answer this question, we investigate the dynamics of step duration time series which follows an occurrence of step error, that being a sudden, large deviation of a step duration from its mean value.

PATIENTS/MATERIALS and METHODS

We used trunk accelerometry to determine the step duration of 30 healthy subjects (18 females, 12 males, mean age 22) during treadmill (4, 5 and 6 km/h) and overground walking along a straight section of sidewalk. Then we identified the abrupt changes in step duration that were greater than the mean value by more than 1.5 standard deviations and were not brought about by an error in the preceding step of the contralateral leg.

RESULTS

We find that when step duration is significantly longer (shorter) than the mean value it is followed immediately by a shorter (longer) step of either the contralateral leg (interleg control) or such compensation is done during the next movement of the ipsilateral leg (intraleg control). In approximately 95% of cases the step error is partially compensated for during the following two steps by either intra- or interleg control. During slow treadmill walking (4 km/h), the interleg control and the intraleg control are equally likely. With increasing speed, the interleg control becomes dominant (58% versus 42% at 6 km/h). In contrast, the intraleg control is more prevalent in overground walking with preferred speed (58% versus 42%). For both the treadmill and overground movement, the left leg is more frequently used to compensate for errors in stride duration (55% versus 45%).

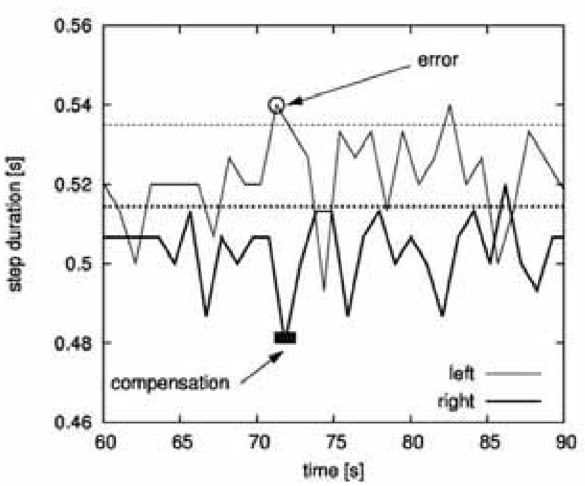

Figure 1: Time series of step durations for treadmill walking at 4 km/h. It is apparent that the duration of the step suddenly decreases immediately following the error.

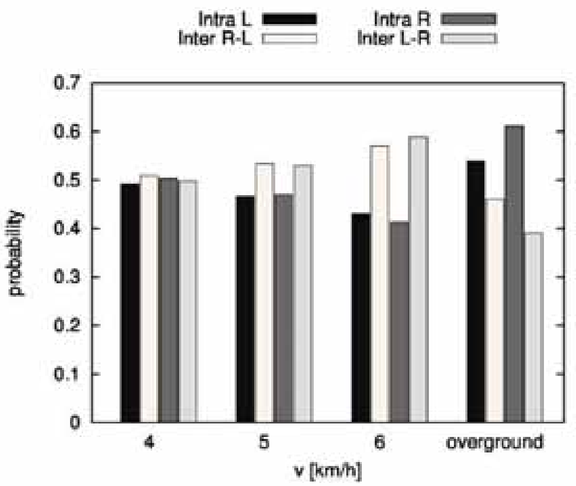

Figure 2: Probability of occurrence of intra- and interleg control mechanisms during treadmill and overground walking.

DISCUSSION and CONCLUSIONS

In this study we demonstrate that speed of gait is maintained by the interplay of intra- and interleg control mechanisms. Dominance of interleg control for high treadmill speeds results from the fact that significant deviations of step duration from the mean value must be immediately compensated to prevent a fall. A different strategy is adopted during overground walking with preferred speed when intraleg control is more prevalent. Both for the treadmill and outdoor walking the left leg is more frequently used to counter errors in step duration. This is a manifestation of functional gait asymmetry and is the first systematic observation of this asymmetry in the context of speed regulation.

THE EFFECTS OF CURVATURE DİRECTİON TO THE PLANTAR PRESSURE DISTRIBUTION İN IDIOPATHIC SCOLIOSIS

Eren Timurtaş (1), Mine Gülden Polat (1)
(1) Marmara University Health Sciences Faculty, Department of Physiotherapy and Rehabilitation, İstanbul, Turkey

INTRODUCTION and AIM

Scolliosis is one of the most frequent orthopedic problems which is seen in adolescent period. Scoliosis' three dimentional deformity affects lower extremites and vertebral column due to asymmetry of load distribution (1). In idiopathic scolliosis, it is seen that, there are discrepancies at kinetic and kinematic parameters of lower extremites during walking in comparison with healthy adolescent (2,3,4,5). For idiopathic scolliosis patients, when analyzed effects of scolliosis assets to the plantar pressure distrubition, it is seen that, plantar pressure distrubition is affected depend on curvature is at which segment (7,8). But there is no academic study effects of curvature direction to plantar pressure. Aim of the study is investigation about effects of curvature direction to the plantar pressure distrubition in idiopathic scolliosis.

PATIENTS/MATERIALS and METHODS

32 adolescents (27 female and 5 male, with mean age of 15,37) with idiopathic scoliosis were included in the study. Scoliosis degree of children with adolescent idiopathic scoliosis were examined by using Cobb method and vertebral rotation rates recorded by scoliometer after recording physical characteristics (gender, body weight, height) of subjects. Peak pressure (kPa), maximum force (N), contact duration (sec) and plantar pressure rate of the contact area (%) were evaluated by using dynamic pedobarography system (EMED-M, 38 × 42 cm, four sensors per square centimeter, 50 Hz; Novel GmbH., Munich, Germany) at self-selected speed. Independent T test was used to compare pedobarographic data of concave and convex side of single major scoliosis. The level of significance was determined as $p<0,05$.

RESULTS

The avarage cobb angle of the facts included in the study has been indicated 28,09° (15°-60°) and the avarage vertebral rotation angle has been indicated 10,54° (6°-22°). The dispersal of the facts based on scoliosis types according to the King classification has been indicated as King1 6, King2 11, King3 12,King4 2,King5 1.When the data from the area, max force and time parameters of convex and concav pedographic compared, the reare slightly important differences. It has been indicated that(p=0,693),(p=0,837),(p=0,423), convex side plantar pressure is significantly higher than the concav side plantar pressure (P=0,004).

DISCUSSION and CONCLUSIONS

According to the information derived from our study, it has been found out that the data of convex and concav side area, max force and time information isn't different. The only difference was in the maximum pressure parameter. The difference in the pressure parameter shows that it affects not only the pressure dispersal based on the segment in which there is a slope in Idiopathic scoliosis but also it causes a plantar pressure assimetry in the direction of the slope (8). The plantar pressure assimetry which changes accroding to the direction of the slope in adolescents with scoliosis supports the results of the studies which suggest that there is a dynamic assimetry in the extremity while walking (4,7). The reason why there is no important difference in the max force and time parameters belonging to the convex and concav side could result from the differences in the scoliosis air cobb angle, slope segment and slope values. In scolliosis patients, plantar pressure difference at lower extremite besides vertebral column curve can cause seconder pathology dependent on lower extremite in the long term. We suggest that, these factors have to be considered for evaluation and treatment of scolliosis patients in clinics. Also in future, by taking into consideration about type of scolliosis and degree of curve, we think that, studies like search effects of curve direction to the plantar pressure distrubition have to be done.

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ANALYSIS AND DESCRIPTION OF GAIT DYSFUNCTION IN PATELLOFEMORAL INSTABILITY

Damian A Clark[1], Danielle L Simpson[1], Jonathan DJ Eldridge, G Robert Colborne[2], Paolo Barbadoro[3], Sandro Gianni[3,4]

[1] Centre for Comparative and Clinical Anatomy, University of Bristol, Southwell Street, Bristol, BS2 8EJ

[2] Institute of Veterinary, Animal and Biomedical Sciences, Massey University, Private Bag 11 222, Palmerston North 4442, New Zealand

[3] 1st Orthopaedic-Traumatologic Clinic, Isituto Orthopedico Rizzoli, Via Pupilli 1 – 40136 – Bologna

[4] Movement Analysis Laboratory and Functional- Clinical Evaluation of Prostheses, Isituto Ortopedico Rizzoli, Via di Barbiano 1/10 – 40136 – Bologna

Communicating author:
Bob Colborne

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ABSTRACT
Introduction and Aim: Patellofemoral instability is a disabling knee condition, its multifactorial nature means there is no commonly accepted single treatment. There are conflicting reports on the effectiveness of treatments due to variability in how patients are diagnosed, classified and treated. The purpose of this study was to classify patients on the basis of their gait mechanics.

Patient/Materials and Methods: Thirteen patients with a mean age of 25.9 (±8.6) years were recruited as pre-operative patients for inverse dynamics analysis of their gait. Gait trials involved simultaneous collection of kinematic and kinetic data via a force platform linked with a 4-camera infrared kinematic system. Clinical patients were grouped into two subgroups based on their knee joint moment during stance, and their total support moments (TSM) during the stance phase were compared against eight healthy control subjects.

Results: Five of the 13 patients were classified into group P1 on the basis that they demonstrated a knee extensor moment during weight acceptance in early stance, and the remaining eight patients were classified into group P2 because they did not demonstrate a knee extensor moment.

Discussion and Conclusions: The TSM of the more affected limb in group P1 was not significantly different from control values in early stance but the difference was significant ($P<.05$) in late stance. In group P2, both the less and more affected limb were significantly different from control TSM values in early stance.

CORRELATION BETWEEN GAIT DEVIATION INDEX AND GROSS MOTOR FUNCTION (GMFCS LEVEL), AGE, HEIGHT, WEIGHT AND GENDER IN CHILDREN WITH CEREBRAL PALSY

M.A. Malt[1], J.M. Fevang[1,2], A. Aarli[1,3], B. Bogen[4]
1 Bergen Gait Laboratory, Haukeland University Hospital, Bergen, Norway
2 Department of Orthopaedic surgery, Haukeland University Hospital, Bergen, Norway
3 Department of Paediatrics, Haukeland University Hospital Bergen, Norway
4 The University of Bergen, Norway

INTRODUCTION and AIM

Three-dimensional gait analysis (3DGA) is widely used to identify gait problems as well as to plan and evaluate treatment of children with cerebral palsy (CP).
3DGA provides a large amount of data in form of graphs expressing motion, moment and power of hip, knee and ankle joints in 3 planes.
Gait Deviation Index (GDI) is a score derived from (3DGA) which provides a numerical value that expresses overall gait pathology (range 0-100, where 100 indicates the absence of gait pathology).
The aim of this study was to investigate the relationship between GDI and different levels of gross motor function (defined as Gross Motor Function Classification System (GMFCS) values), as well as the influence of age, height, weight and gender on GDI in children with unilateral and bilateral spastic CP.

PATIENTS/MATERIALS and METHODS

109 children (73 percent boys, mean age 9.7 years [SD 3,5]) with CP were included. 23 typically developing children were used as controls. The children with CP were classified at GMFCS levels I, II and III.
Multiple linear regression analysis was used to examine correlation with GMFCS level, age, height, weight and gender.

RESULTS

Mean GDI in the control group was 100 (SD 7,5).
Mean GDI in GMFCS-level I was 83 (SD 9), in GMFCS-level II 73 (SD 11) and in GMFCS level III 60 (SD 9).
Multiple linear regression analysis showed that GMFCS-levels had the greatest impact on the GDI-score. Height, weight and gender also influenced the GDI-score, while age did not correlate with GDI-score.

DISCUSSION and CONCLUSIONS

We found correlation between GDI values and GMFCS levels I, II and III. This is in accordance with previous studies. Calculation of GDI seems to be a clinically useful supplement to 3DGA in children with CP to evaluate treatment and to monitor the patients' functional walking ability/gait problems. The influence of height, weight and gender on GDI may be taken into consideration.

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sEMG AND CLINICAL TESTS FOR THE EVALUATION OF LASER THERAPY ON TRAUMATIC SPINAL CORD INJURIES

D. Longo, PT, L. Longo, MD, C. Romanelli, V. Mangè, PT, G. Cherubini, PT
Institute Laser Medicine, International Academy Laser Medicine And Surgery
Firenze – Italy

Main topics: sEMG, laser therapy, traumatic spinal cord injuries

INTRODUCTION and AIM

We experimented the use of Non-Surgical Laser Therapy (NSLT). in the treatment of Traumatic Central Nervous System Injuries (TCNSI), since 2003 year. We treated 216 patients, from year 2003 until December, 2013.
The goal of our study is the immediate evaluation of obtained results with objectives tool and procedure, as sEMG could be.

MATERIALS and METHODS

In 2013, 30 patients with TSCI, occurred at least one year before laser treatment and documented by NMR, ESSP, and ESMP, were enrolled. All patients have total and/or subtotal sensory and motor paralysis under the level of lesion. Lasers used were 808 nm, 10600 nm, and recently 1064 nm, applied with a first cycle of 20 sessions, four a day. Before laser treatment under the level of lesion, muscles' activity was tested with EMG system of surface (sEMG). Clinical evaluations included the research of superficial and deep tactile and thermal sensory under the level of lesion. A therapy protocol was used according to the clinical conditions of each patient. Same clinical evaluations and sEMG were repeated at the end of each cycle of treatment. The cycles of treatment were replicated in average each two month.

RESULTS

Results were regarded as positive if the sensory sensibility increased minimum two metamers under the level of lesion. sEMG showed modifications in CNS-muscle conduction spikes, under the same level. On TSCI, after each cycle of 20 sessions, patients showed improvements in motor function and voluntary command shown by the graphic features. Follow-up is positive after 3 months.

CONCLUSIONS

Clinical evaluations and sEMG seemed to be very useful as tests for an immediate assessment of TSCI Laser therapy procedure.

TECHNICAL QUALITY ASSURANCE FOR THE STRENGTH MEASUREMENTS PERFORMED WITH A HAND HELD DYNAMOMETER

A. Ancillao (1), S. Rossi (2), F. Patanè (3), A. Pacilli (1) & P. Cappa (1)
(1) Dept. Mechanical and Aerospace Engineering, Sapienza University of Rome, Roma, IT.
(2) Dept. Economics and Management – Industrial Engineering, University of Tuscia, Viterbo, IT.
(3) Faculty of Mechanical Engineering, Niccolò Cusano University, Roma, IT.

Main topics: Movement analysis in clinical practice, Analysis of clinical movement data.

INTRODUCTION and AIM

Strength measurements allow the evaluation of the health status of patients. A very common method to assess strength is the use of Hand Held Dynamometer (HHD). To evaluate strength during knee flexion/extension tasks, the patient is required to be seated on a bench while the therapist applies the HHD on the skank and asks the patient to push against it. These measures are clearly affected by operator and patient positioning. Previous studies concluded that this methodology can be considered questionable due to the low values of inter-trial repeatability [1], [2]. The aim of this work is to develop a methodology capable to assure the technical quality of force measurements by means of an optoelectronic system. This study is granted by the MD Paedigree Project that is part of the 7th Framework Program of the European Union.

PATIENTS/MATERIALS and METHODS

An adult healthy subject (25 years old) was recruited. The Plug In Gait marker set was applied to the subject. A MicroFet™ dynamometer (Hoggan Scientific, Salt Lake City, UT) was equipped with four markers as shown in Fig. 1. In accordance with [1], the subject was requested to extend the right knee with as much force as he could, while the therapist had to push back the subjects' leg. The position of the subject and the HDD were reconstructed by an optoelectronic system. The direction, orientation and application axis of the HDD were computed. The knee extension moment was computed along the axes: flex/extension, ab/adduction and intra/extra rotation. As reference, the knee moment was also computed by multiplying the measured force and the leg length. The angular range of motion of the knee was measured, to ensure that the knee maintained the requested position during the trial.

RESULTS

Forces and torques determined during one of the performed trials, are shown in Fig.2 and 3. As expected, the main component of the force was in the antero-posterior direction (x-axis), with an average of 122 N ± 3 N. The peak force measured by the dynamometer was 158 N. The other components were due to imperfect application of the dynamometer and were significantly lower (avg. of -36 N ± 8 N and 12 N ± 5 N) than the antero-posterior one. For the knee moment, the main component was along the flex/ext axis with an average of 41 Nm ± 5 Nm. The dotted line in Fig. 3 is the reference moment (43 Nm). The black line is the intensity of the moment vector.

DISCUSSION and CONCLUSIONS

Forces and torques in the undesired directions were low, while forces and torques in the main directions were consistent with the nominal ones. The undesired components of force and moment could represent a consistent numerical index to characterize the quality of a strength measurement test. In this preliminary study, we concluded that the method is reliable for application to healthy subjects, but further study is required to quantify inter and intra operator repeatability and the method should be tested for application to pathological subjects.

Fig.1: HHD equipped with markers, as used in this study

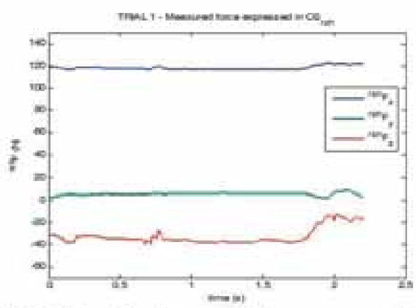

Fig.2: Subject No.1, test: right knee ext, repetition 1: Components of measured force vector.

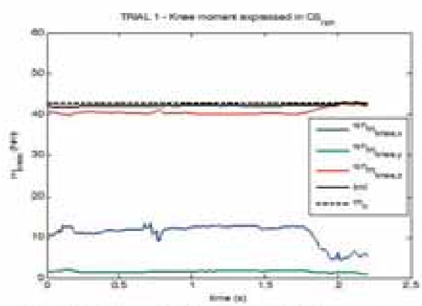

Fig.3: Subject No.1, test: right knee ext, repetition 1: components of knee moment vector.

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PARTICULARLY IN SPASTIC CHILDREN, FOOT PLATE ANGLE IS NOT A VALID ESTIMATOR OF TALO-CRURAL JOINT ANGLE: 3D-ULTRASOUNDIMAGING AND X-RAY ANALYSIS OF EFFECTS ON GASTROCNEMIUS LENGTH

Peter A. Huijing, Menno R Bénard, Jaap Harlaar, Richard T Jaspers and Jules G Becher

Background: In spastic cerebral palsy (SCP), a limited range of motion of the foot (ROM), limits gait and other activities. Assessment of this limitation of ROM and knowledge of active mechanisms is of crucial importance for allowing improvement of clinical treatment.

Methods: For a comparison between spastic cerebral palsy (SCP) children and typically developing children (TD), medial gastrocnemius muscle-tendon complex length was assessed using 3-D ultrasound imaging techniques, while exerting externally standardized moments via a hand-held dynamometer. Exemplary X-ray imaging of ankle and foot was used to confirm possible TD-SCP differences in foot deformation.

Results: SCP and TD did not differ in normalized level of excitation (EMG) of muscles studied. For given moments exerted in SCP, foot plate angles were all more towards plantar flexion than in TD. However, foot plate angle proved to be an invalid estimator of talocrural joint angle, since at equal foot plate angles, GM muscle-tendon complex normalized for tibia length was shorter in SCP (corresponding to an footplate angle dependent difference of at least 1 cm).

X-ray imaging of ankle and foot of one SCP child and two typically developed adults, confirmed that in SCP of total footplate angle changes (0-4 Nm: 15°), the contribution of foot deformation to changes in foot plate angle (8°) were as big as the contribution of dorsal flexion at the talocrural joint (7°). In typically developed individuals there were relatively smaller contributions (10 -11%) by foot deformation to changes in footplate angle, indicating that the contribution of talocrural angle changes to changes of gastrocnemius length was most important.

Using a new estimate for the talocrural joint angle (i.e. the difference between GM muscle–tendon complex length and tibia length, referred to as GM relative length) removed this effect, thus allowing more fair comparison of SCP and TD data. On the basis of analysis of foot plate angle and GM relative length as a function externally applied moments, it is concluded that foot plate angle measurements underestimate angular changes at the talocrural joint when moving in dorsal flexion direction and overestimates them when moving in plantar flexion direction, with concomitant effects on triceps surae lengths.

Conclusions: In SCP children diagnosed with decreased dorsal ROM of the ankle joint, the commonly used measure (i.e. range of foot plate angle), is not a good estimate of actual rotation at the talocrural joint. since a sizable part of the movement of the foot (or foot plate) derives from internal deformation of the foot. A further analysis of a more fair comparison of medial gastrocnemius muscle geometry is indicated.

NOVEL FUNCTIONAL KINEMATIC ANALYSIS FOR CLINICAL EVALUATION OF THE UPPER LIMB REACHING TASK IN SUBJECTS WITH NEUROLOGICAL DISORDERS: THE 5P TEST

Gaffurini P (2), Bissolotti L (1,2)
Rehabilitation Service, Casa di Cura Domus Salutis, Brescia, Italy(1); LARIN: Neuromuscular and Adapted Physical Activity Laboratory, Brescia, Italy(2)

Main topics: Reliability and service development; Rehabilitation

INTRODUCTION and AIM

Neurological diseases as stroke, SCI, PD or MS often bring to a relevant impairment of the upper limb dexterity and function with limitations to the performance of basic activities of daily living. In clinical setting the best possible precise evaluation of functional performance is a common issue for patients with neurological disorders. We present a practical methodology for the objective, qualitative and quantitative evaluation of the upper limb motion during the simulation of a multiple reaching task test while sitting (named: 5Points Test).

METHODS

A new functional test was designed to carry out kinematic analysis of the upper extremity motion during a repetitive reaching task through data acquired by a two optoelectronic cameras system (SMART DX BTS Group, Milan, Italy). A plexiglass board (120cmx80cm) was used to place seven different reflective markers on a semicircular track in front of the patient. In this way, the 180° arch was divided in 6 sectors of 30° (Fig.1). In the aim not to cover the seven reflective markers the patient was asked to reach different targets that were placed before than the marker. Patient was placed in a sitting position with knee placed at 90° of flexion and table height was adjusted to let the elbow at 90° of flexion whit the hand palm placed on the starting position on the selected position on the board. Differently than previous upper extremity models, the present protocol allows the analysis of the reaching motion in different directions, which we consider relevant to test upper limb function in conditions similar to the one of daily life activities. The dedicated kinematic analysis for this particular test allows the clinician to collect data about speed of motion, precision of movement, ability to explore the space, trunk compensation and sense of joint repositioning. The dataset of measurements provides information for clinicians to achieve a better understanding of the upper extremity motion in pathological cases, comprising patients with cognitive impairment such as neglect.

DISCUSSION AND CONCLUSION

Limits of the study: the selected protocol offers a global evaluation of upper limb performance but does not allow the correct discrimination of shoulder and elbow contribution during the test. Strengths of the study: in our opinion the kinematic analysis protocol and the global testing procedure and set up can be considered as a highly cost effective procedure to provide a quick and multidimensional evaluation for patients affected by many neurological diseases. The use of a two optoelectronic cameras and the reduced number of markers used during the test provides a better accessibility to this technology to a higher number of rehabilitation centers and clinicians. the present functional test is intended to allow a cost-effective and clinically feasible global evaluation of kinematic parameters of upper limb. The absence of a discriminative analysis of the different rigid segments is compensated by the amount of objective data that can be obtained in a standard clinical setting just only with two optoelectronic cameras.

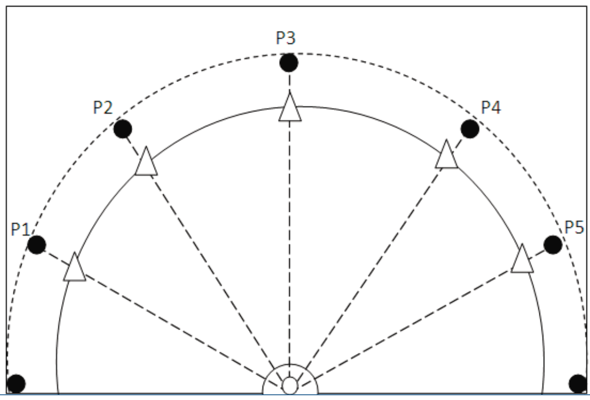

Fig.1: the figure depicts the features of the plexiglass board and the different directions used during the test

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MONITORING PHYSICAL ACTIVITY OF CHILDREN WITH CEREBRAL PALSY: DOES VELOCITY INCREASE SPASTICITY?

M Iosa, D Morelli, L Muzzioli, A Savina, A Di Florio, S Paolucci, F Cincotti
Santa Lucia Foundation I.R.C.C.S., Rome, Italy

Main topics: Analysis of gait and motor disorders, Functional outcome measures in mobility, Rehabilitation

INTRODUCTION and AIM

Cerebral palsy (CP) is the most common cause of physical disability in childhood. It is a neurodevelopmental disorder caused by nonprogressive lesions in the immature brain causing sensorimotor and cognitive impairments, implying the failure to acquire physiologic locomotor schemas [1].. One of the most common type of CP is spastic cerebral palsy. Spasticity has been defined as a velocity dependent increase in tonic stretch reflexes with exaggerated tendon jerks [2]. In literature, there is a gap: many studies reported the benefit of physical activities for children with cerebral palsy, including sports, especially for increasing their social participation. On the other hand the velocity-dependency of spasticity suggested caution in increasing the motor activities of children with CP.

Furthermore, a previous study of our group surprising reported that during running, the harmony of anteroposterior movements of children with CP was even more similar to that of children with typical development (TD) than during walking [3]. We hypothesized that running and spasticity could be based on common primitives related to an ancestral neural networks. The main limitation of that study was the absence of electromyographic measures.

The aim of the present study was to investigate the muscular activity of gastrocnemious during running and walking of children with cerebral palsy using a physical activity monitoring tool developed in the framework of the European Project ABC (EU-Project 287774).

PATIENTS/MATERIALS and METHODS

Ten children with clinical diagnosis of CP (mean age: 7.4±2.4 years, 4 right and 6 left hemiplegia) and ten children with TD (mean age: 9.5±1.1 years) were enrolled in this study. The physical activity monitoring tool was formed by 5 wearable sensors, attached to the skin of children in correspondence of both forearms, of back (L2-L3) and of gastrocnemious muscles. Each sensor allowed for measuring muscular activity and triaxial acceleration. The protocol was formed by: an initial rest phase (baseline, 30s), walking for 5 times along a walking linear patway of 10m, second rest phase (sitting, 30s), running for 5 times along the 10m pathway, final rest phase (sitting, 30s). The Ashworth scale has also been administered for clinically assessing spasticity.

RESULTS

A repeated measure analysis of variance showed as in group of children with CP the EMG-activity recorded for gastrocnemious muscle of paretic side was not significantly different between the three rest phases (F= 1.339, p=0.287), despite the higher activity observed during running and walking in respect of the initial rest (F=5.188, p=0.017). These results are in line with those obtained by an analysis performed on both limbs of children with typical development, in which the differences among the three rest phases did not result statistically significant (F=0.504, p=0.608). Further, all the children with CP, but one, did not show any change into the Ashworth score assessed during rest phase after running in respect of baseline.

DISCUSSION and CONCLUSIONS

After running, the muscular tone of gastrocnemious of children with CP returned at the baseline level without any statistically significant increment due to the intense activity. These results should be considered as preliminary, especially because further studies are needed for investigating if long-time intense training could have a negative long-term effect on spasticity. However, our results suggest the absence of a short-term effect of running on spasticity.

ACKWONLEDGMENTS

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THE EFFECT OF FUR INSOLE ON PLANTAR PRESSURE DISTRIBUTION OF YOUNG LADIES DURING NORMAL WALKING

Shiyang Yan (1,2), Luming Yang (1,2), Suofang Li (1), Jun Zhou(1)
(1) National Engineering Laboratory for Clean Technology of Leather Manufacture, Chengdu, 610065, China
(2) Key Laboratory of Leather Chemistry and Engineering (Sichuan University), Chengdu, 610065, China

Main topics:
Analysis of clinical movement data
Experimental studies in human movement science
Reliability and service development

INTRODUCTION and AIM

As we all know, fur derived from thousands of years ago, which is the first covering of human beings to keep warm and protect themselves. With the time-based development, fur has been evolved into many aspects, such as clothing, rug, shoe, even cosmetic and health-care equipment. Fur is used in shoe-making for beauty and warm, especially in snow boot. According to the experiment with respect to snow boot before, we have supposed that the fur insole has the pressure dispersing effect on the plantar pressure. So the purpose of this study is to demonstrate our hypothesis with scientific research. The aim of this study is to support the improvement of fur product and applications of fur to health-care field.

PATIENTS/MATERIALS and METHODS

The data of plantar dynamic pressures were collected from 17 women (21 ± 3 years) without pathology; they were recruited from Sichuan University. Each participant was required to walk at custom speed by wearing normal insoles and fur insoles respectively. Pedar-X system (Novel GmbH, Munich, Germany) was used to collect data; eight anatomical masks were defined by an available toolbox. All data were statistically analysed by SPSS 17.0 and Microsoft Excel.

RESULTS

The result shows that the max pressures in condition 1 greater than condition 2 in all anatomical areas, except for the values of medial heel and lateral heel, although they are found to be very close in conditions 1 and 2, the values are still a little greater in condition 2. According to the paired t-test result, comparison of two conditions has significant differences in toe 2-5, midmeta, lateralmeta and midfoot areas.

DISCUSSION and CONCLUSIONS

Although the max pressures of wearing fur soles in medial heel and lateral heel areas were greater than wearing normal insoles, no significant differences were found in two conditions, which could be explained by the fact that the midmeta, medial heel and lateral heel are the most pressure distributed areas, which is based on domestic researches [1-2]. However, in previous researches, Kernozek et al. [3] showed that the maximum toe beared the most pressure of the body in young adults, which may due to the different life style and walking habits in different continents [1]. So it is noted that this study is applying for Chinese only. As a result, when participants wore fur insole, it gave a obvious pressure relief in midmeta and lateralmeta. But due to the data deficiency, more samples are needed in the further research.

Table 1: Comparison of max pressure (KPa) in two conditions

Mask	Max pressure (KPa) Condition A	Max pressure (KPa) Condition B	P-value
toe1	177.21 ± 63.21	175.45 ± 90.46	0.902
toe2-5	100.15 ± 41.12	90.11 ± 30.90	0.024
medialmeta	158.24 ± 39.20	151.52 ± 32.68	0.329
midmeta	221.06 ± 51.22	208.21 ± 44.29	0.033
lateralmeta	172.47 ± 30.82	151.78 ± 31.90	0.007
midfoot	67.53 ± 9.38	59.74 ± 8.57	0.000
medial heel	220.26 ± 41.86	221.02 ± 42.03	0.899
lateral heel	193.65 ± 35.12	201.47 ± 38.91	0.406

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DYNAMICAL ASYMMETRY INDEX IN PATIENTS AFTER UNILATERAL TOTAL HIP REPLACEMENT

S. Winiarski (1), K. Aleksandrowicz (2)
(1) Biomechanics Department, University School of Physical Education, Wroclaw, Poland
(2) Department of Physiotherapy, Wroclaw Medical University, Wroclaw, Poland

INTRODUCTION and AIM

In movement analysis different gait pathology indexes are taken into account which include e.i. symmetry indexes [1,2], symmetry ratio [3], gait spectral index [4], normalcy index or gait deviation index [5,6] and are best suitable for the discrete set of gait variables. The purpose of this article is to propose a new method for assessing the asymmetry by using the dynamical asymmetry index (DAI) in patients after unilateral total hip replacement (UTHR). On this occasion we raised following research questions: (1) whether the DAI used in the study is a good indicator of asymmetry found throughout the entire range of motion of the lower limbs and (2) whether the DAI's rate of change (DAI Rate) is a quantitative measure of the speed of change of symmetry.

PATIENTS/MATERIALS and METHODS

Thirty two (32) patients after UTHR took part in the experiment. Biomechanical assessment involved measurements of spatiotemporal gait parameters and the dynamic range of motion using BTS Smart-E motion analysis system. We used a variant of the asymmetry coefficient [1,3] modified for the angular movements of the limbs' joints. This dynamical asymmetry index (DAI) expresses the percentage difference between the angles of the patients left AL(t) and right AR(t) lower limbs during the cyclical variation of movement, using the (1) formula. Normalization of the variation between the right and left angles relative to the duration of the cycle was performed numerically by the decomposition of a time series (trend detection) using the Lagrange interpolation polynomial as a function of the user. The DAI's rate of change (DAI Rate) was calculated numerically using the (2) formula, where DAI(ti+1) is the value of the dynamical asymmetry index for time ti+1, DAI(ti) is the value of the dynamical asymmetry index for time ti, where i is a number in the normalized interval.

$$DAI(t) = \frac{A_L(t) - A_R(t)}{\frac{1}{2} \cdot [A_L(t) + A_R(t)]} \cdot 100\% \qquad (1)$$

$$DAI \;\; Rate\,(t) = \frac{DAI\,(t_{i+1}) - DAI\,(t_i)}{t_{i+1} - t_i} \qquad (2)$$

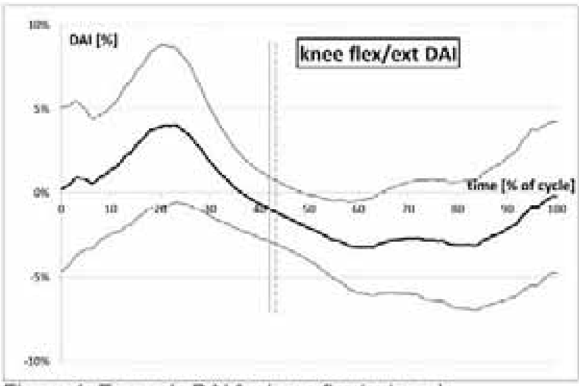

Figure 1: Example DAI for knee flex/ext angle.

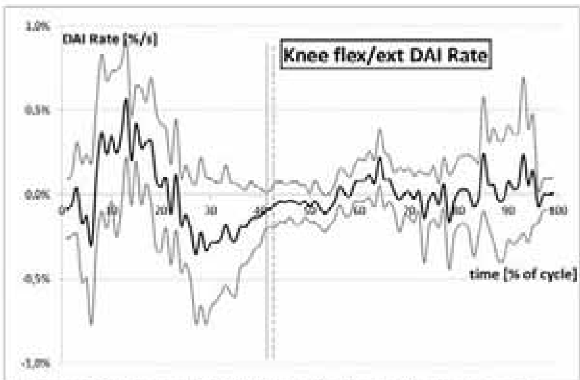

Figure 2: Example DAI Rate for knee flex/ext angle.

RESULTS

Results of DAI and DAI Rate for example knee flexion/extension angles are presented in Fig.1 and Fig.2.

DISCUSSION and CONCLUSIONS

The use of the DAI is considered to be advantageous over asymmetry coefficients used earlier, as it not only evaluates the magnitude of the asymmetry, but also indicates in which phases of movement is asymmetry the greatest/lowest. The DAI is a function of time and requires cyclical variation of the right and left angles during an equal duration of time. DAI is especially dedicated to angular, time variables. The rate of change of the DAI Rate accurately describes the changes of the DAI. For example, a DAI Rate equal to 0 indicates stability in the DAI, a positive/negative - points to the rate at which asymmetry increases/decreases in whole range of motion.

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COMPARING THE EFFECT OF A DORSAL-LEAF-SPRING AFO AND A SPRING-HINGED AFO ON GAIT CHARACTERISTICS IN PLANTARFLEXOR WEAKNESS – A PILOT STUDY

H.E. Ploeger, M.A. Brehm, S.A. Bus, F. Nollet
Department of Rehabilitation Medicine, Academic Medical Center, Amsterdam, The Netherlands
Main topics: Orthotics, Analysis of clinical movement data

INTRODUCTION and AIM

For polio patients with weak plantarflexors, a carbon-fibre ankle-foot orthosis (AFO) can be provided to improve stability by counteracting excessive ankle dorsiflexion, and reduce walking energy cost (EC) by taking over ankle work [1,2]. For this, two types of AFOs can be used: a dorsal-leaf-spring-AFO (DLS-AFO) or a spring-hinged-AFO (SH-AFO). The advantage of the SH-AFO is that stiffness and range-of-motion (ROM) can be adjusted independently towards plantar- and dorsiflexion, which is not possible in the DLS-AFO. Thus the SH-AFO might better allow plantarflexion in the loading response. However, the highest spring stiffness available for the SH-AFO is much lower than that available for the DLS-AFO. It is unknown how this will affect gait in flaccid paresis. In this pilot study we compared the effect of a DLS-AFO and a SH-AFO, both with various stiffness, on gait biomechanics, walking EC and satisfaction in a polio survivor with plantarflexor weakness.

PATIENTS/MATERIALS and METHODS

One polio survivor (58 years) with unilateral plantarflexor weakness (MRC 3) participated. For this patient, a DLS-AFO with five carbon springs (stiffness range: 0.8-7.3Nm/deg) and a SH-AFO with NeuroSwing® hinge with five springs (stiffness range: 0.1-2.3Nm/deg) were custom-made. Gait biomechanics were assessed for 2x5 AFO conditions (k_1-k_5) and for a shoes-only condition. After each condition, satisfaction was rated with a visual analogue scale. Subsequently, walking EC was assessed during a 6-minute walk test for 2x3 AFO conditions (compliant, moderate, stiff) and for shoes-only.

RESULTS

The SH-AFO allowed on average 7±1° plantarflexion in loading response, while plantarflexion with the DLS-AFO reduced from 7° to 3° with increasing stiffness (Figure 1). Compared to shoes-only (17°), all springs in both AFOs reduced ankle dorsiflexion ROM, which reduced with increasing stiffness (k_1-k_5: SH-AFO 12-6°, DLS-AFO 13-9°, Figure 1). Regarding walking EC (Figure 2), a similar pattern was seen for both AFOs, where walking with a moderate stiffness reduced EC the most (SH-AFO-k_4: -21%, DLS-AFO-k_3: -16%). The patient rated the SH-AFO-k_2 (0.3 Nm/deg) as most satisfying to walk with.

DISCUSSION and CONCLUSIONS

The advantage of the SH-AFO, as opposed to the DLS-AFO, is that plantarflexion in loading response did not reduce, which may prevent increased tibia progression at this stage. Furthermore, even with the most compliant spring, the SH-AFO improved gait characteristics. Regarding walking EC, we saw a similar pattern for both AFOs, despite large differences in stiffness levels. Results seem to imply that optimal spring stiffness is AFO-type dependent and that other properties, such as ROM, also impact on the effectiveness.

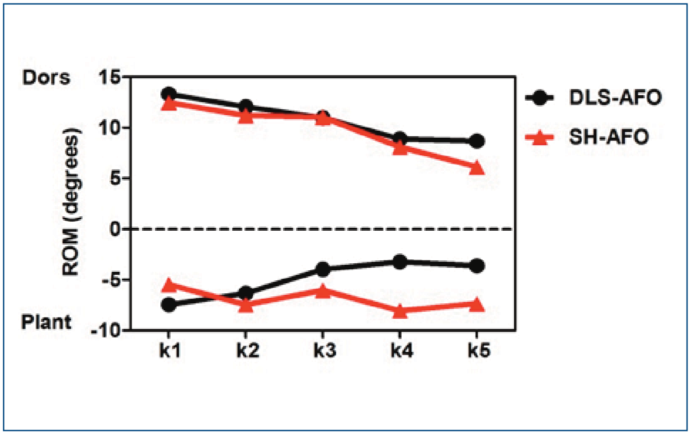

Figure 1: Ankle dorsiflexion (dors) and plantarflexion (plant) range of motion (ROM) relative to the ankle angle at initial contact for five dorsal leaf spring AFO (DLS-AFO) and five spring-hinged AFO (SH-AFO) conditions. ROM reduction is favourable for dorsiflexion, but not for plantarflexion.

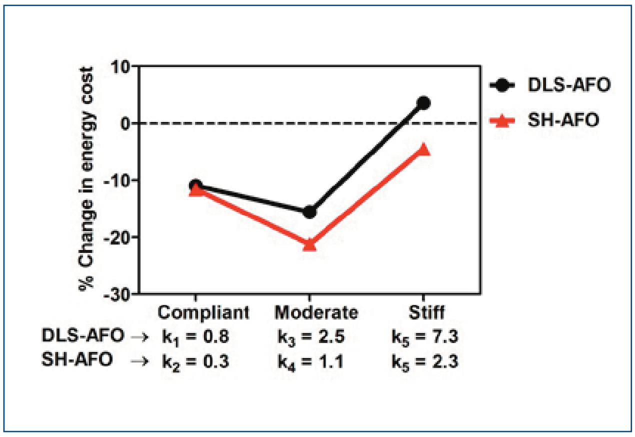

Figure 2: Walking EC as a percentage change compared to walking on shoes-only for three dorsal leaf spring AFO (DLS-AFO) and three spring-hinged AFO (SH-AFO) conditions. Negative values represent improvement. Spring stiffness (k) is in Nm/deg.

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CHANGES IN GAIT FOLLOWING TAPPING OF CEREBROSPINAL FLUID FOR THE ASSESSMENT OF NORMAL PRESSURE HYDROCEPHALUS

DS. Speciali (1), MMB. Bernal (1), W. Godoy (1), SS. Lacerda (1), AM. Kernkraut (1), AM.Vacari (1), I. Hideyo (1), CC. Tanuri (1), PRG. Lucareli (2)

(1) Hospital Israelita Albert Einstein, São Paulo, Brazil
(2) Universidade Nove de Julho, São Paulo, Brazil

INTRODUCTION and AIM

Idiopathic Normal Pressure Hydrocephalus (iNPH) is a syndrome consisting of chronic ventricular dilation, normal cerebrospinal fluid (CSF) pressure and the symptomatic triad of dementia, gait dysfunction and urinary incontinence. Gait disturbance are usually the initial sign and most important symptom, but its objective evaluation has not been established. The tap test (TT) is commonly used to prognosticate shunt responsiveness. Clinical improvement following TT is one of the few established prognostic indicators of a positive response to shunting in patients with iNPH. The aim of this study was to use the Gait Deviation Index (GDI) and spatiotemporal parameters to analyses changes in gait following tapping of cerebrospinal fluid.

PATIENTS/MATERIALS and METHODS

Fifty-two patients with Idiopathic Normal Pressure Hydrocephalus (34 male and 18 female) participated in this study. The gait assessment was conducted using three-dimensional kinematics (VICON®) pre- and pos-tap test. The label of the markers and the processing of the biomechanical model to obtain kinematic data were performed using Vicon Nexus® software and the Plug in Gait® model. The kinematic data were imported into a spreadsheet, where a mathematical routine was used to calculate the GDI and spatiotemporal parameters. The data were analyzed using paired t-student test with the level of statistical significance set at $p < 0.05$.

RESULTS

The mean of the spatiotemporal parameters and GDI are summarized in Table 1. Statistically significant differences were found pre- and pos-tap test for velocity ($p<0.001$) and stride length ($p<0.001$). No statistically significant difference was found for cadence, stance phase, and GDI pre-and pos-tap test.

DISCUSSION and CONCLUSIONS

The results of this study demonstrate that gait velocity and stride length are features most likely to change following TT. Our results provide a quantitative measure of the changes in gait pattern of pre and post tap test. The GDI was not a sensitive tool to show change in gait pattern of patients with iHPN.

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Table 1: The spatiotemporal parameters and GDI pre and pos tap test

	Cadence		Velocity		Stride Length		Stance Phase		GDI	
	Left Side	Right Side	Left Side	Right Side	Left Side	Right Side	Left Side	Right Side	Left Side	Right Side
Pre-TT	106.7 (111.48)	122.36 (155.53)	0.56 (0.21)	0.56 (0.21)	0.36 (0.11)	0.36 (0.12)	36.71 (43.23)	37.15 (42.24)	68.16 (12.14)	66.99 (13.13)
Pos-TT	94.92 (15.06)	92.70 (19.15)	0.61 (0.23)*	0.61 (0.23)*	0.38 (0.12)*	0.38 (0.13)*	31.51 (4.51)	32.17 (4.35)	69.12 (11.27)	67.12 (13.00)

TT = tap test. * Significance statistical p<0.001

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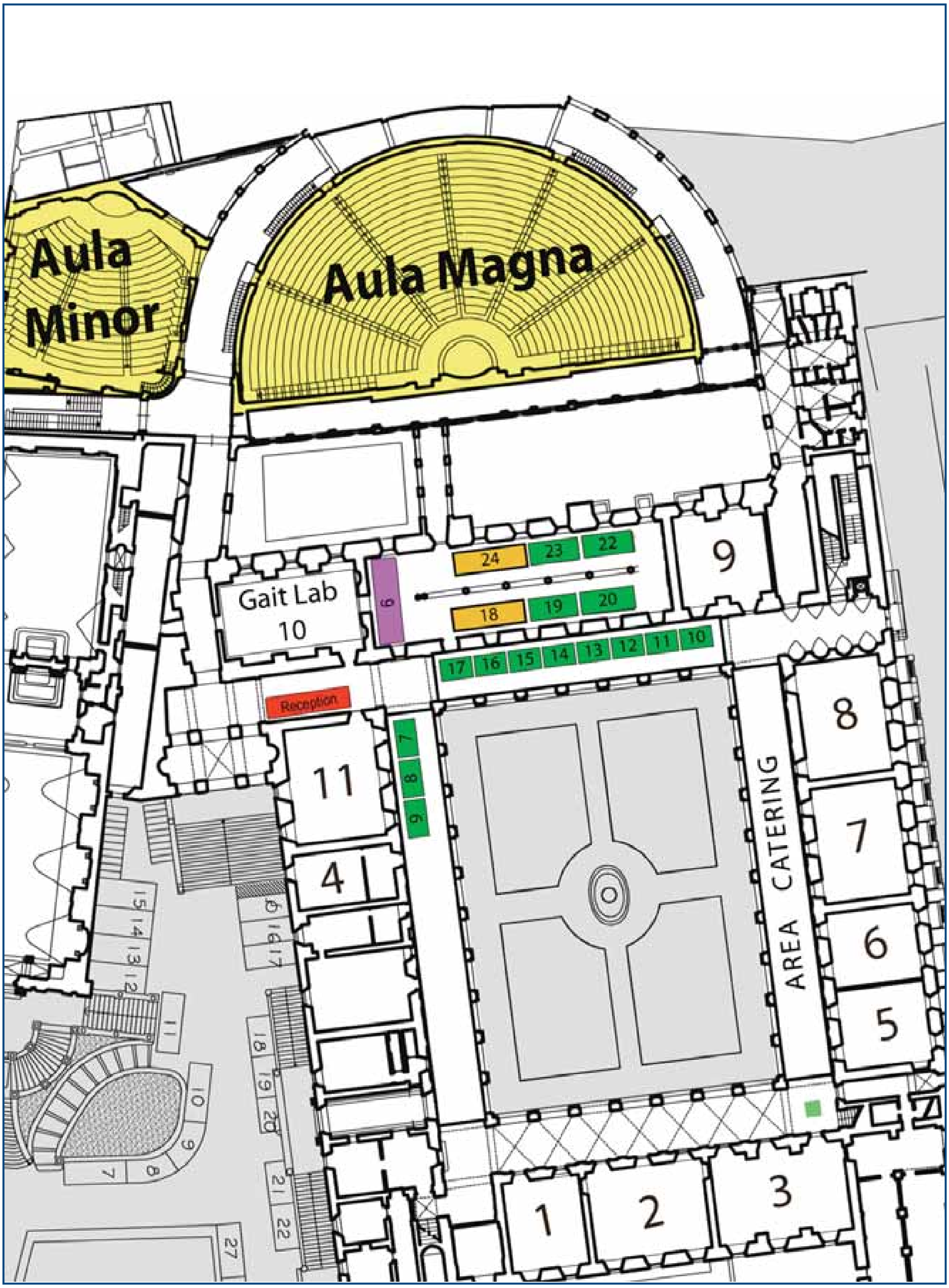
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