Predicting Gross Motor Function Classification System Level From Patient-Reported Functional Abilities

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Introduction: The Gross Motor Function Classification System (GMFCS) is ubiquitous in cerebral palsy (CP) clinical practice and research. The classification is compact, requiring only five cartoons and short descriptions [1]. Traditionally, the GMFCS level is assigned by a health-care provider, though the extended and revised (E&R) version allows for parent rating. The GMFCS has “a particular emphasis on sitting, walking, and wheeled mobility”. We were interested in finding out how the GMFCS was related to a more comprehensive interpretation of “function”, such as the patient/parent-reported Gillette Functional Assessment Questionnaire (FAQ) [2].

Research Questions: Can the GMFCS be determined from the ratings of walking and 22 higher-level functional skills contained in the FAQ? How well do the GMFCS level descriptions reflect functional ability across a wide range of activities?

Methods: Our database was queried to find all patient visits with both a therapist-assigned GMFCS rating (I-IV) and patient/parent-report FAQ scores. The data were divided into a training set (75%) and an independent test set (25%). The random forest was used to predict GMFCS based on patient/parent rating of overall walking ability and 22 higher-level functional skills in the FAQ [3].

Results: The full data set consisted of 6620 observations, and the test set 1614 observations. Accuracy of the model on the test set was 90% [Figure 1]. The true positive rate (TPR) ranged from 89% to 92%, and positive predictive value (PPV) ranged from 86% to 93%. The rate of misclassification by more than one level was exceptionally low (0.3%).

Many self-reported functional abilities from the FAQ did not conform to the GMFCS descriptions. As an example, consider running. According to the description of level II “Children have only minimal ability to perform gross motor skills such as running and jumping”. However, In our sample, 19% of GMFCS level II children reported running to be “easy”, 40% described it as “a little hard”, while 24% found it “very hard”, and 17% couldn’t run at all. Among GMFCS III children, 10% reported running as “easy”, 21% as “a little hard”, 20% as “very hard”, and 49% couldn’t run at all. There were similar disconnects between other self-reported functional activities (jumping, stair climbing, etc…) and the GMFCS description.

Discussion: We have developed an algorithm that can accurately predict GMFCS level from patient/parent-reported functional activity. This model has a variety of uses. In cases where FAQ data are available, a valid and unbiased GMFCS level can be determined based on patient/parent-report. The GMFCS E&R also includes an option for parent report, but still relies on the terse description and cartoons, which may not fully capture the richness of patients’ functional lives. The algorithm can also be useful for retrospective data analysis, since, in some centers, use of the FAQ may have pre-dated use of the GMFCS. The algorithm reveals stark disagreements between patient/parent-reported functional ability and the GMFCS description. This likely arises from the attempt to arbitrarily lump exceptionally diverse individuals into five bins. An intriguing consequence of the algorithm is that it reports both the most suitable GMFCS level, as well as the probability that a patient belongs to each of the four ambulatory GMFCS

<table>
<thead>
<tr>
<th>Predicted</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>TPR</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>432</td>
<td>38</td>
<td>1</td>
<td>0</td>
<td>92%</td>
</tr>
<tr>
<td>II</td>
<td>32</td>
<td>504</td>
<td>24</td>
<td>0</td>
<td>90%</td>
</tr>
<tr>
<td>III</td>
<td>1</td>
<td>39</td>
<td>407</td>
<td>12</td>
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<td>3</td>
<td>11</td>
<td>110</td>
<td></td>
</tr>
</tbody>
</table>

PPV 93% 86% 92% 90% 1614

Figure 1. Performance of the classifier
levels. Thus, an individual may be classified as a [40% 50% 10% 0%] for levels [I II III IV], thus giving a more complete picture of the patient’s overall functional ability. Such a scheme may also pave the way for transition from an ordinal GMFCS to a rational scale version, which would be useful in many research applications.

Cluster analysis to identify foot motion patterns in children with flexible flatfeet – A statistical approach to detect decompensated pathology

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Introduction: The pediatric flexible flatfoot (figure) constitutes the major cause of clinic visits for pediatric foot problems [1]. It is a complex deformity in all three planes and its treatment is widely discussed [1]. Hence there is a strong need for classification which may provide indication for treatments. Few approaches have been developed to differentiate subgroups among flexible flatfeet. Bourdet et al.[2] have classified 4 subgroups using static radiographs. Concerning their dynamic function, gait analysis may provide a more reasonable method to discriminate flatfeet into different groups.

Research Question: The aim of this study was to classify motion patterns among idiopathic flexible flatfeet using threedimensional foot motion data during walking.

Methods: 96 children (192 feet) with clinically diagnosed idiopathic flexible flatfoot between 5 and 17 years were retrospectively included from the database of the gait laboratory. Excluded were syndomal or neuromuscular abnormalities, previous surgeries or tarsal coalition. The Oxford Foot Model (figure) kinematic data was used in order to identify subgroups within flexible flatfeet. Four linear independent angular parameters that were previously shown to be discriminative between flatfeet and typical developing feet were chosen as input for the cluster analysis [3]: 1. peak rearfoot-forefoot dorsiflexion in stance 2. peak rearfoot-tibia eversion in stance, 3. peak rearfoot inversion at push off, 4. mean rearfoot-forefoot abduction in stance. The appropriate number of clusters was evaluated by the hierarchical ward method [4]. The k-means clustering technique was then applied to discriminate patients into the different subgroups [5]. To show the clinical relevance, the number of surgical treatments subsequent to gait analysis was reported for each cluster.

Results: Cluster analysis revealed two distinctive flatfoot patterns. Cluster 1 (98 feet) was characterized by achieving hindfoot inversion in late stance and only mild increased peak midfoot dorsiflexion and peak hindfoot evasion. Cluster 2 (94 feet) was characterized by increased dorsiflexion in the midfoot (sagittal), excessive hindfoot eversion (frontal) and forefoot abduction (transversal). Regarding treatment decisions for cluster 1 and 2, 12 of 98 and 57 of 94 feet received arthroereisis, and 4 of 98 and 19 of 94 tarsal osteotomies.

Discussion: Cluster analysis discriminated two groups in flatfeet, which appear to be different regarding their severity and number of treatments. Cluster 2 had more severe hindfoot eversion and did not achieve inversion during walking, the midfoot was more bent and the forefoot was considerably abducted. This suggests that feet in cluster 2 can be considered as decompensated and requires treatment. This was confirmed with the higher number of interventions performed in
cluster 2. For clinical practice, to distinguish patients between both clusters, logistic regression was applied to all patients. This revealed that peak rearfoot inversion at push-off was the most important discriminator that with every degree of rearfoot inversion, the probability diminishes by 80% to be part of the decompensated patient cluster 2.

References:
Ground reaction force measurements for gait classification tasks: Effects of different PCA-based representations

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Introduction: Representations of gait measurements based on principal component analysis (PCA) are among the most successful parametrization techniques in gait classification tasks [e.g. 1, 2]. Compared to solely using discrete parameters, PCA offers a more holistic approach. However, there is no standard process for the computation of such representations so far. In fact, scientific literature differs fundamentally in the arrangement of the employed data and the PCA decomposition method (e.g. linear vs. kernel). Therefore, the aim of this study is to compare different approaches for the derivation of PCA-based representations of ground reaction forces (GRF) and to evaluate their strengths and weaknesses for gait classification.

Research Question: What is a best practice for the computation of PCA-based ground reaction force representations for human gait classification?

Methods: Gait analysis data from a clinical database were used retrospectively. The database comprises GRF measurements from 279 patients with gait disorders (GD) and data from 161 healthy controls (H), both of various physical composition and gender. Patients were manually classified into four categories, namely a calcaneus (n = 82), ankle (n = 62), knee (n = 69), and hip (n = 66) category. These categories include patients after joint replacement surgery, fractures, ligament ruptures, or related disorders associated with the above-mentioned areas. Bilateral GRF and center of pressure (COP) data were recorded at self-selected walking speed using two force plates. Data were sampled at 2000 Hz and time-normalized to 100% stance. Feature extraction was performed on four different arrangements of the data: (a) PCA of the three components of the GRF of the affected limb (GRFa); (b) PCA of the GRFa with additional COP signals (GRFa+COPa); (c) PCA of the combined GRF for the affected and unaffected limb (GRFa+GRFu); and (d) kernel PCA (KPCA, polynomial kernel) of the GRFa. For this purpose, three data preprocessing types were employed: (i) concatenation of the raw waveforms (e.g. in right Figure) before they were input to a PCA (early fusion), (ii) multiple PCAs of the single waveforms, with concatenation of the resulting principal components (late fusion), and (iii) PCA of commonly used discrete parameters. Resulting principle components retaining 98% of the total variance were then used to train a support vector machine (SVM) for classification of the H vs. GD and H vs. all categories. For the SVM a radial basis function kernel (RBF) and hyper-parameter selection via a grid search were employed. The SVM was trained on a randomly selected data set (65%) and accuracy was evaluated (left Figure) on the remaining data.

Results:
Discussion: An acceptable level of accuracy was reached for the first classification task. The multivariate task was more difficult to solve due to its complexity, thus resulting in lower accuracy. The KPCA seems slightly advantageous in the multivariate task compared to the traditional PCA of the GRFs, but only when entire waveforms are used. The input of the entire waveforms to the PCA compared to the sole use of discrete parameters generally seems to increase classification accuracy. Late fusion outperformed early fusion, and the use of COP signals improved accuracy, while including the unaffected limb’s GRF had no impact. These data may serve as a guide for future work dealing with GRF for human gait classification.

Cavovarus foot correction normalizes knee and hip abnormalities in Charcot-Marie-Tooth disease

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Introduction:

Cavovarus foot deformity (CFD) is typical in patients suffering from Charcot-Marie-Tooth disease (CMT), the most frequent hereditary neurological disorder. Selective muscular atrophy of the foot and shank is followed by progressive bony deformity, flexible in the beginning may result in severe fixed pes cavovarus. Previous research showed that kinematics of the foot significantly improve after operative treatment of the CFD (Dreher et al., 2014) but also need to be applied thoughtfully regarding to the underlying biomechanical conditions (Beckmann et al., 2015). Gait deviations in patients with CFD may also be associated with alterations in transverse plane kinetics and kinematics (Newman et al., 2007, Ferrarin et al., 2012), in terms of altered knee and hip rotation moments and supposed instability of the knee and patella.

Research Question:

Does combined operative bony and soft-tissue correction of the CFD have an impact on kinetics and kinematics of the ankle, knee and hip?

Methods:

We examined 24 patients with CMT and bilateral CFD before and after foot reconstruction surgery including a standardized protocol of bony and soft-tissue procedures. In all cases both conventional plug-in-gait analysis and the Heidelberg Foot Measurement Method were used to determine the sagittal, frontal and transverse plane kinematics and kinetics. Comparisons were done using descriptive statistics and linear mixed models to analyze the postoperative change. A p-value of 0.05 was used as cutoff for significance.

Results:

3D gait analysis revealed significant reduction in hip abduction and external rotation of the hip and ankle during the stance phase after surgery. These changes were accompanied by significant alterations in the hip kinetics. Transverse plane hip rotation moment normalized significantly. Frontal plane hip and ankle abduction moments normalized postoperatively within the standard deviation of the mean normal reference.

Discussion:

CFD has an impact on the biomechanical integrity of the hip. Operative procedures of the CFD not only improve foot kinematics but also have a significant impact on the kinematics and kinetics of the knee and hip. External rotation of the hip and its kinetics normalized significantly. Frontal plane hip and ankle kinetics improved. This investigation shows the multi-level and multi-plane impact of bony and soft tissue correction on gait in patients with CFD in CMT. As long as those secondary abnormalities are not fixed they can be expected to vanish after foot reconstruction.

References:

1. Beckmann, J Foot Ankle Research 2015; 8(65):1-7
Perturbation treadmill training improves clinical rating of the motor symptoms gait and postural stability, and sensor-based gait parameters in Parkinson's disease

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Introduction: Impaired gait and postural stability are cardinal motor symptoms in Parkinson's disease (PD), substantially increase risk of falling, and reduce quality of life [1]. Treadmill training improves gait speed and stride length in PD [2], and might support gait and balance rehabilitation in PD by improving dynamic postural control. In the present study, we investigate a novel form of treadmill training by adding perturbative stimulations to the treadmill surface during walking [3].

Research Question: The aim of this registered, single-blind randomized controlled trial (ClinicalTrials.gov: NCT01856244) was to investigate the effect of an 8 week perturbed treadmill training on the subjective clinical evaluation of the motor symptoms “gait” and “postural stability” in PD. In addition, it was evaluated whether objective spatio-temporal gait parameters recorded by inertial sensor-based gait analysis are able to complement clinical information. Additional functional gait and balance outcomes are presented in a separate publication.

Methods and patient characteristics: 43 PD patients were included and randomly allocated to either the experimental group (perturbation treadmill training, PTT, n=21) or a control group (conventional treadmill training, CTT, n=22). Perturbation during treadmill walking was induced by a prototypical treadmill device consisting of a standard medical treadmill (mercury, h/p/cosmos medical GmbH) fixed on a platform with tilt option (zebris Medical GmbH). The platform allows three-dimensional tilting movements induced by three pneumatic actuators with a lifting capacity up to 30 mm. PD patients were secured with a safety harness and performed 16 sessions of 40 minutes treadmill intervention (8 weeks, twice per week). Outcome measures were collected at baseline, after 8 weeks of intervention, and at a 3 months follow-up visit. Clinical motor assessment comprised the Unified Parkinson Disease Rating Scale part III (UPDRS-III), the UPDRS-III subscores “gait” and “postural stability”, and Hoehn and Yahr disease staging (H&Y). Spatio-temporal gait parameters were assessed using a mobile gait analysis system consisting of accelerometers and gyroscopes laterally fixed to shoes [4, 5]. Statistical analysis included within-group effects during intervention (Wilcoxon-Test), and between-group effects of delta values between time points (Mann-Whitney-U-Test). Baseline characteristics including age, gender, height, weight, disease duration, H&Y disease stage, UPDRS-III, medication, and cognition did not significantly differ between groups. Medication was stable and did not differ between groups during the intervention program.

Results: After 8 weeks of intervention, motor symptoms rated by UPDRS-III (P=0.001; Effect size Cohen’s d=−1.09), UPDRS-III subscores gait (P=0.023; d=−0.63) and postural stability (P=0.008; d=−0.78), and H&Y disease staging (P=0.001; d=−1.01) significantly improved in the PTT group (within-group comparison), whereas in the CTT group only H&Y disease staging improved (P=0.025; d=−0.55). However, a significant between-group effect of delta values to the benefit of the PTT group in the small cohort was not observed. Swing time variability improved only in the PTT group whereas it worsened in the CTT group (between-group effect: P=0.019; d=−0.58). At 3 months follow-up, within-group effects for UPDRS-III, gait, postural stability, and H&Y persisted only in the PTT group (compared to baseline). Gait parameters were comparable to baseline and did not show differences between groups at the follow-up visit.

Discussion: In this study we observed that 8 weeks of perturbed treadmill training improved clinical relevant motor symptoms gait and postural stability which was not present in the group receiving treadmill training without perturbation. Although the clinical score improvement in the
PTT group could not reach statistical significance in comparison to CTT in the small cohort, objective, sensor-based gait parameters “swing time variability” improved in PTT only and reached significance between groups. These findings suggest that objective assessment of the regularity of gait is a sensitive parameter complementing clinical assessments for monitoring postural gait control during treadmill therapy in PD.

Using medical imaging to define the medial-lateral axis of the femur led to significantly different hip rotation kinematics in children with torsional deformities

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Introduction: Kinematics and kinetics during gait are used to inform surgical decision making. For example, hip rotation kinematics are considered the key measurement to decide to perform a femoral derotational osteotomy, and to predict surgical outcomes [1]. However, the accuracy and reliability of hip rotation kinematics has been shown to be the least repeatable [2]. The accuracy of hip rotation kinematics depends on the accurate localisation of the medial-lateral axis of the femur. Conventional methods to localise the medial-lateral axis of the femur is through palpation of bony landmarks (the medial and lateral epicondyles), and define the axis from markers, or a Knee Alignment Device (KAD), over the landmarks. Functional calibration methods have also been derived because the medial-lateral axis of the femur determines the sagittal plane flexion-extension axis of the knee joint. Results on the efficacy of functional and conventional methods in the literature varies [3,4]. Furthermore, the methods have only been tested in healthy adults. There is no guarantee that results derived from healthy adult populations translate to clinical populations, especially children with torsional deformities, for which accurate hip rotation kinematics are paramount.

Research Question: What is the accuracy of conventional and functional methods to locate the medial-lateral axis of the femur in children with torsional deformities?

Methods: Following ethics approval, 20 children (8 with cerebral palsy, 11 with rotational malalignment and 1 with a genetic disorder) with torsional deformities (confirmed with CT medical imaging) and scheduled for 3D gait analysis were recruited to participate in the study. A registered physiotherapist with >5 years experience in gait analysis equipped the children with the standard PiG (VICON, UK) marker set, with additional skin markers on the thighs and shanks. The conventional model used the KAD, and the functional methods used the ATT or 2DoFKnee algorithms with flexion-extension and walking calibration movements [3,4]. The posterior aspect of the condyles were imaged with freehand 3D ultrasound [4] during a static standing trial to determine the location of the medial-lateral axis of the femur. Immediately after walking and without removing the skin markers, the children were transported to the EOS system (a standing low dose bi-plane x-ray system from EOS-imaging, France) to obtain the reference position of the femur and tibia coordinate systems [3], with respect to the skin markers.

The main result was the transverse plane angular difference between the various methods and the EOS benchmark. Statistical analysis used general linear statistical model and Tukey's post hoc tests. To estimate clinical significance, we calculated the proportion of the data more than ±2SD of the variability in hip rotation in our normative dataset from EOS benchmark.

Results: Both conventional and functional methods were significantly different from the EOS benchmark. Approximately 50% of the data were greater than +2SD of normal variability from the EOS benchmark. In contrast, freehand 3D ultrasound was only 1° different in average (NS, p=0.146) and all data were within 2SD of normal variability. As a result, hip rotation kinematics from the medical imaging based methods (EOS, freehand ultrasound) were almost identical whereas hip rotation kinematics from conventional and functional methods were significantly different.
<table>
<thead>
<tr>
<th>Method</th>
<th>Difference EOS from mean (SD)</th>
<th>Significance</th>
<th>Tukey Group</th>
<th>Proportion &gt;2SD</th>
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</thead>
<tbody>
<tr>
<td>3DUS</td>
<td>1° (4°)</td>
<td>NS, p=0.146</td>
<td>A</td>
<td>0%</td>
</tr>
<tr>
<td>ATT – Flexion</td>
<td>13° (10°)</td>
<td>S, p&lt;0.001</td>
<td>B</td>
<td>47%</td>
</tr>
<tr>
<td>ATT – Walk</td>
<td>13° (7°)</td>
<td>S, p&lt;0.001</td>
<td>B</td>
<td>50%</td>
</tr>
<tr>
<td>2DoFKnee – Flexion</td>
<td>14° (14°)</td>
<td>S, p&lt;0.001</td>
<td>B</td>
<td>57%</td>
</tr>
<tr>
<td>2DoFKnee – Walk</td>
<td>13° (9°)</td>
<td>S, p&lt;0.001</td>
<td>B</td>
<td>50%</td>
</tr>
</tbody>
</table>

**Discussion:** We found significant differences between medical imaging-based and conventional/functional methods to determine the medial-lateral axis of the femur. The use of medical imaging-based methods seems warranted given the importance of hip rotation kinematics for clinical decision making in children with torsional deformities.

The repeatability of stability outcome measures during treadmill walking in healthy controls and spinal cord injury patients

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Introduction: Balance control is essential for many activities of daily living and is defined by the ability to control the extrapolated centre of mass (XCoM) relative to the base of support (BoS). Dynamic balance is maintained by stabilizing the XCoM within the BoS [1]. During walking, the XCoM is not always within the BoS, which is natural and necessary for forward progression. Various stability outcome measures based on the CoM trajectory and BoS have been used to describe differences in balance control between healthy controls and patient groups that often have balance problems, such as stroke and spinal cord injury (SCI). To be useful for the evaluation of interventions, the repeatability of these stability outcome measures should be further investigated.

Research Question: What is the repeatability of six different stability outcome measures during treadmill walking in healthy controls and SCI patients?

Methods: Healthy controls (n=21) and patients with incomplete SCI (n=10) performed two times a two-minute walk test (2MWT) on a instrumented treadmill in the self-paced mode in a virtual reality environment (GRAIL). Force data were collected by two embedded force plates, the position data of the markers were collected by a Vicon system. Six different stability outcome measures were determined: dynamic stability margin (DSM) [2], margin of stability (MoS) [3], distance between XCoM and CoP in anterior-posterior (Distance_{AP}) and mediolateral (Distance_{ML}) direction [4] and CoM-CoP inclination angle in anterior-posterior (Angle_{AP}) and mediolateral (Angle_{ML}) direction [5]. ICCs and Bland-Altman tests (Limits of Agreement, LoA) were used to analyse repeatability.

Results:

<table>
<thead>
<tr>
<th></th>
<th>ICC</th>
<th>Measurement score</th>
<th>Mean difference</th>
<th>LoA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Measurement score</td>
<td>Test 1</td>
<td>Test 2</td>
<td>Lower</td>
</tr>
<tr>
<td>DSM (mm)</td>
<td>Controls</td>
<td>0.87</td>
<td>7.2 ± 6.9</td>
<td>6.6 ± 8.3</td>
</tr>
<tr>
<td></td>
<td>SCI</td>
<td>0.90</td>
<td>-39.1 ± 30.4</td>
<td>-32.9 ± 28.1</td>
</tr>
<tr>
<td>MOS (mm)</td>
<td>Controls</td>
<td>0.88</td>
<td>17.5 ± 6.3</td>
<td>17.4 ± 7.2</td>
</tr>
<tr>
<td></td>
<td>SCI</td>
<td>0.86</td>
<td>30.2 ± 8.9</td>
<td>31.3 ± 11.4</td>
</tr>
<tr>
<td>Distance_{AP} (mm)</td>
<td>Controls</td>
<td>0.88</td>
<td>128.2 ± 34.1</td>
<td>136.4 ± 37.2</td>
</tr>
<tr>
<td></td>
<td>SCI</td>
<td>0.92</td>
<td>20.3 ± 55.1</td>
<td>31.1 ± 53.0</td>
</tr>
<tr>
<td>Distance_{ML} (mm)</td>
<td>Controls</td>
<td>0.88</td>
<td>27.1 ± 8.0</td>
<td>26.2 ± 8.9</td>
</tr>
<tr>
<td></td>
<td>SCI</td>
<td>0.71</td>
<td>44.1 ± 9.0</td>
<td>46.5 ± 10.0</td>
</tr>
<tr>
<td>Angle_{AP} (°)</td>
<td>Controls</td>
<td>0.87</td>
<td>23.0 ± 4.2</td>
<td>24.6 ± 4.6</td>
</tr>
<tr>
<td></td>
<td>SCI</td>
<td>0.95</td>
<td>13.0 ± 5.1</td>
<td>13.5 ± 4.8</td>
</tr>
<tr>
<td>Angle_{ML} (°)</td>
<td>Controls</td>
<td>0.89</td>
<td>11.9 ± 1.7</td>
<td>11.4 ± 2.2</td>
</tr>
</tbody>
</table>
SCI 0.79  8.5 ± 1.6  8.4 ± 1.5  0.2 ± 0.7  -1.3  1.6

*Significant difference between Test 1 and 2, p<.05

**Discussion:** Based on the ICC, repeatability of all stability outcome measures demonstrated to be good in healthy controls and SCI patients. However, the LoA of all stability outcome measures seemed relatively large (>30%) indicating that stability outcome measures cannot be used to detect small individual changes.

Axial and frontal plane skeletal hip alignment are crucial for gait in asymptomatic adults

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Introduction: Hip orientation is commonly described by parameters in both the frontal and axial planes. Frequently studied angles such as femoral and acetabular anteversion, neck shaft angle (NSA) and acetabular abduction have been shown to be highly variable, even among asymptomatic subjects [1]. However, it is still not known how these parameters and their inter-individual variability are related to functional activities such as gait. The purpose of our study is to investigate the relationship between skeletal and kinematic parameters of the hip during walking.

Research Question: How do skeletal hip parameters relate to gait?

Methods: 145 asymptomatic adult subjects (age= 29.2±11.1 years, 70F) with no prior orthopaedic treatment underwent 3D gait analysis from which the kinematic parameters of the pelvis, hip, knee, ankle and foot were generated (ROM, means, minima, maxima) [2]. All subjects underwent full body biplanar X-rays with 3D reconstruction of the pelvis and the femurs from which the following skeletal parameters were generated: acetabular abduction, acetabular anteversion, NSA and femoral anteversion. In order to subdivide the sample into homogenous sub-groups, agglomerative hierarchical clustering was used for the aforementioned skeletal parameters and 3 classes were delimited for each. Kinematics were compared between classes, for each parameter separately, using ANCOVA while controlling for confounding demographic factors (sex, age, height, weight) and post-hoc comparisons were computed between classes using REGWQ test.

Results: Classes of acetabular abduction (average acetabular abduction: class 1: 49˚±2˚, class 2: 54˚±1˚, class 3: 58˚±1˚) showed no significant differences in gait. As for the femoral anteversion (class 1: 5˚±5˚, class 2: 16˚±2˚, and class 3: 27˚±5˚), 7 kinematic parameters related to the pelvis in the frontal plane, to the hip in the frontal and axial planes and to the knee in the sagittal plane were found to be significantly different between classes (Figure 1). As for the acetabular anteversion (class 1: 14˚±2˚, class 2: 20˚±1˚, class 3: 26˚±1˚), ROM pelvic obliquity showed significant differences between classes (class 1: 11˚±4˚, class 2: 10˚±4˚ and class 3: 8˚±3˚) as well as maximum knee extension in stance (class 1: 0.5˚±4˚, class 2: 3˚±5˚ and class 3: 1˚±5˚) and mean knee flexion/extension (class 1: 19˚±4˚, class 2: 21˚±4˚ and class 3: 20˚±4˚). The NSA (class 1: 122˚±2˚, class 2: 129˚±2˚, class 3: 136˚±3˚) showed a significant difference between classes in step length and 5 kinematic parameters related to the hip and knee in the sagittal plane (Figure 1).

Discussion: This is the first study to assess the role of the skeletal parameters of the hip in dictating gait in asymptomatic subjects. Among frontal parameters, only NSA was related to gait kinematics. As for axial parameters, both acetabular and femoral anteversion had influenced kinematics. Hence, both frontal and axial plane parameters would seem to be crucial for surgeons when planning for total hip replacement with the aim of best restoring patients’ functionality.

<table>
<thead>
<tr>
<th>Kinematics</th>
<th>Class 1: 15</th>
<th>Class 2: 16</th>
<th>Class 3: 27</th>
</tr>
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<tbody>
<tr>
<td>ROM pelvic obliquity (°)</td>
<td>11</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>ROM hip abd/adduction (°)</td>
<td>15</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>Mean hip int/external rotation (°)</td>
<td>-1</td>
<td>3</td>
<td>3</td>
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<tr>
<td>Max knee flex in stance (°)</td>
<td>13</td>
<td>17</td>
<td>14</td>
</tr>
<tr>
<td>Max knee extension in stance (°)</td>
<td>0</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Mean knee flex/extension (°)</td>
<td>18</td>
<td>21</td>
<td>20</td>
</tr>
<tr>
<td>Max knee flex in swing (°)</td>
<td>59</td>
<td>63</td>
<td>61</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Kinematics</th>
<th>Class 1: 122</th>
<th>Class 2: 129</th>
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</tr>
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<tbody>
<tr>
<td>ROM hip flex/extension (°)</td>
<td>44</td>
<td>45</td>
<td>42</td>
</tr>
<tr>
<td>Max knee flex in stance (°)</td>
<td>16</td>
<td>15</td>
<td>11</td>
</tr>
<tr>
<td>Max knee flex in swing (°)</td>
<td>61</td>
<td>62</td>
<td>59</td>
</tr>
<tr>
<td>Knee extension at initial contact (°)</td>
<td>6</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Mean knee flex/extension (°)</td>
<td>21</td>
<td>20</td>
<td>18</td>
</tr>
<tr>
<td>Step Length (m)</td>
<td>0.64</td>
<td>0.67</td>
<td>0.66</td>
</tr>
</tbody>
</table>

Images:
- Acetabular abduction
- Acetabular anteversion
- Neck shaft angle
- Femoral anteversion
Measuring upper body motion provides unique information about gait impairment in the early stages of Parkinson’s disease

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Introduction: Subtle changes in upper body motion during gait may be a marker of incipient pathology, intervention response and disease progression in Parkinson’s disease (PD) [1]. It is unknown whether variables obtained from the upper body during gait are merely a reflection of lower body mechanics (as measured by spatiotemporal characteristics) or can provide novel additional information about PD. If unique information can be gained, it may improve the objective characterisation of PD gait in the early stages of the disease and so inform intervention strategies and accurately quantify their effect.

Research Question: Can measuring upper body motion during gait provide unique information about PD gait from spatiotemporal characteristics; and can this information help classify people with early stage PD and age-matched controls independently of traditional spatiotemporal gait measurements?

Methods: Seventy people with PD (69.2 ± 9.9 yr, Female: 23, UPDRS III: 36.9 ± 12.3) and 64 age-matched controls (71.6 ± 6.8 yr, Female: 29) walked for two minutes around a 25m circuit. Sixteen spatiotemporal variables were measured using a 7m meter Gaitrite mat located along the circuit, and were selected a priori according a five-domain (pace, rhythm, variability, asymmetry and postural control) validated model of gait [2]. We measured upper body motion using three inertial sensors (128 Hz, APDM) located at the head, neck and pelvis. A broad range of characteristics were chosen based on previous gait literature and included the magnitude, smoothness, harmonicity, attenuation, regularity and symmetry of upper body motion. Upper body characteristics were calculated for anterio-posterio, mediolateral and vertical directions. This process resulted in 78 upper body variables [1,3]. Pearson’s correlations were calculated to test how strongly upper body and spatiotemporal characteristics are correlated. Univariate receiver operator characteristic (ROC) curves were used to quantify how well each upper body and spatiotemporal characteristic could discriminate people with PD from controls. Binary logistic regression analysis was performed to determine whether the upper body variables provide additional discriminative information when combined with spatiotemporal characteristics.

Results: The spatiotemporal characteristics relating to pace were strongly correlated with regularity (r = 0.72), and mildly correlated with symmetry (r = 0.55). Rhythm was mildly correlated with magnitude and smoothness (r = 0.33, for both). Apart from these exceptions, upper and lower body gait domains did not significantly correlate. The univariate analysis showed that 44 of the 78 upper body variables significantly discriminated PD from control participants (p<.05). When the 16 spatiotemporal characteristics were entered (forward stepwise) into a binary logistic regression, the model classified group membership with 74% accuracy. Upper body variables resulted in a model with 83% accuracy. When spatiotemporal characteristics entered the model first and upper body variables were added as a second step, the latter variables significantly contributed (p<.001) to an increase of 16% in the accuracy of the prediction model (from 74% to 90%).

Discussion: Most upper body variables provided additional and unique information about PD gait with respect to traditional spatiotemporal variables obtained from the lower body. Multivariate analyses showed that this additional information was beneficial in discriminating early PD from controls. We recommend measuring upper body motion in conjunction to traditional spatiotemporal characteristics will help characterise PD gait in a more holistic manner.

References:

O10

Increasing tendon stiffness enhances the effectiveness of stretching interventions in children with cerebral palsy

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Liverpool John Moores University, Liverpool, UK, Alder Hey Children’s NHS Foundation Trust, Liverpool, UK, KU Leuven, Leuven, Belgium

Introduction: Stretching is often used to increase/maintain joint range of motion (ROM) in children with cerebral palsy (CP). However, outcomes of long-term stretching interventions appear to be highly variable and often unsatisfactory. It has been shown that during passive ankle joint rotation the Achilles tendon lengthens more than the in-series gastrocnemius muscle in children with CP. This reduces the stretching stimulus to the muscle and might explain the limited effectiveness of stretching interventions. Properly designed resistance training programmes have been shown to increase tendon stiffness in children. An increase in tendon stiffness would reduce the stiffness of the muscle relative to the tendon, so that when subsequently stretching the muscle-tendon-unit, the stretching stimulus to the muscle will be increased.

Research Question: Can we increase the stretching stimulus to the medial gastrocnemius muscle fascicles by increasing Achilles tendon stiffness in children with cerebral palsy?

Methods: Fourteen children with CP (age: 10.0±2y, 8/6 hemiplegic/diplegic, GMFCS level: 8/6, I/II) participated. Children were randomly assigned to a combined intervention (n=8) or a stretching only (n=6) group. The combined intervention group performed strengthening exercises of the calf muscle for 4 weeks followed by 6 weeks of combined strengthening and stretching exercises of the calf muscles. To assure similar physiological load and contact with experimenters, the stretching only group performed strengthening exercises of the upper limb for 4 weeks followed by 6 weeks of stretching exercises of the calf muscle. Achilles tendon elongation during isometric ankle plantarflexion contractions was measured using ultrasound at baseline, after 4 weeks and after 10 weeks. Tendon stiffness was defined as the slope of the tendon force-elongation curve at a common force. Fascicle lengths were measured with ultrasound while participants lay prone with the knee at 20° flexion and the ankle hanging off the bed (resting) and during passive joint rotations. Parameters were assessed for normality with a Shapiro-Wilk test and compared to baseline at 4 and 10 weeks within groups with a Wilcoxon rank sum test.

Results: Achilles tendon stiffness increased by 4.3±7.9 N/mm at 4 weeks and by 14.3±5.8 N/mm at 10 weeks in the combined intervention group (p=0.01; Figure 1). This caused the joint angle at which the muscle fascicles started to lengthen to decrease in the combined intervention group (p<0.05). ROM increased in the dorsiflexion direction in both groups equally after stretching (p<0.05), similarly fascicle length at maximum dorsiflexion increased equally after stretching in both groups (p<0.05). Resting fascicle length increased in the combined intervention group only (p<0.01; Table 1).

Figure 1: Change in tendon stiffness per group. Circles show individual data points, lines show median values.
Table 1: Changes in fascicle and joint parameters at baseline and after 10 weeks

<table>
<thead>
<tr>
<th></th>
<th>Combined intervention</th>
<th></th>
<th>Stretching only</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline 10 weeks</td>
<td></td>
<td>Baseline 10 weeks</td>
<td></td>
</tr>
<tr>
<td>ROM (°)</td>
<td>57.1(10.3)</td>
<td>62.9(9.9) *</td>
<td>55.3(15.4) *</td>
<td>64.1(11.2) *</td>
</tr>
<tr>
<td>Max. fasc. length (mm)</td>
<td>51.2(13.8)</td>
<td>55.5(11.6) *</td>
<td>42.6(12.5)</td>
<td>45.6(13.1) *</td>
</tr>
<tr>
<td>Resting fasc. length (mm)</td>
<td>35.6(9.6)</td>
<td>40.2(8.9)</td>
<td>32.5(6.7)</td>
<td>32.3(6.4)</td>
</tr>
</tbody>
</table>

**Discussion**: We showed that tendon stiffness can be increased in children with CP through an appropriately designed resistance training programme. Therefore, the muscle was stretched earlier in the ROM and thus received a larger stretching stimulus. More importantly, we showed that even though there was a similar increase in ROM in both groups, a remodelling of the fascicle morphology occurred only in the combined strengthening-stretching intervention group. We are now assessing whether this remodelling leads to functional movement improvements.

Automatic tracking of the muscle-tendon junction between the medialis gastrocnemius and the Achilles tendon in sequences of images resulting from dynamic ultrasound acquisition: a validation study

Francesco Cenni1,2, Davide Monari1,2, Herman Bruyninckx1, Erwin Aertbeliën1, Lynn Bar-On2,3, Barbara Kalkman4, Simon-Henri Schless2,3, Kaat Desloovere2,3

1KU Leuven, Department of Mechanical Engineering, Leuven, Belgium, 2Clinical Motion Analysis Laboratory, University Hospital, Leuven, Belgium, 3KU Leuven, Department of Rehabilitation Sciences, Leuven, Belgium, 4Liverpool John Moores University, Research Institute for Sport and Exercise Sciences, Liverpool, UK

Introduction: Dynamic measurements of the junction between muscle and tendon (MTJ) from sequences of ultrasound (US) images can be used to ascertain the lengthening properties of the medial gastrocnemius (MG) and Achilles tendon (AT) during passive or active motion. It is known that these properties are altered in children with spastic cerebral palsy (SCP) compared to typically developing children (TD) [1]. In hyper-echoic muscles such as in SCP, digitisation of the location of the MTJ is commonly performed manually. However, such manual tracking is operator-dependent and time consuming. While automatic methods for tracking the MTJ have been introduced [2], their performance has not been validated in TD or SCP populations.

Research Question: Is an automatic tracking method for digitising the location of the muscle tendon junction of the medial gastrocnemius valid for TD and SCP children during slow passive stretch?

Methods: Twelve TD (age: 9.9±2.0y) and 12 SCP (age: 10.4±2.3y, 5/7 hemiplegic/diplegic, GMFCS level: 6/6, I/II) children were recruited for this study. Children lay prone with their upper leg strapped to the table and lower leg resting at a standardised knee angle. A series of 2D US images (Telemed, Lithuania) were acquired at 30Hz with a linear transducer (59mm), securely fixed over the MTJ junction along the main AT pulling direction. US images were recorded during manually applied slow passive ankle motions across the full range of motion. An experienced operator manually digitised the MTJ location to create the reference data. An in-house software package to automatically track the MTJ was implemented, by modifying a previous algorithm [2] and based on the Lucas–Kanade computer vision method for optical flow estimation. Besides a digitisation of the MTJ in the initial image, this algorithm also requires the definition of the region to be tracked, and the velocities of each pixel within that region are then processed. A quality index for tracking (QIT= mean velocity/standard deviation velocity) was also developed. First, to determine the optimal set of algorithm parameters, different region locations and velocity selections within the region were tested for a subgroup of 4 children (2 TD and 2 SCP). Automatic and manual tracking results were compared using the root mean square errors (RMSE) and the corresponding absolute value of the MTJ excursion discrepancies. Secondly, these parameters were applied on the remaining TD and SCP participants.

Results: First, the optimal combination of parameters showed the best results when the tracking region was located on the MG deep aponeurosis, around 10 mm from the MTJ. These results corresponded to a RMSE of 2.9mm and a discrepancy of 2.8mm. Further, a significantly higher QIT was found with lower RMSE/discrepancies (r= -0.73 and r= -0.69, respectively). Secondly, these parameters were applied on a larger group of TD and SCP children and the corresponding results are reported in table 1.
Table 1. Average ± SD of the tracking parameters. Ten TD and 10 SCP (GMFCS level: 5/5, I/II) children were analysed.

<table>
<thead>
<tr>
<th>Group</th>
<th>RMSE (mm)</th>
<th>MTJ automatic (mm)</th>
<th>MTJ manual (mm)</th>
<th>Absolute value discrepancy (mm)</th>
<th>QIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCP (GMFCS I)</td>
<td>2.5 ± 2.2</td>
<td>17.2 ± 4.7</td>
<td>17.8 ± 5.5</td>
<td>1.2 ± 1.5</td>
<td>4.82 ± 1.5</td>
</tr>
<tr>
<td>SCP (GMFCS II)</td>
<td>3.1 ± 1.7</td>
<td>22.1 ± 5.1</td>
<td>21.5 ± 4.8</td>
<td>1.5 ± 1.0</td>
<td>3.83 ± 0.7</td>
</tr>
<tr>
<td>all SCP</td>
<td>2.7 ± 1.8</td>
<td>19.6 ± 5.0</td>
<td>19.7 ± 5.2</td>
<td>1.4 ± 1.7</td>
<td>4.38 ± 1.2</td>
</tr>
<tr>
<td>TD</td>
<td>2.9 ± 1.7</td>
<td>28.3 ± 4.7</td>
<td>28.7 ± 3.8</td>
<td>2.7 ± 2.9</td>
<td>4.62 ± 1.0</td>
</tr>
</tbody>
</table>

Discussion: This research developed a modified tracking algorithm to deal with the specific problems in hyper-echoic muscles. The QIT is developed for online tracking performance evaluation and to determine the optimal region and tracking parameters. The best results in terms of RMSE and discrepancies are obtained by tracking the MG deep aponeurosis, which translates with an offset with respect to the actual MTJ. The error introduced by the automatic tracking is smaller than the clinical relevant difference between SCP and TD groups (table 1). In addition, the QIT can be used to detect bad tracking performance and to fall back to manual digitisation in selected images. Future validation should be undertaken in other motion conditions, such as gait, where the relevant algorithm parameters can be tuned for the specific needs. To increase the reproducibility of this research, the developed software package is made available at: github.com/u0078867/Py3DFreeHandUS.

Treadmill perturbations to quantify stretch reflexes during gait in children with cerebral palsy

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Introduction: Spasticity, i.e. exaggerated velocity-dependent stretch reflex activity, is one of the key impairments in neurological diseases, but its effect on gait is unclear [1]. To quantify spastic reflexes during gait, ankle rotations have been applied by mechanical devices [2,3], but these are cumbersome and can affect gait. Recently, it has been shown that treadmill accelerations can be used to evoke stretch reflexes during gait in the calf muscles of healthy adults [4]. However, the applicability of this approach in children and in patients with neurological diseases has yet to be demonstrated.

Research Question: Can treadmill accelerations be used to quantify stretch reflexes during gait in typically developing (TD) children and children with cerebral palsy (CP)?

Methods: 12 TD children (10.6±3.1 y) and 12 children with CP (age: 9.9±2.8, GMFCS I-III) walked on a split-belt instrumented treadmill (GRAIL system, Motek, Amsterdam) at self-selected fixed walking speed for a total of 6 minutes. Treadmill backward accelerations of one belt at three different intensities were applied to the most affected (CP) or right leg (TD) just after initial contact, 5 times each in random order. 3D kinematics were collected according to the Human Body Model [5]. EMG of 8 muscles per leg was measured, and muscle-tendon lengths and velocities were calculated using OpenSim. EMG was normalized to the peak value during unperturbed walking. As outcome measures, we evaluated changes due to the perturbations in knee and ankle angle, soleus (SO) and gastrocnemius (GM) length and velocity, and RMS EMG.

Results: In TD, perturbations with increasing intensity resulted in increased ankle dorsiflexion, up to 4.9±1.3°, without changes in knee angle. This caused an increasing stretch velocity of GM and SO, resulting in increasing bursts and average muscle activity in these muscles up to three times the unperturbed value (Fig. A). Reactions in CP were more variable, but showed a similar pattern. Ankle dorsiflexion increased up to 1.8±1.8°, increased stretch velocity in both muscles and increased average muscle activity over 3.5 the unperturbed value (Fig. B). There was no significant difference in the RMS EMG between TD and CP. Co-contraction with the tibialis anterior muscle did not change with perturbation intensity for either TD or CP.

Discussion: It can be concluded that stretch reflexes can be evoked using treadmill perturbations in both TD children and children with CP. The enhanced reflex activity in some of the children with CP compared with TD indicates that treadmill perturbations are a promising method for assessing spasticity during gait in a clinically applicable manner. The lower and more variable changes in joint angles and muscle-tendon lengthening in CP are likely due to the altered posture in early stance. Further analysis will focus on quantifying the change in EMG relative to the change in muscle-tendon lengthening and comparison with clinical spasticity scores. Furthermore, estimating ankle joint stiffness using ground reaction forces would allow to unravel the passive and active contributions to joint hyperresistance during gait in patients with spasticity.
Typical temporal statistics associated with postural transitions that were recorded from older adults during a both a semi-structured and a free-living protocol recorded using video technology.

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Introduction: With the advancement of iMEMS inertial sensor based devices combined with machine learning techniques, algorithms for physical activity measurement using body worn sensors has soared in recent years. A drawback with algorithms that are produced purely using machine learning techniques however is that potentially confounding activities could produce unrealistic results during the classification of postural transitions. This study thus reports on the typical temporal statistics associated with postural transitions that were recorded from older adults during a both a semi-structured and a free-living protocol recorded using video technology (>25fps). Previously Reyes-Ortiz et al. have proposed ranges for transitions as part of an activity classification system, however a smaller data-set of activities was used to compile these statistics [1].

Research Question: What are the typical ranges of transition duration performed by older adults that can be expected in a free-living situation?

Methods: A total of 20 older adult participants were recruited from the Trondheim area in Norway. The subjects were recorded performing a semi-structured protocol in the Laboratory environment while being recorded at 25fps (frames-per-second) using wall-mounted video cameras and annotated using the Anvil software (v5.1.13). These subjects ranged in age from 68-90 years (76.4±5.6 years), body mass from 56 to 93 kg (73.7±11.4 kg), and height from 1.56 to 1.81m (1.67±0.072 m). Subjects performed a series of standing, sitting at a table, sitting, on an soft armchair, sitting on a chair, lying on a bed, walking at various speeds, shuffling (short stepping movements), object-picking from the floor, leaning while standing and while sitting, kneeling down and transitions between static postures. [2].

Results: Table 1 presents the ranges of transition duration for 43.92 hours of physical activity data which has been manually annotated to 25fps. The transition ranges for standing, sitting, lying and walking are presented. The highest mean transition duration is from lying to standing (4.22 seconds). To cover 97.7% of activity durations (3 standard deviations) an upper limit of 4.13 seconds + (3*1.56 seconds) = 8.81 seconds can be tolerated.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Transition Duration (Mean±SD)</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standing</td>
<td>standing - transition standing: 1.6±0.763s n=11</td>
<td>1.6±0.763s n=11</td>
</tr>
<tr>
<td></td>
<td>standing - transition sitting: 2.55±1.02s n=404</td>
<td>2.55±1.02s n=404</td>
</tr>
<tr>
<td></td>
<td>standing - transition lying: 4.13±1.44s n=63</td>
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</tr>
<tr>
<td>Sitting</td>
<td>sitting - transition standing: 2.39±1.48s n=346</td>
<td>2.39±1.48s n=346</td>
</tr>
<tr>
<td></td>
<td>sitting - transition sitting: 2.27±1.65s n=272</td>
<td>2.27±1.65s n=272</td>
</tr>
<tr>
<td></td>
<td>sitting - transition lying: 2.97±1.21s n=84</td>
<td>2.97±1.21s n=84</td>
</tr>
<tr>
<td>Lying</td>
<td>lying - transition standing: 4.22±1.5s n=51</td>
<td>4.22±1.5s n=51</td>
</tr>
<tr>
<td></td>
<td>lying - transition sitting: 3.61±1.26s n=75</td>
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<td>lying - transition lying: 2.22±3s n=12</td>
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<td></td>
<td>lying - transition walking: 3.95±1.39s n=96</td>
<td>3.95±1.39s n=96</td>
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<tr>
<td>Walking</td>
<td>walking - transition sitting: 2.93±1.55s n=332</td>
<td>2.93±1.55s n=332</td>
</tr>
<tr>
<td></td>
<td>walking - transition lying: 4.13±1.56s n=87</td>
<td>4.13±1.56s n=87</td>
</tr>
</tbody>
</table>

Discussion:
We have analysed the typical ranges of postural transitions that occur during physical activity in older adults. These ranges can be used as part of machine learning algorithms for the detection of physical activity, to inform the typical duration of postural transitions in older adults.

References:


Influences of Hip Adductor Muscle Weakness on Stiff Knee Gait Pattern in Healthy Individuals

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Introduction: Stiff knee gait (SKG) is highly related with peak knee flexion velocity in late stance (1). According to simulation studies, some hip adductor muscles (adductor longus and gracilis), which are active in pre-swing phase, plays an active role to gain appropriate knee flexion velocity to achieve peak knee flexion in swing phase (2). Adductor muscles, which are commonly stretched, lengthened or temporarily paralysed to prevent hip subluxation. The previous work demonstrated that, <40% maximum voluntary muscle force (MVMF) drop causes SKG pattern (3). Although the treatments to prevent hip subluxation commonly cause less than 40% muscle force drop.

Research Question: Does less than 40% maximum voluntary adductor muscle force drop cause SKG pattern in healthy individuals?

Methods: Thirteen healthy participants (5 men, 26 limbs, Av. Age: 22 ± 1.4, Hight: 164.1 ± 8.4 cm, Weight: 59.3 ± 9.08 kg) were included in the study. As it was described in Fowles et al.’s work (4), adductor muscles were stretched by a strict protocol (135 sec x 13 repetition and 5 sec-resting). Stretching intensity was symmetrically set as 6/10 in severity according to visual analogue scale (VAS, discomfort onset as 10). The same two researchers applied stretching to all participants by maintaining the pelvis symmetry (Fig. 1). In order to stretching under the pain threshold, the same researcher verbally acknowledged in every 30 seconds. Muscle strength was assessed in full-knee extension before and after the stretching procedure. The participant whose adductor muscle force drop less than 40% was joined the work. Four SKG parameters (P1: Peak-knee-flexion, P2: Range in early-swing, P3: Knee-range, P4: Time-duration in early-swing) (5) were compared before and after the stretching by computerized 3D gait analysis at self-selected speed. If three or four parameters were completed it is considered as SKG, less than two parameters classified as a borderline. Paired t-test was used for the statistical comparison (p<0.05).

Results: Hip adductors strength, 34.02% ± 0.03 (from 243 ± 97 N to 153 ± 55 N), dropped after the stretching. The mean gait velocity also reduced from 1.17 ± 0.1 to 0.99 ± 0.19. P1 (from 57.7 ± 3.5° to 54.2 ± 4.9°) and P3 (from 55.6 ± 4° to 51.9 ± 4.3°) were significantly reduced. Although range and time duration in early swing (P2 and P4) did not significantly change (P2: from 28.8 ± 6° to 28.1 ± 5.1° and P4: from 13.1 ± 1.5° to 13 ± 1.2°) (Fig. 2).

Discussion: As stated in earlier work (3), even though >40% muscle drop causes SKG by fulfilling three of the four SKG parameters, <40% (approximately 35%) maximum adductor muscle force drop caused borderline SKG. After the surgical lengthenings, stretchenings or neural agent applications, <40% MVMF drop is more expectable in clinic. Therefore, the treatment protocols, which reduce the adductor muscle force, may have potential to contribute stiff knee gait pattern. Contribution of developing SKG pattern may have seen more obvious, if adductor MVMF drop exceeded 40%. Acknowledge: We thank Prof. PT. Ozdincler AR. permitting to do this work as the head of the department.
Fig. 1. Illustration of adductor muscle stretching.

Fig. 2. Demonstration of four SKG parameters. P1, P3 significantly reduced after stretching (*).

Compensatory gait strategies for reduced ankle work in patients with unilateral flaccid calf muscle weakness

Niels Waterval, Jaap Harlaar, Frans Nollet, Merel-Anne Brehm

Introduction: Impaired calf muscle strength in patients with neuromuscular diseases typically reduces ankle work during push-off, leading to increased energy dissipation (i.e. negative work) at contralateral heel-strike. To overcome the reduced push-off work and consequent energy dissipation, patients have to compensate by producing more positive work elsewhere to maintain their walking speed. Increments in positive hip work in the affected leg and positive total work in the non-affected leg have been proposed as possible compensation strategies in patients with spastic calf muscle weakness and in below knee amputees. However, knowledge about which compensations are used in neuromuscular disease patients exhibiting flaccid calf muscle weakness is currently lacking, and may be useful to inform treatment decisions, including the specs of orthotic devices.

Research Questions: Is (a) negative work in the non-affected leg during loading response increased? and (b) are positive hip work in the affected leg increased and total positive work in the non-affected leg increased in patients with unilateral flaccid calf muscle weakness compared to healthy controls?

Methods: We included 17 patients with unilateral flaccid calf muscle weakness (10 male, mean age: 56.4±13.9 yrs., calf strength: MRC 3; range 0-5) and 10 healthy subjects (4 male, mean age: 32.5±14.9 yrs.). A 3D gait analysis while walking barefoot on a fixed non-dimensional walking speed of 0.4 (±1.2 m/s) was taken to determine ankle, knee and hip power in both legs for the entire gait cycle and for different gait phases. From these we calculated positive and negative joint work parameters and defined negative and positive total work as the sum of ankle, knee and hip work of that leg. Differences in these outcomes between patients and healthy subjects were tested with independent sampled t-tests.

Results: Negative work in the non-affected leg during loading response was significantly higher in patients compared to healthy subjects (-0.15±0.1 vs -0.07±0.0 J/kg, p < 0.001). In addition, positive hip work in the affected leg was significantly increased by 52% (0.41 (0.09) vs. 0.27 (0.07) J/kg, p = 0.001, Figure 1), which was most apparent in loading response and during swing. Also, positive total work in the non-affected leg was significantly increased by 33% (0.92±0.14 vs.0.69±0.13 J/kg, p < 0.001). Specifically, patients generated more knee work and hip work in the affected leg during loading response, mid-stance and swing compared to healthy subjects, while no differences in ankle work were seen (Figure 1).

Discussion: We showed that patients with unilateral flaccid calf muscle weakness and subsequent reduced push-off work perform more negative work at contralateral heel strike, which they compensate for by increased positive hip work in the affected leg and increased positive knee work and hip work of the non-affected leg. The increased impact and work at the non-affected leg may place this leg at risk for overuse injuries such as knee pain. Future research should evaluate if assistive devices optimised at supporting ankle push-off reduce the increment in negative work and necessity of compensatory work in these patients.
Figure 1: Positive work of the ankle, knee and hip

References:

2. Olney, Phys Therap. 1990;70(7):431-8
Assessment of trunk frontal kinetics in subjects with cerebral palsy showing a Duchenne gait pattern.

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Introduction: Duchenne gait is characterized by trunk lean towards the affected stance limb with the pelvis stable or elevated on the swinging limb side during single limb stance phase [1]. It is a well-known compensation mechanism to unload hip abductors in the presence of hip abductor weakness. Conventional 3D-gait analysis has become an established clinical standard for monitoring lower limb joint kinematics and kinetics in gait, but there exists not yet a standard for monitoring the trunk [2-4].

Research Question: What is the relationship between hip abduction and trunk kinetics in patients with cerebral palsy (CP) having excessive lateral trunk motion?

Methods: Data of 18 subjects (19.41 ± 6.87 years) with bilateral spastic cerebral palsy (CP) and 20 typically developing subjects (TD) were collected retrospectively. Our criteria for selection of the CP group were barefoot walking without any aid, presenting with excessive lateral trunk motion (Duchenne gait pattern) with little movement of head and arms (monitored by video inspection). Subjects had been monitored by conventional gait analysis of the lower extremity using the plug-in gait protocol with additional markers at the shoulder girdle for detecting trunk motion [5]. A generic musculoskeletal full body model (OpenSim 3.3) was used for modeling the gait. Using MATLAB, joint angle ranges of motion, maximum and minimum values of joint moments (Nm/kg) and powers (W/(kgm/s)) in the frontal plane for left and right legs as well as generated mechanical work were calculated for statistical analysis. Also, we checked the face validity of the lower limb part of our model comparing results with the standard model approach (plug-in gait) obtaining largely similar results.

Results: Significant differences for moments and powers were found between groups. The maximum and minimum values of the lumbar joint moment in CP were twice as large as in TD. Furthermore, maximum lumbar power was seven times as large in CP compared to TD (tab.1) and the generated work per meter travelled was even 20 times higher in CP (15J/kg.m vs 0.75J/kg.m). In contrast work performed in each hip joint was decreased by a factor of two (5.4J/kg.m in CP vs. 9.8J/kg.m in TD).

<table>
<thead>
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<th>TD, mean(std)</th>
<th>P-value</th>
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Table 1. Moment and power maximum values for CP and TD groups. Normalized by body mass (kg) and gait speed (m/s)
Discussion: In this study, we presented a simple kinetics HAT model attached to the conventional gait model of the lower extremity to monitor kinetic effects of lateral trunk motion known as Duchenne gait. To the best of our knowledge, this is the first work looking into trunk kinetics in subjects with cerebral palsy showing Duchenne gait. Results show that excessive lateral trunk motion may be an extremely effective compensation mechanism to unload the hip abductors in single limb stance. It becomes visible that decreases in frontal plane hip moments and powers go hand in hand with a significant increase in lumbar joint moment and power. This study opens new opportunities for further studies about the role of trunk kinetics in clinical applications and how this information could be feasible for clinicians.

High Intensity Circuit Training and Progressive Resistance Training improve functional performance but not the Gait Profile Score

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¹Medical University of Graz, Graz, Styria, Austria, ²Graz University, Graz, Styria, Austria

Introduction: Progressive Resistance Training (PRT) is an established and effective intervention to improve muscle strength in children with cerebral palsy (CP). However, the impact of PRT on functional ability is limited. Moreover, many childhood activities consist of bursts of intense activity and the rapid generation of force is reduced in children with cerebral palsy [1]. High Intensity Circuit Training (HICT) is an intervention with intervals of high intensity combined with short breaks that leads not only to improvements of aerobic but also anaerobic capacity [2]. Therefore HICT might be more suitable for children with CP. Additionally, the effectiveness of home-based strength training in CP remains to be clarified.

Research Question: The aim of this study was to compare strength and functional gains of home-based PRT and HICT and examine their influence on gait and participation in children with CP.

Methods: 22 children (14 diplegic and 8 hemiplegic, mean age 12 years 8 months, 19 GMFCS I and 3 GMFCS II) were randomly assigned either to a home-based eight week PRT or HICT. Each exercise program was performed three times a week, consisting of five identical functional exercises. The PRT group trained with a progressive overload while the HICT group performed as many repetitions as possible within 30 second intervals. Outcome measures included total isometric strength, Muscle Power Sprint test (MPST), Timed Stairs Test, 6 minute walking test, Gait Profile Score, Timed Up and Go test and participation questionnaires (ASKp and PODCI). Normal distributed data was analyzed using a two-way repeated measures ANOVA, other data with a Mann-Whitney U test.

Results: Intervention compliance in the PRT and HICT-group was 86% and 88%, respectively. Both groups enhanced the total isometric muscle strength (HICT: 19.6% /PRT: 3.7%) with only the improvement of the HICT group reaching significance. The HICT program was more successful in improving plantar and knee flexor strength. Both groups scored significantly better in the muscle power sprint test (HICT: 24.8% /PRT: 7.4%), but the improvement of the HICT group was higher. PRT-participants reached better results in the Timed-stairs-test, also compared to HICT improvement. The Gait Profile Score did not improve in either group. Additionally there was also no change of any other measures of mobility or participation for both groups.

<table>
<thead>
<tr>
<th></th>
<th>HICT</th>
<th>PRT</th>
<th>Diff (%)</th>
<th>HICT</th>
<th>PRT</th>
<th>Diff (%)</th>
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<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td></td>
<td>Pre</td>
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Discussion: Both training programs improved functional outcomes and show that “you gain what you train”. Therefore children in the PRT group achieved better results in the test with submaximal continuous load (timed-stairs-test) and participants in the HICT group performed better in the test that required short bursts of high energy (sprint test). This was the first study investigating the functional effectiveness of home-based strength programs for children with CP. Both exercise programs can serve as a valuable extension to institutional training. Nevertheless, the HICT program was more effective in improving total strength and might be therefore a preferable muscle strengthening intervention in children with CP.

Muscle fatigue occurs during a short walking exercise in children with cerebral palsy who walk in a crouch gait

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Introduction: Crouch gait is one of the most common walking pattern in children with bilateral cerebral palsy (CP). This gait leads to joint stress due to excessive knee flexion and may limit children walking capacity. A previous study reported a greater knee flexion in children with CP who walk in crouch gait after a short walking exercise representative of daily life activities (1). Since crouch gait requires higher joint extension moments, the deterioration of crouch gait after few minutes of walking may be related to neuromuscular fatigue.

Research Question: Does neuromuscular fatigue occur during a short walking exercise in children with CP who walk in a crouch gait?

Methods: To date, 9 children and adolescents with bilateral spastic CP (2 females; mean age ± SD: 13 ± 2 years; body mass: 40.3 ± 8.4 kg; height: 155.9 ± 15.4 cm; GMFCS II-III) were included in the study. Children were included if they had a knee flexion greater than 15° during the stance phase of gait and if they were able to walk for 6 minutes with or without walking aid. Maximal voluntary isometric force of knee flexors/extensors and hip flexors/extensors/abductors was measured using a handheld dynamometer. Then, participants walked barefoot around a 25-m pathway, continuously, for 6 minutes at their self-selected and comfortable speed. Standardized encouragements were provided at the third minute. Kinematic and electromyographic (EMG) data were recorded at each minute of the 6-minute walking exercise (6mwe). EMG was recorded from the rectus femoris (RF), vastus lateralis (VL), tibialis anterior (TA), gluteus medius (GMD), semitendinosus (ST), and gastrocnemius lateralis (GAL). The kinematic analysis included: walking speed, step length; maximum, minimum and range of motion (RoM) of the hip, knee, and ankle joint angles in the sagittal plane during single-limb stance. Muscle fatigue was assessed through a non-linear analysis of the EMG median frequency (Fmed). A global force index was obtained through muscle force data. One way repeated measure ANOVA were performed to assess the effect of time on kinematic and Fmed variables throughout the 6mwe, and Fisher’s least significant difference post-hoc was used when appropriated. Pearson correlations between kinematics and Fmed as well as muscle forces data were tested.

Results: No significant differences were found between the first and the other minutes concerning the walking speed, the step length, and the hip and ankle angles. Significant differences were found concerning the maximum knee joint angle, which increased when comparing the first minute with the 2nd, 3rd, 4th, 5th and 6th minute (p< 0.05). The Fmed of the RF and of the GAL significantly decreased at the 3rd, 4th, and 6th minute (p<0.05) and at the 2nd and 6th minute (p<0.05), respectively, compared to the first minute.

Significant negative correlation was found between Fmed variation of the RF and maximum knee joint angles variation between the first and 6th minute of the 6mwe (r = -0.861). Significant negative correlations were also found between maximum knee angle variation and knee extensor muscle force (r = -0.751), as well as maximum knee angle variation and the global force index (r = -0.805).

Discussion: The more severe crouch gait appearing during the short walking exercise was related with muscle fatigue. As maximum knee joint angle increased during the walking exercise, the Fmed of the RF decreased, which indicates the apparition of neuromuscular fatigue. Furthermore, the correlation between maximal knee flexion variation and Fmed variation of RF suggest that RF muscle group is highly related with the more severe crouch gait. This hypothesis is reinforced by the correlations between maximal knee flexion variation and knee extensor muscle force as well as the global force index. These correlations highlight that children who had a greater increase of the knee flexion after the 6mwe also had lower muscle force, especially at the knee extensor muscle groups. EMG and muscle force data will be further evaluated with a larger sample size. The results of the present study indicate that the more severe crouch gait
seen in these children with CP was related with muscle fatigue appearing at the RF after few minutes of walking, and with muscle weakness.

References: (1) Parent, Clin Biomech, 2016; 34 :18-21
Is ultrasound characterisation of tissue composition related to rate of force development in children with Duchenne Muscular Dystrophy?

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¹KU Leuven, Leuven, Belgium, ²University hospitals Leuven, Leuven, Belgium

Introduction: Muscle weakness is the most important and debilitating symptom in children with Duchenne Muscular Dystrophy (DMD), mainly caused by alterations in muscle structure. Several studies have used muscle imaging, such as ultrasonography (US), to quantify these changes and analyse their association with muscle weakness [1,2]. A higher increase in echo-intensity (EI) value in US images of the rectus femoris (RF) muscle was directly related to a decrease in muscle strength of the knee-extensors [1]. However, disease progression in DMD is muscle-specific [3], and different results might be found for other muscles in the lower limb. Further, the main focus of previous research on muscle weakness was measured as maximal torque, but rate of force development (RFD) has been suggested as also having an impact on functional performance.

Research Question: Therefore, the aim of this study was two-fold: 1), determine whether RFD in children with DMD is altered compared to typical developing (TD) children and 2), if RFD is altered, can this be attributed to an increase in EI-values?

Methods: Ten children with DMD (median age (25%-75%): 8.2 (6.8-10.0)) and nine TD children (median age (25%-75%): 9.9 (7.4-12.8)) participated in this study. Maximal voluntary isometric contractions (MVICs) were collected of knee-extensors (KE) and knee-flexors (KF), from which maximal normalized net joint torque (Nm/kg) and RFD (N/s) were extracted. Muscle imaging data were acquired of the RF- and semitendinosus (ST) muscles with a 3D freehand US technique [4] and EI was calculated from the US images according to the method described by Shklyar et al [5]. A Mann-Whitney U-test (p ≤ 0.005) was used to determine differences in maximal net joint torque, RFD, and EI between the two groups (DMD and TD). Spearmans’ rank correlation coefficient was used to analyse the relationship between MVIC-outcomes (net joint torques and RFD), and EI.

Results: The children with DMD were significantly weaker than the TD children in both muscle groups (both p < 0.0005) and had a significantly lower KF RFD (p = 0.004). With respect to EI, the children with DMD showed higher values than the TD children in both muscle groups (both p < 0.0005). The results of the correlation analyses are plotted in figure 1.

Discussion: RFD was found to be decreased in children with DMD compared to the TD children, albeit not significantly for KE RFD. Dystrophin has been suggested to play an important role in force transmission [7], which could explain the decreased RFD in children with DMD. The highest correlation in DMD children was found between EI and KF MVIC (r = -0.44), indicating that the increase in non-contractile tissue resulted in a decrease in maximal force of the knee flexors. Albeit small, negative correlations were also found between EI with KE MVIC and KF RFD (r = -0.21 and r = -0.33 resp.) suggesting that the extent of muscle deterioration affects both maximal force and RFD. The limitations of this study were the small sample size, and the slightly older TD children. For future research, the cohorts should be extended and an age-matched control group
needs to be used for comparison. Finally, the distal muscles of the lower limbs should also be included in future analyses.

Non-linear Relationship between Lower Limbs Muscle Strength and Walking Efficiency in Children with Cerebral Palsy

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Introduction: In daily life, the community integration of children with CP depends on their ability to walk independently, but also (1) to walk continuously to reach the surrounding, (2) to have an efficient gait to delay onset of fatigue, and finally (3) to increase walking speed in some challenging situations (i.e. crossing the street) [1]. It has been previously demonstrated that muscle strength is related to gross motor function and gait. A higher strength is related to a higher gait speed or walking efficiency [2-3]. However, studies reporting those associations assumed a linear relationship between muscle strength and walking capacities, whereas curvilinear relationship have been reported in other populations [4] meaning that a threshold of strength is required to optimized walking capacities.

Research Question: The main goal of this study was to assess the relationship (i.e. curvilinear or linear) between lower limb muscle strength and different walking capacities, including walking speed (comfortable and fast), walking endurance, and walking efficiency in children with spastic bilateral CP.

Methods: A sample of 32 children and adolescents (19 males; mean age ± SD: 11.9 [3.8] years; body mass: 35.9 [13.7] kg; height: 142.9 [20.0] cm; GMFCS I-III) with spastic bilateral CP were included. A clinical gait analysis (CGA) was performed including three different walking exercises: (1) discontinuous walking exercise as classically done in CGA, (2) continuous 6-minute walking exercise, performed at comfortable speed, and (3) fast walking exercise. The gait efficiency was calculated using the Energy Expenditure Index (EEI) [5] and prior to the CGA, the maximal isometric strength of the hip abductors and the hip and knee flexors and extensors was measured using a handheld dynamometer. Participant’s capacity to increase walking speed was calculated as the difference between fast walking speed and discontinuous walking speed. A global strength index (GSI) was calculated as the sum of maximal isometric strength. Pearson product-moment correlation coefficients (r) were calculated to quantify the relationships among all measures. Four regression models were fitted to quantify the curvilinear relationship between walking capacities and the GSI.

Results: The average walking speed was 61.0 ± 11.8 m/min, 62.2 ± 15.3 m/min and 80.7 ± 17.4 m/min for the discontinuous, continuous and fast walking exercise (significantly different from other conditions, +40%, p<0.001). The average EEI was 1.1 ± 0.6 beats/m and the average global strength index was 4.60 ± 1.5 Nm/kg. The GSI was negatively associated with the EEI and positively associated with the three walking speeds (p<0.05). The percentage of difference in walking speed was positively associated with the GSI (p<0.05). The GSI explained 28%, 31%, 18% and 27% of the variance of the EEI, the discontinuous, continuous and fast walking speed, respectively (all p<0.05) in the linear models. The GSI explained 34%, 34%, 21% and 26% of the variance of the EEI, the discontinuous, continuous and fast walking speed (all p<0.05), respectively in the curvilinear models.

Discussion: The results support the hypothesis of a non-linear relationship between lower limbs muscle strength and walking capacities. In conclusion, our results suggest that a threshold of minimal strength is required to optimize walking capacities in children with CP.
References:

Gait deviations in children with Duchenne Muscular Dystrophy can be directly attributed to muscle weakness in two lower limb muscle groups.

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¹KU Leuven, Leuven, Belgium, ²University hospitals Leuven, Leuven, Belgium

Introduction: Muscle weakness is the most prominent symptom in children with Duchenne Muscular Dystrophy (DMD) and it is assumed to have a crucial impact on gait [1]. Although several studies have described the gait deviations and their relation with muscle weakness in children with DMD [2,3], no study actually analysed the association between decreased muscle strength and gait alterations in this population. Further, previous research focussed on gait at self-selected walking speed, while walking at a higher walking speed might highlight additional markers of weakness in the gait pattern of children with DMD.

Research Question: Therefore, the aim of this study was to explore the association between muscle weakness and gait deviations in children with DMD when walking at self-selected speed (v1) and as fast as possible without running (v2).

Methods: 14 DMD children (median age (25-75%): 8.8 (6.8-9.9)) and 14 TD children (median age (25-75%): 8.2 (7.4-10.0)) participated in the study. Maximal voluntary isometric contractions (MVICs) of the knee extensors (KE), knee flexors (KF), dorsiflexors (DF) and plantar flexors (PF) were collected. From the MVICs, averaged joint torques over three trials (in Nm/kg) were calculated. 3D gait analysis was performed at two walking speeds (v1&v2), from which non-dimensional walking speed [4], and maximal internal net joint moments for knee extension (mKE), knee flexion (mKF), plantarflexion (mPF), as well as ankle torque during loading response (mLr) and ankle power generation during push-off (pA) were extracted. Significant differences between the two groups were analysed with a Mann-Whitney U-test (p ≤ 0.005). The relationship between the MVIC-outcomes and the gait parameters was analysed with Spearmans’ rank correlation coefficient.

Results: The children with DMD showed significantly lower net joint torques during all MVICs (all p ≤ 0.001), a higher mLr at v1 and lower mPF values (v1&v2) (all p ≤ 0.005). No significant differences were found for non-dimensional walking speed, mKE, mKF and pA between the two groups at both v1 and v2. The results of the correlation analysis are shown in figure 1.

Discussion: In the children with DMD, weakness of the knee-extensors and plantar flexors defined by MVICs, was directly associated with an internal net plantar flexion torque during loading response (fig.1A) and an increased maximal plantar flexion moment during gait (fig.1B-C) respectively. The knee-extensors are one of the first muscle groups that are impaired in DMD. By employing a tip-toe walking pattern, the ground reaction force can be positioned closer to the knee-joint centre, thereby decreasing knee-extension moment during stance [2,3]. DMD children with stronger plantar flexors, might be more capable of keeping this tip-toe position, consequently tolerating the lower maximal internal net plantar flexion torque before push-off. The higher walking speed did not provide additional information. However, the included number of subjects was small.

Figure 1. Spearmans’ rank correlations significant group differences. Interpreted according to Altman’s classification [5].
and should be increased in future research. Further, the more proximal joints should also be included in the analyses.

Effects of progressive resistance or high-intensity strength training on muscle function and Achilles tendon mechanical properties in children with cerebral palsy

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¹University of Graz, Graz, Austria, ²Medical University of Graz, Graz, Austria

Introduction: Muscle weakness is one of the negative symptoms in children with spastic cerebral palsy (SCP). Progressive resistance training (PRT) has been proved to increase muscle strength in these patients [1], however, its effect on muscle-tendon properties is still not clearly understood. There is evidence that PRT leads to increased tendon stiffness in healthy children [2], whereby high-velocity strength training was more effective in improving knee extensor muscle morphology and function in children with SCP when compared to low-velocity training [3]. These findings give reason to expect also adaptations in the tendon properties following high-velocity strength training. Overall, the possible different effects of PRT or high-intensity circuit training (HICT) on Achilles tendon properties and muscle strength in children with SCP are not well understood. Therefore, the aim of this study was to investigate the effects of functional PRT and HICT respectively on Achilles tendon mechanical properties and muscle strength of the plantar flexors in children with SCP.

Research Question: Do functional PRT and HICT lead to adaptations in Achilles tendon mechanical properties and improve muscle strength of the plantar flexors in children with SCP?

Methods: Twenty-one diplegic or hemiplegic children with SCP (GMFCS level I and II) were randomized to an 8-week home-based PRT or HICT-group. Both training programs were performed 3-times a week and comprised 3 sets of 5 identical functional lower limb exercises. In the PRT-group, load was progressively increased by means of a weight vest if more than 12 repetitions were performed on 3 consecutive days. In the HICT-group, exercise load was defined by the number of repetitions, which were performed within a 30s interval and was increased if a child was able to perform 2 additional repetitions. Achilles tendon mechanical properties (e.g. stiffness and Young's modulus) and maximum isometric torque were measured before and after the interventions. Two-way repeated measures ANOVA including post-hoc comparisons and non-parametric tests in case of not normally distributed data were performed.

Results: Intervention compliance in the PRT and HICT-group was 85% and 87%, respectively. Absolute peak torque and Achilles tendon stress increased significantly only in the HICT-group (28% and 21%, respectively). Achilles tendon mechanical properties (Table 1) did not change and did not differ significantly between groups.

Table 1 Pre-and Post-training peak torque and tendon mechanical properties (mean ± SD)

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<th>Peak elongation (mm)</th>
<th>Peak strain (%)</th>
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<td>PRT</td>
<td>Pre</td>
<td>37.4 ± 26.5</td>
<td>9.4 ± 4.5</td>
<td>5.1 ± 2.5</td>
<td>14.8 ± 7.7</td>
<td>62.1 ± 27.2</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>35.2 ± 23.7</td>
<td>10.5 ± 6.2</td>
<td>5.9 ± 3.3</td>
<td>13.5 ± 6.5</td>
<td>45.0 ± 31.3</td>
</tr>
<tr>
<td>∆ (%)</td>
<td></td>
<td>-5.9</td>
<td>11.7</td>
<td>15.7</td>
<td>-8.8</td>
<td>-27.5</td>
</tr>
<tr>
<td>HICT</td>
<td>Pre</td>
<td>43.8 ± 26.4</td>
<td>9.9 ± 5.8</td>
<td>5.0 ± 3.0</td>
<td>15.4 ± 8.5</td>
<td>57.0 ± 25.1</td>
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<tr>
<td></td>
<td>Post</td>
<td>55.9 ± 36.7</td>
<td>10.9 ± 6.0</td>
<td>5.6 ± 3.0</td>
<td>18.7 ± 11.1</td>
<td>52.0 ± 28.0</td>
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<tr>
<td>∆ (%)</td>
<td></td>
<td>27.6</td>
<td>10.1</td>
<td>12.0</td>
<td>21.4</td>
<td>-8.8</td>
</tr>
</tbody>
</table>

PRT, progressive resistance training; HICT, high-intensity circuit training. *Significant difference (p≤0.05) pre-post.
**Discussion:** In contrast to classical PRT, HICT with functional exercises resulted in increased strength in children with SCP. Therefore HICT might be favourable to improve strength capabilities in these patients. However, following 8 weeks of training, no changes in the tendon mechanical properties could be observed. Hence, we assume that the stimulus to change the tendon’s properties was not intense and/or not long enough.

Old adults explore multi-joint covariation patterns to execute sit-to-stand safely.

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Introduction: Standing up from a chair or bed is a frequent activity of daily life and requires sufficient muscle strength, power and balance [Hughes 1994; Riley 1991]. Due to the age-related decline in muscle strength, power, and joint angle coordination abilities, old adults often have difficulties during sit-to-stand tasks (sts) and adapt a strategy that matches individual abilities [Mehr 1993; Hughes 1994]. Such an age-related adaptation in sts strategy is possible because abundance in the number of involved joints provides the neuromuscular system with flexibility to perform the same sts task with different joint angle configurations [Scholz 1999; Latash 2007]. Indeed, old compared to young adults execute sts by using a larger range of the available joint configurations [Greve et al 2013]. Here, we examine the idea that this increase in motor flexibility reflects an exploration process to find those motor solutions that guarantee safe chair rise while performing at the limits of the available strength and balance capacities.

Research Question: Do healthy old as compared to young adults explore a larger range of the available joint angle configurations when standing up from a chair under high force and balance demands? Based on preliminary work [Greve et al 2013] and the well-documented age-related deficits in muscle strength and balance abilities we expected that motor flexibility increases in old but not young adults with an increase in a) force, b) balance and c) force and balance demands.

Methods: To establish how old as compared to young adults employ the available range of motor solutions we subjected joint position data to a combined permutation and uncontrolled manifold (UCM) analysis [Yen 2010; Cluff 2012]. The sagittal plane CoM position was the performance variable. In the combined UCM and permutation analysis we decomposed trial-to-trial variability in the joints into multi-joint covariation patterns keeping the CoM position on the mean value (GEVCOV) and multi-joint covariation patterns causing variability of the CoM position around the mean (NGEVCOV). Furthermore age differences in sit-to-stand strategies, sagittal plane joint kinematics, agonist-antagonist coactivation, muscle strength (handheld dynamometry) and functional capacities (SPPB) were established.

Results: Repeated measures ANOVA revealed a significant interaction effect between variability (GEVCOV and NGEVCOV) and age (p=.036). Post hoc analysis showed that healthy old as compared to young adults explored a larger range of multi-joint covariation patterns and this larger covariation was characterized by NGEVCOV (p = .038; t25=2.2; old: .039±.12, young: -.059±.11). The larger NGEVCOV was independent of the strength or balance demand of the sit-to-stand task. The across trial standard deviation of the sagittal plane CoM position at lift-off was similar between age-groups. Furthermore the old as compared to young adults were significantly weaker but had similar functional capacities, performed the sts movement slower with more peak trunk flexion at lift-off. These age-differences in physical capacities and sit-to-stand strategy were similar to those reported previously.

Discussion: Our findings show that during repeatedly executed sit-to-stand tasks healthy old adults explored a larger range of those multi-joint covariation patterns allowing small variations of the whole body CoM position at lift-off (NGEVCOV). We suggest that this larger NGEVCOV reflects an exploratory process employed by the old adults to find a CoM position at lift-off that allows them to execute the chair rise safely near the maximum strength capacities.

Gait Profile Score in post-stroke subjects accounting for the effect of gait speed.

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**Introduction:** The Gait Profile Score (GPS) measures the quality of an individual's overall walking pattern [1] and has been widely applied in Clinical Gait Analysis. Despite walking speed affecting gait patterns, and individuals with pathology tending to walk slower than the able bodied, the assessment of the gait pattern commonly uses a reference dataset without considering the influence of the gait speed. Therefore, the aim of this study was to develop a speed adjusted GPS in healthy individuals and test this novel method on post-stroke individuals.

**Research Question:** Does the newly speed adjusted GPS provide a more unbiased estimation of the individual's gait pattern compared to the original GPS?

**Methods:** Sixteen subjects who had a history of stroke (age: 63.5±9.8 years) and 15 age-matched able-bodied (age: 59.2±5.7 years) subjects participated in the study. The stroke group subjects had to walk on barefoot, at their comfortable speed, on a 10 m walkway. The control group performed overground walking trials at their comfortable speed, and at 30% faster and 30% slower. In addition, they walked on the treadmill at eight different gait speeds. Quadratic equations to predict the average control subjects' kinematic data as a function of dimensionless gait speeds at each of the 51 time-normalized points of the gait cycle and for the 15 kinematic variables were derived. Comparison of overground walking with the treadmill based predictions validated this approach in the able-bodied cohort at different walking speeds. A modified score (GPS\(^v\)) was then defined analogously to the GPS but using the predicted speed-matched control data as a reference rather than those captured at self-selected speed. Both GPS\(^v\) and GPS were then calculated for the stroke patients.

**Results:** The post-stroke subjects walked slower than the control group (post-stroke: 0.28±0.09, control: 0.42±0.06, \(p<0.001\)). The values of GPS and GPS\(^v\) of each post-stroke subject are shown in Figure 1. Larger differences between GPS and GPS\(^v\) were found in subjects that walked at slower speeds. In contrast, subjects that walked at similar speed than the control group presented smaller differences. The average across post-stroke subjects was 7.8° for the GPS\(^v\), and 8.2° for the GPS.

![Graph showing differences between GPS and GPS\(^v\)](image)

**Discussion:** Overall, the difference between the GPS and GPS\(^v\) in post-stroke subjects was relative small (0.4°). It seems that the gait speed does not influence the interpretation of the quality of the gait pattern for this specific group. This is probably because less severely affected stroke survivors tend to walk reasonable quickly leading to little need for correction for walking speed whereas in more severely affected survivors the differences from normal are so large that this dominates the smaller speed related effects.

**Acknowledgments:** Claudiane is thankful to FAPESP for her scholarship (#2014/13502-7).

The effects of Automated Mechanical Peripheral Stimulation in functional mobility and neuroplasticity of subjects with Parkinson’s Disease: a Hierarchical Cluster Analysis.

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Introduction: Automated Mechanical Peripheral Stimulation (AMPS) treatment has been investigated as a complementary therapy to improve gait performance in subjects with PD¹,²,³. A single session of AMPS treatment is able to modify the resting state functional magnetic resonance in regions as the sensory-motor cortex, nucleus striatum and cerebellum³. The enhancement of brain connectivity in these areas would be related to the functional mobility improvement and the increase of BDNF. Indirectly, a better functional mobility performance might, indirectly, lead to reductions of Cortisol levels. To test this hypothesis a Hierarchical cluster analysis (HCA) model was applied.

Research Question: Could the HCA distinguish if there are differences between the effective AMPS and placebo groups?

Methods: Thirty subjects with PD were randomized into two groups: effective stimulation (AMPS, N=15; HY:2.93±0.70; UPDRSIII: 24.69 ±7.80) or placebo stimulation (SHAM AMPS, N=15; HY: 2.59±0.82; UPDRSIII: 25.13 ±10.31). Each group received eight sessions of treatment. AMPS was delivered by Gondola™ (Gondola Medical Technologies SA, Switzerland). Patients referring to Placebo Group were treated with placebo (SHAM) AMPS using a steel stick with a larger diameter (12mm). Both PD groups were treated 8 times once every 4 days. All the PD patients were treated in the off-levodopa phase. Blood samples for measurements of blood variables were taken from the antecubital vein at rest in the morning hours between 7–9h a.m. in the fasting state. Serum BDNF (Promega, USA) and serum cortisol (Monobind Inc., USA) were analyzed by Enzyme-Linked Immunosorbent Assay (ELISA) following the manufacturer’s recommendations. Gait parameters and Timed Up and Go (TUG) test was assessed by an inertial sensor (BTS G-WALK). HCA approach was used to determine group sets of similar features and homogeneous clusters among the subjects with PD for both groups. The input data for HCA were the post 8 sessions of the therapy data for: gait velocity [m/s], stride length [m], TUG time [s], cortisol [μcg/dL], BDNF [pg/mL] and UPDRSIII.

Results: The final cluster solution was set at two clusters (0.02747 based on average linkage distances). This decision was confirmed by the cophenetic correlation coefficient of 0.6858 and by the inconsistency coefficient of 1.1528 for the link of the two-cluster solution, and also by visual inspection of the dendrogram (Figure 1). The Cluster 1 (C1 - BLUE) is composed by 10 patients being 9 from the SHAM AMPS group and 1 from the AMPS group; the Cluster 2 (C2 - RED) has 20 patients with PD being 14 from the effective AMPS group and 6 from the placebo group.

Conclusion: The HCA was able to find differences between effective AMPS and placebo groups. These results can be
explained by previous studies whose have demonstrated that AMPS improves the clinical parameters and enhances the spatiotemporal gait parameters.


Discussion:

References:

Functional sit-to-stand exercises evoke greater neuromuscular activation, than isometric bed exercises in community-dwelling, older adults

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Introduction: Rehabilitation after hip-replacement surgery routinely includes isometric bed exercises. However, these have little impact on pain, hip motion, strength and functional mobility [1]. Sit-standing is required for mobilisation and discharge, involving: asymmetrical weight-bearing, stability and concentric-eccentric hip muscle contractions. Therefore, sit-stands may be a preferential exercise to bed exercises in the hours after hip-replacement surgery.

Research Question: Is muscle activation of the hip and thigh muscles greater during isometric bed exercises, than sit-stands in older adults?

Methods: 24 participants performed: isometric bed exercises and sit-stand exercises (random-order) on one occasion. Bed exercises were ten submaximal contractions (each 5 s) separately for gluteal, abductor, quadriceps and inner range quadriceps muscles (60 s rests). Sit-stands involved chair rising to an upright position (sit-stand), then returning to a seated position (stand-sit) as many times possible within 30 s. Electromyograms (EMG) were recorded from the rectus femoris, vastus medialis, gluteus medius, biceps femoris and gluteus maximus, via a Biometrics PS850 system, during exercises. Signals were normalised to % of isometric maximal voluntary contraction, with separate analysis for standing and sitting phases. One-way, Friedman's repeated measures ANOVA identified activation differences between each muscle during exercise modes. Paired Wilcoxon Signed-Rank tests located specific activation differences.

Results: Quadriceps activation ranged from: 2-60% for bed exercises and 54-81% for sit-stands (quadriceps); 10-20% for bed exercises and 27-45% for sit-stands (hamstrings); 10-44% for bed exercises and 34-59% for sit-stands (gluteals). Vastus medialis activation was greater sit-standing, than gluteal (by 65%; p<0.0001), abductor (by 60%; p<0.0001) and inner range quadriceps bed exercises (by 36%; p<0.0005). Biceps femoris activation was greater sit-standing, than gluteal (by 29%; p=0.01), abductor (by 36%; p<0.0001), inner range quadriceps (by 34%; p<0.0001) and quadriceps bed exercises (by 24%; p=0.04). Gluteus maximus activation was greater sit-standing, abductor (by 46%; p<0.0001), inner range quadriceps (by 50%; <0.0001) and quadriceps bed exercises (by 44%; p<0.0001). Gluteus medius activation was greater sit-standing, than inner range quadriceps (by 30%; p<0.0001) and quadriceps bed exercises (by 22%; p=0.01); chair rising activation exceeded sitting activation (by 19%; p=0.03).
**Discussion**: Hip and thigh muscles were activated differently between isometric bed and sit-stand exercises, with rising during the sit-stand requiring greatest activation. For no bed exercise did muscle activity exceed that required to chair rise. All muscles were activated over 40% only for sit-stands; the level required stimulating muscle strength adaptation [2]. A larger, subsequent study will examine these observations in patients recovering from total hip-replacement surgery, and determine functionally how they relate to gait performance and balance. If similar results are found, practice could change to replace bed exercises with sit-stands and other functional exercises in the acute recovery after surgery.

The Walk Ratio: Gender differences or height differences?

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1University of Bergen, Bergen, Norway, 2Western Norway University College of Applied Sciences, Bergen, Norway

Introduction: The relationship between step length and cadence, often called the Walk Ratio (WR) has been suggested to be invariant across walking speeds, reflecting an optimal balance between forward propulsion and energy expenditure. The WR has been referred to as an indicator of impaired central control during walking, and may prove to be a useful tool to identify gait pathology. In previous studies, gait characteristics such as stride length (lower among women) and cadence (higher among women) have been found to differ between genders. However, it remains unclear how this would affect the WR. Further, as men tend to be taller than women, and both step length and cadence are height dependent, the role of stature should be investigated.

Research Question: Does the WR differ between men and women after adjusting for body height?

Methods: The participants were community-dwelling volunteers aged 70-80 years who were tested at a university gait laboratory. They walked a distance of 10.5 meters, with gait characteristics captured by a body-worn sensor for the middle 6.5 meters. The participants walked under four conditions: i) preferred speed, ii) fast speed, iii) dual task (DT) and iv) uneven surface (US). WRs were calculated as step length/cadence. Both step length and cadence were normalized using the following formulas:

Step length = (step length/height) * (average height)
Cadence = Cadence * (height/average height)^1/2

Men and women were compared using t-tests for independent samples.

Results: The sample consisted of 70 men and women (60 percent women, average age 75.5 years, SD 3.4). Unadjusted WRs were significantly different between men and women for all walking conditions while significant differences disappeared when WRs were adjusted for body height, except for fast walking.

<table>
<thead>
<tr>
<th></th>
<th>WR men</th>
<th>WR women</th>
<th>P-value</th>
<th>WR men</th>
<th>WR women</th>
<th>P-value</th>
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</thead>
<tbody>
<tr>
<td>Pref.</td>
<td>0.65</td>
<td>0.56</td>
<td>≤.001</td>
<td>0.61</td>
<td>0.58</td>
<td>.092</td>
</tr>
<tr>
<td>Fast</td>
<td>0.65</td>
<td>0.54</td>
<td>≤.001</td>
<td>0.61</td>
<td>0.56</td>
<td>.002</td>
</tr>
<tr>
<td>DT</td>
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<td>0.64</td>
<td>.021</td>
<td>0.70</td>
<td>0.67</td>
<td>.494</td>
</tr>
<tr>
<td>US</td>
<td>0.64</td>
<td>0.56</td>
<td>≤.001</td>
<td>0.61</td>
<td>0.58</td>
<td>.189</td>
</tr>
</tbody>
</table>

Discussion: Gender differences disappeared when the WR was adjusted for height. The WR may be a promising feature for identifying gait pathology. However, adjusting for body height seems prudent, as results may otherwise be misleading.

References:
A randomized controlled trial on providing ankle-foot orthoses in the early rehabilitation after stroke: the kinematic effects

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Introduction:

Regaining walking ability is an important goal in rehabilitation post-stroke. Ankle-foot orthoses (AFOs) are often prescribed after stroke and are found to improve ankle kinematics [1]. Most research studying AFO-use after stroke included chronic stroke patients, of which many were already using an AFO in everyday life. One may argue that in these subjects the effect of removing an AFO is tested. However, studying the actual AFO-provision early after stroke is more in line with daily clinical practice, which warrants for research studying the effect of actual AFO-provision. Furthermore, studies focusing on the optimal timing of AFO-provision after stroke are missing. This is important as one may speculate that for example the development of compensatory strategies in proximal lower limb segments may decrease when foot-drop in the distal segment is limited in an early stage because of early AFO-provision. Therefore, we conducted a randomized controlled trial to study the effects of providing AFOs on two different moments in the rehabilitation post-stroke.

Research Question:

1) To study the short-term effects of the actual AFO-provision in subjects early post-stroke; and
2) to study whether timing of AFO-provision influenced these effects.

Methods:

Unilateral hemiparetic stroke patients admitted to the rehabilitation center were included. Subjects were maximal six weeks post-stroke and an indication for AFO-use. Subjects were randomly assigned to AFO-provision: early (at inclusion) or delayed (eight weeks later). Three-dimensional gait-analysis with and without AFO was performed within two weeks after AFO-provision. The primary outcome measure was ankle dorsiflexion. Secondary outcome measures included hip and knee flexion, hip abduction and pelvic tilt and obliquity. All angles were calculated at initial contact, at foot-off and during swing. Furthermore, walking speed was measured.

Results:

Twenty subjects (8 early, 12 delayed) were analyzed. Gait analysis was performed 39.8 (9.1) and 90.2 (6.4) days after stroke in the early and delayed group, respectively. Ankle dorsiflexion at initial contact, foot-off and during swing improved after AFO-provision (-3.6° (7.3) vs 3.0° (3.9); 0.0° (7.4) vs 5.2° (3.7); -6.1° (7.8) vs 2.6° (3.5), respectively), all p<0.001. Knee (+2.3°) and hip flexion (+1.6°) increased at initial contact (both p≤0.001), no effects at foot-off or swing were found. Hip abduction, pelvic tilt and obliquity and walking speed were not affected by AFO-use. Furthermore, early or delayed AFO-provision did not affect results.

Discussion:

This study found kinematic changes after providing AFOs to subjects after recent stroke. Ankle angles changed from plantarflexion to dorsiflexion at initial contact and during swing. Minor effects were found for knee and hip flexion and no effects were found on hip abduction and pelvic movement. This means that in our study AFO-provision did not affect possible compensatory strategies around hip and pelvis like pelvic hiking or circumduction. The point in time at which an AFO was provided post-stroke, early (week 1) or delayed (week 9 of the study), did not influenced the effects of AFO-provision on the short-term. Whether or not long-term effects are present is subject for future studies.
References:

1. Tyson SF; 2013, Clin Rehabil.
Aging effects on muscle synergies during split-belt walking

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Introduction: People adapt their gait every day under different circumstances, e.g. are slowing down, speeding up, or reacting to sudden perturbations. With advancing age there are changes in the locomotor system, which affect the ability to adapt the gait. A way to study gait adaptations in a laboratory situation is by using a split-belt treadmill, a treadmill with two belts that can each run with different velocities. By suddenly changing the speed of one of the belts, participants have to adapt their gait to successfully walk on the split-belt. Previous split-belt studies have shown a decrease in adaptation performance in older adults compared to young adults, especially in the temporal parameters. Older adults have a reduced ability to change relative swing time in the gait cycle\textsuperscript{1,2}. One of the suggested underlying mechanisms of kinematic changes during split-belt walking is that the adaptations are bases on ipsi- and contralateral muscle activity patterns. In healthy young subjects 4 basic muscle activation patterns, with differed in the temporal organization has been suggested to underlay the split belt adaptation\textsuperscript{3}.

Research Question: Aims of the present study are 1) to examine the effect of split-belt walking on lower extremity muscle activity patterns and the temporal modulation of those patterns in the different phases of split belt walking; 2) to determine whether or not the muscle activity patterns and the temporal modulation of those patterns changes with age e.g. examine differential effects between young and old adults in number of components related to an identified synergy and the contribution of individual muscles to the synergy.

Methods: 24 healthy young (age range 20 – 30 y) and older (age range 50 – 60 y) participated. Participants walked on a M-Gait split-belt treadmill (Motekforce Link, New York, USA) with embedded force plates. During split-belt walking there were three phases. 1) Baseline phase: walking at symmetric speeds of 1.4 m/sec and 7 m/sec for 3 min, = directly followed by 2) the adaptation phase: asymmetric split-belt walking for 10 minutes with the fast belt at 1.4 m/sec and the slow belt at 0.7 m/sec) and finally ended by 3) post adaptation phase: a symmetric condition of 6 min walking at. 0.7 m/sec with tied belts. Ground reaction forces and electromyography (EMG) was collected from 8 lower limb muscles on each side of the body. Nonnegative matrix factorization (NNMF) was applied to identify underlying temporal patterns in the EMG recording. Muscle activation patterns obtained during the baseline (last 10 strides), early adaptation (first 10 strides) and late adaptation (latest 10 strides) phases were compared using a cross-correlation analysis. Differences between young and older participants in muscle synergies and contribution of muscles to the identified patterns were examined.

Results: In young and older adults 4 modes (> 90%) represented temporal muscle activation during split-belt walking in all phases. The temporal shifts in the muscle activation patterns were related to the time of push-off in the fast limb and heel contact in the slow limb during. Age effects were found in the shift in the contribution of the muscles loadings from distal to more proximal muscles during the adaptation phase.

Discussion: With advancing age the ability to directly adapt the gait pattern is changed. Although older adults similar to younger adults are capable to adjust their gait pattern to split-belt walking they use a different muscle synergy especially in the early adaptation phase. These changes might be explained by a age related deteriorating in proprioception, an increased co-contraction of lower-extremity muscles and/or a shift from a more distal to proximal muscle control to increase stability.

References:

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2) Vervoort et al., 2017 subm. Gait Posture
3) MacLellan, et al., 2014, J Neurophysiol;111:1541 - 1552
Changes in physical activity during hospital stay for patients after stroke

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Introduction:

Early mobilization has proven to be an important factor in stroke treatment while hospitalized [1]. However, too early and too intense mobilization may cause unfavorable outcome 3 months later [2]. Hence, there is a need for more research to get a deeper understanding of physical activity during the initial hospital stay in patients after stroke.

Research Question:

Will physical activity change over 3 to 7 days post stroke for patients admitted to a comprehensive stroke unit?

Methods:

58 patients diagnosed with acute ischemic stroke were included within one week post stroke. Two activity monitors (ActivPAL Professional sensor system from PAL Technologies Ltd) were attached, one at the middle part of sternum and one at the unaffected sides’ thigh up to one week or until discharged, to continuously during 24 hours monitor physical activity. Data from the two sensors were processed in Matlab R 2015B, and coded to get information about time in lying, sitting, and upright position and time/transition ratio for both sitting and standing per day. Time effect over one week was analyzed using Friedmans test.

Results:

There were relatively large between-patients variations within each day for both sitting time (IQR 3.9-10.7 hours) and time in an upright position (IQR 0.3-1.0 hours). Median time spent sitting increased from 31 % to 45 % throughout the week, while median time in an upright position remained roughly the same, (4.2-4.5 %). Time/transition ratio for sitting increased during the first week, whereas time/transition for standing remained about the same throughout the week. Patients with complete measures for 7 days (n=30) showed significant time effects with increased time spent both sitting (p=0.01) and upright (p=0.03) from the first to the seventh day.

Discussion:

Patients spent less than 10% of a 24-hour period in an upright position. The increased time in sitting throughout the week correspond well with previous findings, but our findings regarding time standing are less than previously fund. This is reflected in time/transition ratio, with only ratio for sitting increasing throughout the week. However, as far as we’re concerned, this is the first time continuous measurements have measured actual time in activity in the acute phase post stroke.

References:

SURFACE EMG ANALYSIS IN PARKINSON DISEASE PATIENTS BEFORE AND AFTER UNDERWATER GAIT TRAINING

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Introduction: Parkinson’s disease (PD) is a progressive neurological condition, characterized by a dopamine deficiency causing tremor, rigidity, bradykinesia and gait problems mainly arising from dopamine deficiency [1]. Gait disturbance is a key component of motor disability in PD patients, therefore there is a wide literature describing their walking abnormalities, most often carried on through motion analysis techniques [2]; despite this, works focused on surface emg (Semg) analysis are lacking. Hydrotherapy (Ht) has been proposed as an innovative rehabilitative strategy for the treatment of motor symptoms and quality of PD. In particular water buoyancy abolishes gravity thus reducing the weight that joints, bones, and muscles have to bear; consequently, an underwater training allows early active mobilization and dynamic strengthening.

Research Question: this work aims to evaluate improvements in muscular activation in 10 PD patients before and after a Ht program, and compared their results to a group of healthy subjects (Control group=CG).

Methods: 20 subjects participated in the study divided in two groups: PD patients (mean ± standard deviation (SD) BMI: 28±3, age: 71±6 years), and CG (mean ± standard deviation (SD) BMI:28±3, age: 65.5±7 years). Subjects were asked to walk barefoot at their preferred walking speed in the gait laboratory of GVDR (Cadoneghe, Padova, Italy). Several walking trials per subject were collected. The electrical activity of 8 muscles for each lower limb were collected by means of a portable Semg system (FREEEMG1000, 1000 Hz, BTS Padova) together with the ground reaction forces. Surface EMG signals of the following muscles were recorded: Rectus Femoris (RF), Tibialis Anterior (TA), Bicipes Femoris (BF) and Gastrocnemius Lateralis (GL). Sensors were positioned according to Blanc and Dimanico [3] after appropriately cleaning and preparing the skin. Sensors were 3 cm of diameter and positioned 1 cm apart. The right and left muscle activation patterns were analyzed and the envelope of the signal computed (the peak (POP) and the position of the peak with respect to gait cycle (POP%) were extracted [4].

Results: Before Ht PD patient showed earlier POP% of all muscles analysed, no significant differences were observed on POP. After Ht only BF maintained its earlier activation, meanwhile all the other muscles reported values similar to CS. Paired T test between variables before and after Ht in PD groups showed a delayed POP in post
In respect to pre Ht and confirmed results of the Independent T test between groups. In the comparison between pre and post Ht POP a higher activation of all muscles acquired were observed except for GL.

**Discussion**: these results showed that Ht have positive effects on muscles activation timing in PD patients. With this respect Ht seems to help them in the reorganization of the muscle’s recruitment pattern, with the exception of BF. This is probably due to the fact that its altered activation is caused by the hip excessive flexion which is a characteristic of PD patients. Therefore it could be hypothesised that a longer rehabilitation activity is needed to restore its functionality. These results may impact positively on the development of Ht treatment for PD.

References:

Reliability of gait speed in children – effects of instruction, distance and age.

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Introduction: Gait assessment is a major component in the evaluation of children with disabilities, both in form of in-lab gait analysis and walking capacity tests. There is however an extensive methodological variability in the literature on gait assessment including instructions, speed, and distance covered (Graham et al, 2008). Since several gait parameters are speed dependent (Schwartz et al, 2008), this variability complicates the comparison of gait parameters across gait tests. Research examining how differences in walking distance and instructions affect walking speed reliability, especially in children is limited.

Research Question: The purpose of this study was to examine the effect of walking distance on gait speed following different instructions in children between 7 and 15 years of age.

Methods: 55 children (26 boys and 29 girls) with an even age distribution between 7 and 15 years performed 25 m gait tests and 5 minutes capacity tests following 5 different instructions (walk as you normally do, walk slower than you normally do, walk faster than you normally do, jog and run). Average speeds over the 25 m track and for each minute of the 5 minutes test were calculated. Repeated measures ANOVA were performed to assess the effect of instruction, time (duration) and age on walking speed and ICC was performed to evaluate absolute agreement between average speed of the 5 minutes capacity tests and 25 m gait tests for all instructions.

Results: Within the 5 minutes capacity test we found a main effect of instruction on speed ($P<0.05$) and an interaction effect of age ($P<0.001$). There was however no effect of walking time on speed ($P=0.150$) and no interaction with age ($P=0.267$) (fig 1).

Between the 5 minutes capacity tests and the 25 m gait tests we found a significant effect of instruction ($P<0.001$) and a significant interaction with age ($P = 0.009$) (fig.1-3).

The reliability between tests was moderate for all instructions, with walking fast showing the lowest (ICC= 0.494 (95% CI 0.11 to 0.71)) and running the highest (ICC= 0.689 (95% CI 0.02 to 0.88)) reliability.

Discussion:

The reliability of walking speed between the 25 m gait tests and the 5 minutes capacity tests were only moderate. The differences between tests were dependent on both speed and age. Normative values across a range of speeds and ages should be identified in order to make relevant comparisons between gait tests.
Correlation between the Gait Profile Score and standard clinical outcome measures in children with idiopathic clubfoot.

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Introduction: In this study, we evaluate the usability of measures of overall gait deviations, in children with idiopathic clubfoot; the Gait Profile Score (GPS) and the gait Variable Scores (GVS)[1]. In clinical settings, gait deviations are often visually assessed and classified according to severity using structured protocols such as the Clubfoot Assessment Protocol (CAP)[2]. However, the relationship between measures of overall gait deviations and clinical assessments are still to be determined.

Research Question: How do gait deviations determined in an overall index based on three-dimensional kinematics correlate to gait deviations assessed by visual clinical assessment in children treated for clubfoot.

Methods: A cohort of 22 consecutively born children with idiopathic clubfoot were eligible. At the age of 7 years, they were referred for three-dimensional gait analysis (3D-GA). Three representative gait cycles from each affected foot were used. Based on the gait analysis results, the overall gait deviations, expressed as mean GPS (overall and affected side) were calculated for each foot separately, as well as the mean GVS for ankle dorsal/plantar flexion and foot internal/external rotation. On the same day, the children also underwent a clinical assessment according to the CAP, a valid and reliable instrument in clubfoot follow-up. CAP is divided into four domains, each including several items, assessing different aspects of clubfoot pathology including gait deviations. The scores for CAP (affected side and total), the four CAP domains and the CAP item “walking” were correlated to GPS. The item “walking” was furthermore analysed in its relation to selected GVSs. Correlations were considered a priori and analyzed using the Spearman correlation coefficient (r).

Results: In total, 20 children (three girls and 17 boys, ten unilateral and ten bilateral) accepted to participate. The mean age at gait analysis and CAP follow-up was 7 years (SD 3.4 months). As hypothesised a priori significant correlations were found between the CAP affected side/total and both GPS affected side (r=-0.41, p< 0.05) and GPS overall (r=-0.47, p< 0.01). The CAP domain morphology was correlated to the GPS overall (r=-0.5, p< 0.01). Most important, the score from the CAP item walking was significant correlated with GPS affected foot (r=-0.50, p< 0.01), GPS overall (r=-0.40, p< 0.05) as well as the GVS for foot rotation (r=-0.50, p< 0.01) and foot dorsiflexion/plantarflexion (r=-0.47, p< 0.01).

Discussion: As expected, higher correlations were found between foot related variables from gait analysis and CAP. The findings of this study indicate that the GPS index with GVS could be used in clubfoot follow up, to objectively assess treatment outcome.

Case-control study to identify deviations in gait and physical examination in children and adolescents with Dravet syndrome

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Introduction: Dravet Syndrome (DS) is a severe infantile onset epilepsy syndrome with a prevalence of 1/30,000. Developmental delay, also in gross motor function, becomes a serious concern during the second year of life [1]. Scarcely literature based on mere clinical or observational data suggests that more than half of the patients aged >13 years have developed a crouch gait [2-4]. Furthermore, Rodda et al. identified structural deformities of the lower limbs in DS and hypothesized that they contribute to the development of the observed pathological gait pattern [2].

Research Question: Which deviations can be identified using instrumented 3D gait analysis, including comprehensive physical examination (PE) in children with DS?

Methods: 3D gait analyses (Vicon T10, 100 Hz, Nexus 1.8.5 software, VCM) including PE for range of motion, alignment and foot deviations was performed on 16 patients with DS, aged 3-23 years (mean age 12.36 ± 5.74 years). Lower body joint angular time profiles in the DS group (in red) were compared to those of age- and gender-matched typically developing children (TD, in black) by paired samples t-test using statistical parametric mapping (* = p < 0.05).

Results: SPM revealed significant differences for hip (p=0.006), knee (p=0.003) and ankle (p<0.001) in the sagittal plane at the end of stance as well as for the ankle in the transverse plane (p=0.003) over the entire gait cycle. PE revealed mild hamstrings shortening (popliteal angle between 50° and 70°) in 6/15, excessive dorsal flexion (≥ 25°, knee 90°) in 9/16, slightly increased femoral anteversion (30°) in 8/15 and pes planovalgus in 13/16 patients.

Discussion: The gait deviations in the sagittal plane and structural deformities reported by Rodda et al. were also observed in this study. Based on 3D gait analysis and SPM, a gait pattern with increased hip and knee flexion as well as ankle dorsal flexion was observed. However, this was not the typical crouch pattern as observed in CP, as the sagittal plane deviations are not present in early stance but are concentrated at the end of stance phase. An explanation for this increased flexion in the sagittal plane can be found in the PE that reveals hypermobility in dorsal flexion which might compromise second rocker. On the other hand, hamstrings shortening seems not to be of this kind that it introduces increased knee flexion at initial contact and early stance.
Although femoral anteversion was slightly increased, no rotational deviations were found proximally. However, increased ankle external rotation over the gait cycle as well as high presence of planovalgus warrant further investigation of their impact on gait. From this preliminary study, we can conclude that clear gait deviations are seen in children with DS. However, to fully understand the cause and clinical impact, in depth analysis of all gait parameters, including kinetics and muscle activation patterns in a larger cohort are needed.

Mechanisms to improve foot clearance while stair ascending in patients with bilateral spastic cerebral palsy and stiff knee gait

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Introduction: Due to the limited knee range of motion (ROM) a main problem of patients with cerebral palsy (CP) and stiff knee gait is to achieve adequate foot clearance while walking on even ground [1]. It was shown that patients with stiff knee gait improve their foot clearance mainly by increasing knee flexion while walking on uneven ground [2]. Stair climbing as an activity of daily life and part of the GMFCS [3] requires a much higher foot clearance than walking on even ground, but little is known about how in detail involved patients manage this task.

Research Question: Which compensatory mechanisms are used by patients with bilateral spastic CP and stiff knee gait to maintain foot clearance while ascending stairs?

Methods: 17 adults (PAT; ø 34y) with bilateral spastic CP (GMFCS II-III) and stiff knee gait (15 bilateral, 2 unilateral) as well as 24 healthy subjects (HS; ø 32y) underwent 3D-motion-analysis while walking on even ground and ascending a staircase using the step-over-step strategy. Mean and standard deviation of maximum joint angles in sagittal and frontal plane of 32 stiff and 48 healthy legs in swing phase (Sw) and stance phase (St; contralateral plantar flexion) were calculated. Further, the difference between maximum joint angles in level walking and ascending stairs was compared in PAT versus HS. Data was analysed by linear mixed models.

Results: All patients were able to ascend stairs and used the handrail at least one-sided. A significant increase in cranial pelvic obliquity (p=0.006), hip abduction (p=0.007), hip flexion (p<0.001) and knee flexion (p<0.001) was shown by patients during stair ascend compared to level walking (Tab.1). The difference of ankle plantar flexion (1.8°; p=0.002), hip abduction (3.1°; p<0.001) and knee flexion (29.6°; p=0.020) between level walking and ascending stairs was significant higher in patients than in healthy subjects. Patients showed a significant increase in sagittal knee ROM among the gait cycle of 29.1°±12.4° (25.8° level to 54.9° stairs) while HS showed a significant increase of 15.0°±6.0° (64.7°level to 79.7°stairs).

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Tab. 1: Mean and standard deviation of maximal joint angles in level walking and ascending stairs in healthy subjects (HS) and patients with stiff knee gait (PAT) *= significant change in ascending stairs versus level walking
**Discussion:** Patients with limited peak knee flexion in swing on even ground showed a much higher peak knee flexion while ascending the stairs and were closer to the norm values, indeed. Thus, this mechanism may be seen as the main compensatory mechanism for maintaining foot clearance in stair ascending. Other compensatory mechanisms like circumduction (hip abduction and cranial pelvic obliquity) or contralateral ankle plantar flexion [1] were used as well. In further studies it might be interesting to investigate the fact that patients with stiff knee gait, who obviously are able to flex their knees even more than it would be required for normal walking, do not use this in level walking. Maybe the difference in knee angular velocity comparing level walking (fast bending) to stair ascending (slow bending) has an influence on peak knee flexion. This knowledge might be useful to open up new therapeutic options to facilitate level walking in patients with CP and stiff knee gait.

Classification of joint gait patterns in children with hereditary spastic paraplegia

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Introduction: Children with hereditary spastic paraplegia (HSP) often present with movement patterns that are similar to those of children with spastic diplegic cerebral palsy (CP) [1]. Up till now, there is a wide variety of gait classification systems aimed at characterizing CP gait [2]. On the contrary, gait deviations in HSP have not yet been thoroughly explored. A gait classification system could potentially improve communication between health care providers by fine-tuning the diagnosis and ultimately assist in assessing treatment outcome or prognosis of ambulation [1,3].

Research Question: Is a joint pattern classification system developed for children with CP also valid for children with HSP?

Methods: The retrospective sample of convenience consisted of 21 HSP patients (4 girls, 17 boys) who had not previously received botulinum toxin (BTX-A) injections or undergone lower limb surgery or intrathecal baclofen pump implantation. The average age was 8 years 8 months (range between 2 years 5 months and 16 years 8 months) and 17 patients walked without additional support. One representative trial per side was included for exploration. All trials were classified according to the gait classification by Nieuwenhuys et al. [3], which was found to be reliable and valid for children with CP [4–6]. The validity of this classification system in HSP children was tested by comparing the observed frequency of their joint patterns to that of 286 children with CP [6]. Specifically, patterns were compared based on whether they appeared similarly in the two populations (≤5%) or whether certain patterns were more frequently observed in either HSP or CP.

Results: Joint patterns of HSP patients were easily classifiable according to the rules of the chosen classification system. Only 1 pattern (insufficient prepositioning of the ankle in terminal swing) was not observed at all in HSP children, whereas other joint patterns were more prevalent in children with HSP (Table 1).

| Table 1. Comparison of observed frequency of joint patterns between HSP and CP children |
|------------------|----------------------------------|-------------------------------------|
| **Observed frequency** | **Similar (≤5%)** | **More prevalent in HSP** |
| Pelvis anterior tilt | Hip external rotation | Pelvis anterior tilt + IncrROM |
| Pelvis posterior tilt (+ IncrROM) | Foot minor deviations sagittal | Hip minor deviations sagittal |
| Hip continuous flexion | Foot outtoeing | Knee flexion at IC + earlier extension |
| Knee flexion IC | | Knee increased + delayed peak flexion |
| Knee HE (+ flexion IC) | | Knee decreased + delayed peak flexion |
| Knee minor deviations stance | | Horizontal second ankle rocker |
| Knee decreased peak flexion swing | | Ankle stance equinus gait |
| Reversed second ankle rocker | | Ankle minor deviations swing |
Discussion: This classification system appeared to be applicable for children with HSP. Out of the 49 joint patterns, 21 were similarly prevalent in both populations, whereas the remaining 28 patterns were more prevalent in HSP (n=13) or CP (n=15). This suggests that the differences lie within the individual characteristics of each disease, but are still prevalent in both groups (apart from 1 pattern). Previously, ‘recurvatum’ knee was more frequently observed in HSP than CP patients (n= 14 vs. n=1 respectively) [7], however, in the current sample, knee (hyper)extension was similarly frequent in both groups. Further research based on the different HSP diagnoses is needed to clarify these results and further validate the use of this classification system in children with HSP.

Which Part of the Triceps Surae Muscle Contributes More to Functional Foot Equinus in Spastic Hemiplegic CP Gait?

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Introduction: Equinus deformity is a common complication of patients who suffer from hemiplegic (unilateral) cerebral palsy. Surgical correction is required to restore foot dorsiflexion. Clinically the gastrocnemii part is usually shorter than the soleus. The general opinion is to spare the soleus and if possible focus on lengthening the gastrocnemii doing a vulpius or strayer procedure in order to preserve force of the plantarflexors and to avoid crouching.

Research Question: Does the muscle model calculation from inverse dynamics support the common concept?

Methods: All patients from the first cohort study where an Achilles tendon lengthening combined with a tibialis anterior shortening was performed (n = 12) were included and their data anonymised. Patients with too poor data were excluded (10 = patients remained). The data before and at the time for the long-term follow-up study were considered. The gait data were imported a slightly changed Lower Leg extremity Model of AnyBody Technology software. The mean of five trials for every patient was compared pre- to postoperative and to normal data (which was equally handled, n=10). Not overlapping standard deviation was considered significant. A muscle force (Fig.3) combined with a negative muscle shortening velocity (Fig.2) indicated a concentric, with a positive muscle shortening velocity an eccentric contraction.

Results: Ankle Dorsiflexion reaches a maximum of 0 degrees at 10% of stance phase preoperatively. Later in stance dorsiflexion decreases, indicating the foot going into equinus position. Postoperatively ankle dorsiflexion was very close to normal with a permanent and significant increase between 0% and 45% of stance phase (Fig. 1).

Preoperatively the function of the soleus muscle was concentric between 10% and 25%, opposite to normals (Fig. 2, arrow, Fig. 3), which changed to an eccentric contraction at the same phase postoperatively, corresponding to normals. The gastrocnemii muscles in contrast showed an eccentric contraction during 10% and 40% pre- and postoperatively and were not different from normals (Fig. 2,3).

Discussion: This modelling study shows a completely different muscle action of the soleus muscle compared to the gastrocnemii. Our data indicate that...
- the soleus muscle shows a more abnormal action than the gastrocnemii, and
- an Achilles tendon lengthening seems to be an adequate procedure to correct the abnormal soleus action.
Kinematics associated with a knee flexion gait pattern caused by isolated contracture of iliopsoas, hamstring and gastrocnemius.

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Introduction:
Excessive Knee Flexion Gait Pattern (KFGP) is a common gait deviation in many pathological conditions [1, 2]. The contractures of the muscle-tendon complex can lead to KFGP. Three muscles have been identified as possible responsible of KFGP: iliopsoas, hamstring and gastrocnemius [1, 3, 4].

Research Question:
The aim was to compare associated kinematics to a KFGP between isolated iliopsoas, hamstring and gastrocnemius contractures.

Methods:
Several levels of contracture (mild, middle and severe) were emulated bilaterally using an exoskeleton [5] on 10 healthy participants for iliopsoas, hamstring and gastrocnemius muscles. A gait analysis session was performed to evaluate the joint kinematics according to the different emulated contractures. Thirty one parameters were chosen to analyze the kinematics of the thorax, pelvis, hip, knee and ankle. A principal component analysis (PCA) was used to determine the kinematic parameters influenced by contractures. In order to have similar level of knee flexion between the different conditions (three different muscle contractures at three levels of severity), three groups of knee flexion were created based on the mean position of knee flexion during stance phase: (Group 1[20°-30°]; Group 2[30°-40°]; Group 3: [ ≥ 40°]). The effect on kinematics (based on parameters selected via PCA) of the three muscle contractures was compared using Kruskal-Wallis test in each group.

Results:
In addition to a permanent knee flexion observed with the 3 muscle contractures (Fig 1), the contracture of the iliopsoas induces a large hip flexion with pronounced anteversion of the pelvis; the contracture of the hamstrings induces an ankle dorsiflexion during the support phase with a retroversion of the pelvis; the contracture of the gastrocnemius induces an absence of first and second rocker of the ankle with a slight flexion of hip and a slight anteversion of the pelvis.
Fig 1: Mean kinematics for the pelvis, hip, knee, and ankle in the sagittal plane and foot progression according to the emulated contracture (iliopsoas, hamstring and gastrocnemius) and to the group of knee mean position in stance (“Group 1: 20-30°”, “Group 2: 30-40°” and “Group 3: 40° and more”). Solid line: mean kinematics; dashed line: standard deviation; blue line: iliopsoas; red line: hamstring; green line: gastrocnemius

Discussion:

Based on these results, it is possible to identify the muscles responsible for a KFGP. A better knowledge of this type of kinematics will support the interpretation of the gait analysis by targeting the altered muscle more precisely and faster.

References:

What determines in-toeing and out-toeing gait in asymptomatic adults?

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Introduction: Foot progression angle (FPA), measuring in-toeing and out-toeing gait, is a known risk factor of multiple pathologies of the lower limbs, such as osteoarthritis [1] and plantar ulcers in diabetic subjects [2]. However, it is not well known how FPA is related to morphological parameters of the pelvis and the lower limbs in asymptomatic adults.

Research Question: What are the differences in pelvic and lower limb morphologies between subjects walking with different foot progression angles?

Methods: 145 asymptomatic subjects (70F; age=29.2±11.1 years) underwent 3D gait analysis from which pelvis and lower limb kinematics as well as the FPA were extracted. Subjects then underwent full body low-dose biplanar radiographs. Pelvises and lower limbs were reconstructed in 3D, from which morphological parameters were calculated: pelvic incidence, sacral slope, pelvic tilt, acetabular coverage of the femoral head (AcetCov, in %), acetabular tilt, abduction and anteverision, neck-shaft angle, femoral torsion (FT), varus/valgus, knee flexion/extension, tibial torsion (TT), femorotibial rotation (FTR). FPA data were classified using agglomerative hierarchical clustering into 3 classes: internal, neutral, and external FPA. Demographic data (age, height, weight, and sex) were compared between classes using Kruskal-Wallis and Fisher exact tests. Morphological parameters and hip rotational kinematics (mean, ROM) were compared between the FPA classes using ANCOVA while controlling for demographic data, with REGWQ post-hoc comparisons.

Results: FPA varied from -28.7° to 3.1° (6 subjects with positive FPA). FPA classes were as follows: external (E) [-17° ±3°], neutral (N) [-9°±2°] and internal (I) [-3°±3°]. Weight (E: 79kg vs I: 63kg, p<0.001), height (E: 174cm vs I: 165cm, p<0.001) and sex (E: 11F/33M vs I: 29F/12M, p<0.001) significantly differed between classes, and were controlled for in subsequent comparisons. ANCOVA between the 3 classes revealed significant differences for TT (E: -29° vs. I: -25°, p=0.016), FTR (E: -13° vs. I: -8°, p<0.001) and AcetCov (E: 43% vs. I: 41%, p=0.008). FT did not differ between classes (E: 15° vs. I: 17°, p=0.6).

Discussion: Subjects of the male sex and with a higher weight and height seem to have a more external FPA. Femoral torsion was not different between the groups with internal and external FPA. However, tibial torsion and femorotibial rotation were significantly different between the two groups. Interestingly, hip rotational kinematics did not differ between subjects with internal and external FPA. These results show that differences in FPA between asymptomatic adults are independent of hip axial plane kinematics or femoral torsion and are primarily related to differences in coverage of the femoral head by the acetabulum and in distal lower limb morphology in the axial plane. A better understanding of the relationship between FPA and lower limb morphological parameters might be useful in the management of subjects with FPA alterations.

Increased acetabular coverage over the femoral head
Increased femorotibial rotation
Increased tibial torsion
Subjects with external foot progression angle

Decreased acetabular coverage over the femoral head
Decreased femorotibial rotation
Decreased tibial torsion
Subjects with internal foot progression angle
Does self-perceived gait relate to objective gait assessment in young adults with cerebral palsy?

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Introduction: Treatments of CP gait are based on objective measurements [1] but neglect often the perception of the patient. We don’t know enough about how the patients perceived their gait [2]. We can speculate that the function and appearance of gait are two important factors for a patient. Indeed, studies concerning parental perceptions of CP reported a good correlation between parents’ perception and objective walking ability of their child [3,4,5]. However, there is a lack of studies concerning the walking perception reported by the CP patient himself.

Research Question: Does self-perceived gait relate to objective gait assessment in young adults with cerebral palsy? What are gait parameters associated with self-perceived gait?

Methods: Young adult patients with CP were selected in this study. Patients were asked to answer the question: “On a scale from 0 (worst walk) to 10 (optimal walk), how would you describe your walk to his day?” This question was used to assess self-perception of their current gait with a visual analogue scale (VAS). To assess objectively gait deviations, Gait Profile Score (GPS), Gait Variable Scores (GVS) and normalized gait speed were calculated from a clinical gait analysis performed at the laboratory [6]. Pearson’s correlations were computed to evaluate the associations between the GPS, GVS and normalized gait speed with self-perceived gait score (subjective gait score). Correlations were considered significant for a P-value < 0.05.

Results: 42 young adult patients with CP (59% of men and mean age: 20.4 ± 4.8 years) were included in this study, with 76% of GMFCS 1, 17% of GMFCS 2 and 7% of GMFCS 3. 48% were hemiplegic, 48% were diplegic and 4% were tetraplegic. Nettative correlations were found between subjective gait score with: GPS (r=-0.38, p=0.014), GVS hip add-abduction (r=-0.39, p=0.012), GVS hip rotation (r=-0.39, p=0.011), GVS knee flexion (r=-0.33, p=0.038), GVS ankle plantar-dorsiflexion (r=-0.41, p=0.008). A positive correlation was found between subjective gait score and normalized gait speed(r=0.41, p=0.008).

Discussion:

This study shows that our cohort of young CP adults has a perception of their gait related to objective gait evaluations. The most related gait parameters are walking speed, ankle and knee movements in the sagittal plane and hip rotation. Walking speed has one of the most important parameter of walking for autonomy [7]. Ankle and knee patterns in the sagittal plane are the
parameters used to classify CP gait patterns [8,9]. Hip rotation deviation is a frequent gait deviation that could be related to a mix between function and appearance [10]. Understanding how CP patients perceived their gait is essential to better manage their treatment and their quality of life on long-term. Future studies are needed to identify factors that influence gait perception of CP patients.

References:
Clinical use of a foot tapping test – a pilot study of agonist-antagonist coordination of the ankle joint in children with cerebral palsy

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Introduction: Foot tapping tests with various methodologies of alternating between dorsi- and plantarflexion have been applied as a quantitative assessment of ankle plantar-dorsiflexion coordination and lower extremity motor function in healthy adults and adult neurological patients. Decreased agonist-antagonist coordination may influence balance, co-contraction and cause divergent ankle kinematic patterns during gait. This may be important information in clinical decision making. Currently, we have few objective measures to ankle coordination in children with cerebral palsy. This pilot study took an explorative approach to identifying a foot tapping test that can differentiate children with cerebral palsy (CP) from typically developing children (TD), with the purpose of validating a foot tapping test as a clinical measure of agonist-antagonist coordination.

Research Question: Can foot tapping tests be used as an objective clinical test to evaluate muscle coordination in the ankle of children with cerebral palsy?

Methods: Eight children with unilateral CP (9.6 ± 2.7 years; 6♂, 2♀) and ten age matched TD children (9.8 ± 2.5 years; 3♂, 7♀) participated. Three different variants of foot tapping tests were performed in a randomized order. In all tests, the participants were seated with a fixed hip flexion of 90° and knee flexion of 110°, and performed three trials in each test. Two tests were performed with the child’s foot lifted 3 cm, tapping the forefoot on the ground (Fig. 1a). Tapping was performed as fast as possible for 10 sec. (FastTap) and as 21 metronome guided taps at 1.6 Hz (FFTap). The third test was of 21 taps performed with the foot flat on the ground alternating between heel and toe tapping at 1.6 Hz (HTTap) (fig.1b), mimicking first and third rocker position of the gait cycle. Clinical performance measure was the total number of taps for the FastTap test, and frequency error and frequency variation in the FFFtap and HTTap tests. Surface EMG of the medial gastrocnemius (GAST) and tibialis anterior (TA) was recorded at 1000 Hz (Myon 320, Prophysics, Zürich, Schweiz). Muscle co-activation (MCo) of TA and GAST was calculated from the filtered EMG signal with muscle onset and offset set at 30% maximum activity in each trial. MCo was expressed as average percent of time with co-contraction for all taps in FastTap.
Results: In the FastTap task, CP performed less taps than TD (CP: 24 taps (13-39) vs. TD: 39 taps (34-53); p=0.002). There was no difference in performance in FFTap og HTTap. There was a higher MCo in CP than TD with the FastTap method (CP: 18.05% (1.2%-54.3%) vs. TD: 5.65% (0.5%-18.4%); p=0.041). The correlation between MCo and FastTap performance in CP was moderate but not statistically significant (R=-0.503, p=0.204).

Discussion: The results indicate that FastTap could have potential as a clinical assessment of ankle coordination in children with cerebral palsy. The significantly higher MCo in the CP group indicates that the FastTap clinical performance could be related to increased agonist-antagonist co-contraction. However, large group variability and only moderate correlation between MCo and performance implies that the clinical result of FastTap is influenced by other factors than co-contraction.

In conclusion, the FastTap test can be applied as a performance measure, but decreased performance cannot be directly ascribed to increased co-contraction. Comparison between affected and non-affected side as well as non-affected side to TD may reveal the contribution of passive stiffness, contractures and spasticity to FastTap performance.
The role of muscle forces on foot internal stresses and plantar pressure distribution: differences between healthy and diabetic neuropathic subjects.

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Introduction: It is well known that the best approach towards diabetic foot is prevention through early identification of signs and symptoms and to classify subjects at risk. Recent literature supports the hypothesis that changes in foot internal stresses may play an important role in the aetiopathogenesis of the diabetic foot [1]. Therefore, strengthening, stretching and functional training program are combined with the use of insoles to improve gait biomechanics and foot function in these subjects [2] aiming to reduce the stress of the plantar tissue.

Research Question: To what extent do extrinsic and intrinsic muscles forces impact foot internal stresses and plantar pressure distribution, and especially in the light of risk to develop plantar ulcers in diabetic foot patients.

Methods: Gait analysis, musculoskeletal dynamic simulations (MSM, OpenSim) and finite element modelling (FEM, Abaqus) have been combined in order to estimate muscles forces, internal stresses and plantar pressure distribution. One healthy (age 39, BMI 23.9 kg/m²) and one diabetic subject (age 72, BMI 37.2 kg/m²) were chosen, and subject specific structure and tissues properties were applied as in [3]. Each subject has a foot MRI scan. A 6 cameras stereophotogrammetric system (BTS Srl, 60Hz) synchronized with 2 plantar pressure (Imagortesi, Piacenza, 150Hz), 2 force plates (Bertec Corp, 960Hz), and 12 channels surface electromyography system (PocketEmg 1000 BTS, 1000Hz) were used to register data. Surface electromyography activity of Tibialis Anterior, Gastrocnemius Lateralis, Rectus Femoris, Gluteus Medius, Extensor Digitorum Communis and Proneus Lateralis was acquired. An extended marker set for 3D multi-segment foot kinematics and whole body was applied [4]. For the foot MSM 3 different models were used: a generic2 DOF model (OpenSim GaitModel 2392), a 6DOF foot model [5], a 6DOF with intrinsic foot muscles. All the models included the extrinsic muscle forces calculated with the scaled generic OpenSim model. These muscle forces were used as boundary conditions together with ground reaction forces and kinematics in the FEM. The subject specific FEMs were developed according to [3] but this approach was extended to include connectors (with insertions based on the subjects’ MRI) to simulate extrinsic and intrinsic muscle forces. Hence 3 different FEMs were created for each subject: (1) using extrinsic muscles forces calculated from GaitModel 2392 (MOD1), (2) using extrinsic muscles calculated by the 6DOF model (MOD2) and (3) using extrinsic and intrinsic muscle forces calculated with 6DOF (MOD3). Four phases of the gait cycle were simulated [3]. Results of the simulations were validated through direct comparison with the experimental plantar pressure (gold standard).

Results: Overall the diabetic neuropathic patient FEM obtained the best correspondence between simulated and experimental plantar pressure. The models that best performed were: for the initial contact (IC) and the loading response (LR), MOD1; for the midstance and the pushoff (PO), MOD2 and 3. Best results were found for the PO for the diabetic patient and the IC for the control subject. Best results were found for forefoot and hindfoot for the diabetic and the control subject respectively.
Discussion: The current work evaluated the effect of extrinsic and intrinsic muscle forces calculated using different MSM foot models on internal stresses estimation. Best approximation of the experimental plantar pressures was found using MOD1 for IC and LR phases in hindfoot and using MOD2 for PO in forefoot. For what concerns the internal stresses values, since there is no possibility for a direct measurement, they are assumed to improve, when the plantar pressure map of the model improves too.

Is arm swing an effective factor on plantar pressure during walking?

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Introduction: Arm swing is an asymmetrical pattern for hemiplegic population and an effective parameter, which alters kinematics, kinetics and foot-pressure behaviour on walking.(1) Although, generally, lower extremities are targeted for improving walking parameters in physical therapy and orthopaedics, restricted upper extremity swing motion can be a part of the foot pressure abnormalities for these patients (2). Interestingly, no study, that we are aware, has investigated the effects of restricted arm swing in able-bodies, on foot pressure behaviour in different walking speeds. Therefore, the aim of this study was to investigate the alterations of plantar pressure behaviour due to the asymmetrical arm swing in healthy volunteers.

Research Question: Is arm swing an effective factor on plantar pressure parameters during walking?

Methods: Twenty-eight healthy volunteers included in the study (av. age: 22.7±1.19). For the foot pressure analysis, the Mat-Scan system (Tekscan Inc. Mass. USA) was utilized. The foot pressure was analysed in 3 different conditions; 1- both arms freely swing (FS), 2- the dominant arm swing was restricted by elastic band at the level of umbilicus (RS) to reduce the swing range, and 3- The dominant arm was held by an arm sling, which keeps the arm across the opposite shoulder (H). Video recording was performed, in order to check the arm condition and the cadence for all volunteers while they were walking in three different cadences (self-selected, 70 bpm (slow walking), 110 bpm (fast walking)) by using metronome. The first and the second peak forces (F1, F2 (kg/cm²), the time of these forces (t1, t2 (sec)), impulse of force applied to the corresponding foot (under the force-time curve), stance times and maximum forces were the interested parameters. Paired T-test was used for the comparison (p<0.05) (3).

Results: In self-selected speed, between RS and FS; t2 (from 2.09±0.19 to 2.05±0.16), mean area (from 38.9±9.6 to 37.8±9.09) and stance duration (from 0.67±0.6 to 0.65±0.6) were lower in RS than FS. Between H and RS: t2 (from 2.07±0.14 to 2.05±0.16) was higher in H than RS (2.05±0.16). Between FS and RS; stance duration was higher in FS relative to RS (0.65±0.6) and H (0.66±0.5)(p<0.05). In fast walking, between FS and RS; maximum pressure was (from 77.6±16.6 to 79.6±16.1) lower in FS than RS (79.6±16.1). Between FS and H: F1 (from 79.6±18 to 77.6±17) was higher in RS. (p<0.05). In slow walking, between FS and RS; F1(from 69.5±15.6 to 68.2±13.3) was higher in (from 68.7±13.8 to 69.5±15.6) higher in FS than RS. (p<0.05).
Discussion: The present study demonstrated that, restricted arm motion alters the plantar pressure behaviour during walking in healthy individuals. Restricted arm motion, both in RS and H conditions, affects the plantar pressure behaviour by increasing the peak pressure in stance during fast walking, which may relate with increased plantar flexion moment. During slow walking, stance duration increases by the restriction of the arm, which may be a compensations to onset stance phase stability. Correlation of the plantar pressure alterations with the gait kinetics and kinematics should be investigated by utilizing 3D gait analysis.

References:

Combining orthotic joint load measures with instrumented 3D gait analysis

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Introduction:
To select suitable orthotic joint components the pathology, gait pattern, desired function, activity, weight and orthotic design as well as experiences of the user and the orthotist have to be taken into account. To guide the patient specific component selection, schemes like the Amsterdam Gait classification and configuration guidelines from manufacturers exist [1] based on durability tested in isolated mechanical test procedures. Effective joint loads occurring in everyday orthotic use are largely unknown and components appear occasionally over- or under-estimated and wearing off too early or appear heavy and bulky which does not support acceptance. Former studies show that height, weight and gait velocity do not always correlate directly with orthotic joint loads [2]. Those have been measured before, requiring large modifications of existing orthotics or special built constructions [3]. To gain insight into actual load profiles measured in everyday scenarios constructive changes to regular orthotics should be minimized.

Research Question:
To learn about effective loads and influencing factors, internal orthotic joint moments (iOJ) are analyzed in parallel to full body kinematics and kinetics. The Aim of this study is to combine both systems in a setup which can then be applied to patients.

Methods:
One healthy subject (f, 32y, 55 kg, 168 cm) is provided with a pair of custom built ankle foot orthotics (GRAFO) in carbon fiber technics with full length rigid sole, circular foot support, frontal shank support, and lateral hinge joints (17LA3=16, Otto Bock) limited to 0° dorsal-extension, with unrestricted plantar-flexion. The original joints are replaced with the same type but strain gauge instrumented version to measure 3 components of AFO joint torque. A module attached to the joint determines the shank angle with respect to the global coordinate system via inertial sensors. Modifications add 60g to the AFO [4]. Kinematics and kinetics during level walking are captured via instrumented 3D gait analysis (3DGA) using the Plugin Gait Marker set. On a 12 meter walk way, light barriers located 6 m apart, start and stop the capturing via radio communication and synchronize all systems operating at 100Hz (Fig 1). Temporo-spatial parameters (TSP) are derived from accelerometer data in combination with iOJ and validated with the 3DGA outcome. Time series are normalized to 100% gait cycle (%GC) after verifying synchrony

Results:
TSP compared between iOJ and 3DGA differ in the range of one standard deviation (Δvelocity: 0.05 m/s, Δstride length: 0.03 m, Δcadence 1.6 steps/min). The first peak sagittal iOJ-moment appears at 20%GC with 0.56 Nm/kg at the dorsal stop and a second peak at 48%GC with 0.51 Nm/kg. First peak of 3DGA sagittal ankle joint moments is 1.27 Nm/kg at 20%GC and 1.48 Nm/kg at 48%GC respectively (Fig.2).

Discussion:
Merged data collection can be operated by a single person conveniently. Combined kinetics shows the orthotic joint contribution to total load (Fig.2). The first peak in iOJ is higher than the second one which is a different pattern in 3DGA. The ankle kinematic proves that at 20% GC the dorsal joint limitation is reached, explaining the load peak. While in late stance, the iOJ contributes only 1/3 to the 3DGA moment. When replacing AFO joints with the iOJ-System, the alignment has to be reproduced carefully. The protocol can be applied to incline or staircase conditions. Further analyses of patients with various prerequisites, like spasticity etc. can be performed with this protocol. The insight of user-orthotics-interaction colud and guide component selection, dimensioning and alignment to meet patient specific needs.
References:


A model to calculate the progression of the centre of pressure under the foot during gait analysis

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Introduction: Knowledge of how the centre of pressure (COP) progresses under the foot during walking is useful to understand foot function. Reference COP progression profiles for children without neurological or orthopaedic problems are well documented in the literature [1]. From these reference profiles, indices have been created to identify abnormal medial or lateral loading [2]. The progression of the COP is typically obtained from pedobarography equipment. However, pedobarography may not be available in clinical gait analysis laboratories. We propose a foot sole model able to calculate the progression of the COP from standard kinematic and kinetics data collection protocol.

Research Question: What is the progression of COP in typically developing children aged 4 to 16 years, obtained from a newly developed foot sole kinematic model?

Methods: The foot sole model is designed as an adjunct to the conventional gait model. The model creates a coordinate system to indicate the plantar surface of the foot during stance. The coordinates of the COP on the surface of the forceplate are transformed into the local foot sole coordinates to produce the COP progression profile. The model levels the height of the heel marker to the toe marker to impose horizontality with the floor. This ensures accurate registration of the foot sole but also limits the use of the model to patients who can stand with flat feet during static calibration. The longitudinal axis of the foot sole is defined from the height levelled HEE to TOE markers.

The foot sole model was applied to 49 typically developing children aged 4-16 years, 14 male, 35 female; mean age 9.9 (3.7) years, mean height 141 (18.9) cm, and mean weight 39.4 (18.9) kg. Three-dimensional gait analysis was collected at the Paediatric Gait Analysis Service of NSW in The Children’s Hospital at Westmead. An 8-camera MX T20 Vicon System (OMG, UK) was used to collect kinematics sampling at 100Hz. Force data was collected using 3 AMTI forceplates sampling at 1000 Hz (AMTI, USA)

Results: Figure 1 (a) presents the output of the model for a typical child. The position of the COP is plotted every 2% of stance and color coded according to the total force (in % bodyweight). Note that the anterior-posterior, medial-lateral and vertical ground reaction force values may be displayed instead of the total force. The black dots represent time instants when the foot was within 3° of horizontal. Figure 1 (b) presents the normative COP progression profiles for the 49 typically developing children formatted similarly to [1]. The hindfoot, midfoot and forefoot sections were delineated by the projection of the ankle joint centre (AJC) and TOE markers on the floor.
Normative COP progression is shown to begin in the hindfoot and remains there for 8% of stance. It continues to traverse through the midfoot for 76% of stance and finishes in the forefoot for 16% of stance. The COP progression profile starts lateral of the longitudinal axis of the foot and remains on the lateral side of the midfoot section before finishing medially in the forefoot section.

**Discussion**: We presented a model to register the position of the COP with the plantar surface of the foot. This model is meant to support foot assessment in gait laboratories lacking pedobarography equipment. We also provided reference COP progression data processed with the foot sole model from typically developing children.

**References:**


The influence of weight bearing on foot shape in children with planovalgus feet.

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Introduction:

In the clinical routine, foot deformities are commonly evaluated both with and without weight bearing [1]. This allows detecting flexibility of a foot deformity, i.e. the arch of a pediatric planovalgus foot collapse during weight bearing while it is normal in a non-weight bearing position [2]. Furthermore, the hindfoot was more everted and the shank less externally rotated in planovalgus feet in weight bearing position compared to neutral feet [3]. Concerning treatment recommendations, however, it is not clear how reduced flexibility is related to pain. One problem is to objectively quantify these changes in foot shape.

Research Question:

Can the changes in foot shape due to weight bearing be objectively measured using three-dimensional foot analysis in pediatric planovalgus feet? Is there a difference between symptomatic and asymptomatic feet?

Methods:

163 feet (symptomatic (SPF) (n=47), asymptomatic planovalgus feet (APF) (n=102) and reference feet (RF) (n=14)) were measured using 3D-foot analysis during sitting and standing position. Specific parameters for planovalgus foot namely the medial foot aspect, hindfoot valgus and rotation of the shank (tibia torsion) are analysed in standing position and compared to the data of sitting (unloaded) position. Furthermore, the differences between standing and sitting position are compared between all three groups (RF vs. APF, and APF vs. SPF). Both sides (feet) are analysed by linear mixed models and Bonferroni method.

Results:

In sitting position the medial arch is increased (16°), the medial column more laterally tilted (20°), the hindfoot in more varus position (14° hindfoot tilt, 15° hindfoot varus) and the tibia less internally rotated (6°). The foot shape changes in all parameters significantly. The largest differences were seen between reference feet and asymptomatic planovalgus feet, mostly significant (see table). However, there are no differences between asymptomatic and symptomatic planovalgus feet.

<table>
<thead>
<tr>
<th>Parameter (mean ± SD)</th>
<th>RF</th>
<th>APF</th>
<th>SPF</th>
<th>RF vs. APF (p-value)</th>
<th>APF vs. SPF (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medial arch [°]</td>
<td>15.8 ± 3.3</td>
<td>15.9 ± 4.1</td>
<td>16.7 ± 3.3</td>
<td>1.000</td>
<td>0.467</td>
</tr>
<tr>
<td>Medial column inclination [°]</td>
<td>-11.2 ± 4.0</td>
<td>-20.3 ± 6.0</td>
<td>-22.1 ± 7.2</td>
<td>0.001</td>
<td>0.146</td>
</tr>
<tr>
<td>Hindfoot obliquity [°]</td>
<td>-7.8 ± 3.9</td>
<td>-14.5 ± 4.4</td>
<td>-15.3 ± 5.4</td>
<td>&lt; 0.001</td>
<td>1.000</td>
</tr>
<tr>
<td>Hindfoot valgus [°]</td>
<td>-9.3 ± 3.6</td>
<td>-15.0 ± 3.4</td>
<td>-15.2 ± 4.1</td>
<td>&lt; 0.001</td>
<td>1.000</td>
</tr>
<tr>
<td>Tibia Torsion [°]</td>
<td>-10.5 ± 7.5</td>
<td>-3.4 ± 7.9</td>
<td>-5.6 ± 8.3</td>
<td>0.028</td>
<td>0.726</td>
</tr>
</tbody>
</table>

Table: Differences between standing and sitting position. Comparison RF vs. APF and APF vs. SPF. Positive differences demonstrate a larger value in standing position; negative differences a larger value during sitting. Significance level p = 0.05.

Discussion:

There are several changes in foot shape due to weight bearing. It can be inferred that these changes indicate foot flexibility, especially in planovalgus feet. The symptomatic feet demonstrate
marginal larger changes in shape and therefore indicate increased foot flexibility. The method should be checked on rigid planovalgus feet due to their stiff and flat medial arch in weight bearing and non-weight bearing position [4].

Simulating Physiological Discomfort of Exoskeletons Using Musculoskeletal Modelling

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Introduction: Exoskeleton robots are promising assistive/rehabilitative devices that can help people with muscular strength deficits or allow the recovery of patients who suffer from pathologies such as stroke. While experimental evaluation of prototypes of exoskeletons is common (e.g. [1]), biomechanical predictive simulations that can minimize design iterations and provide information about the variables that cannot easily be measured experimentally seem necessary.

Research Question: In in-silico integration of a human musculoskeletal system and an exoskeleton, there will be two levels of evaluation: 1) at the muscle level, which is called the muscle redundancy problem and 2) at the device level, which should be considered in interaction with the physiological aspects of the human body. We introduce three biomechanical discomfort measures, muscle activation effort, representative joint reaction force and total metabolic cost, to quantify the performance of the assistive device for optimization study. How changes of these design criteria are pronounced when the assisted and the unassisted baseline cases are compared would be investigated in two examples: box-lifting and sit to stand.

Methods: AnyBody Modeling System v6.1 [2] was used for musculoskeletal simulations. The full human body model in the AnyBody Managed Model Repository v1.6.4 was applied. Assistance device was conceptualized as stiffness at the hip and knee joint for the box-lifting and sit-to-stand task, respectively. An optimization study was carried out to find the optimal stiffness for each case that compromises the three objectives. To this goal, Pareto Front concept was applied.

Results: Figs. 1 and 2 show the Pareto Front of the multi-objective optimization problem in box-lifting and sit-to-stand tasks, respectively.

Discussion: For the sit-to-stand study, compared to the unassisted baseline, the assistive device with the optimal stiffness resulted in 9.1% reduction in the knee joint reaction force whereas the gain was 12.6% in the activation effort and 26.4% as metabolic benefit. These values imply a significant difference between the three measures. These three quantities (with hip reaction force) however showed consistency in the device benefit in the box-lifting task (49.2%, 48.8%, and 49.6%). This can lead us to a conclusion that first the device gain might not be reflected well in one design objective, but pronounced more in another. In addition, variables related to single joints or muscles might not include all the variations. Unless a specific joint of interest is given a...
priori, it may be difficult to find the mostly affected joint to consider the corresponding reaction force as a design objective, especially in complex musculoskeletal models with multiple degrees of freedom and many multiarticular muscles. This is one major drawback of using joint reaction force as the objective. Considering physiological measures simultaneously such as the Pareto Front concept in design and evaluation of assistive devices might be the means to foresee short to long term effects of the assistance strategy.

A predictive simulation approach suitable for gait control strategies design to be used on lower limbs assistive devices

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Introduction: The design of motion control strategies for assistive devices as exoskeletons requires tools to analyse and estimate gait parameters in the absence of experimental data about the hypothetical scenarios been studied. In this sense, predictive simulations techniques offer a valuable means for these purposes, [1], [2] and [3]. In these works, the gaits are completely synthesised by means of minimizing some objective functions, which can lead to unrealistic movements when complex scenarios and pathologies are being considered. The presence of assistive devices in musculoskeletal models has been recently simulated using OpenSim, [4]. In that work the influence of assistance at different joints in muscle recruitments is predicted, whenever the experimental data is tracked however new movements due to assistive components are not predicted.

Research Question: It is possible to perform predictive dynamic simulations of closed-loop controlled actuators included as assistive devices into musculoskeletal models whose movement tracks experimental data?

Methods: In this work, the Simulink-OpenSim interface presented in [5] has been updated to work with the latest versions of OpenSim, Visual Studio and Simulink and modified to implement the approach being presented whose workflow is shown in Figure. The gait pattern used as the base muscle-driven simulation corresponds to the experimental data obtained with motion capture system during trials with a child affected by cerebral palsy. A 3D scaled musculoskeletal model of the child has been built using the 3D gait2354 OpenSim model with 23 degrees of freedom and 54 muscles.

Results: The OpenSim IK, RRA and CMC tools have been applied to obtain the activations for the muscle-driven simulations. The movements simulated correspond to the stance/swing phase of the right/left leg. Three different PD control actuations in the left knee joint maintaining the rest of movements unaltered has been successfully simulated.

Discussion: The simulated movement of the musculoskeletal model used with this approach is not virtually obtained from optimization criteria, but by tracking experimental data, which would lead to more reliable results. Only small modifications at some joints are introduced in order to investigate the benefits of external assistance. This approach allows to design controls using feedback to track deviations from the specified reference patterns, maintaining at the same time the rest of the movements unaltered. On the other hand, as the time history of activations of the
unassisted joints is already available and is not recomputed, computational burdens are significantly reduced.

Musculoskeletal modelling simulation with optimisation to predict the morphological parameters of the calf muscle

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Introduction: Musculoskeletal models (MSMs) have been used to study normal and pathological gait and the effects of surgical treatment [1]. Optimisation techniques have been commonly used to determine the muscle excitations required to generate experimental kinetics and kinematics, assuming fixed key muscle morphological parameters. In this study, however, we have chosen to optimise muscle parameters within the MSM in order to match the experimental moment, given known excitations derived from EMG. Results are presented for the ankle moments in a test group of typically developing children (TD), children with cerebral palsy (CP) and idiopathic toe walkers (ITW) where calf muscle parameters were optimised.

Research Question: Is it feasible to use MSM with optimisation to predict the morphological parameters of the calf muscle?

Methods: 18 children (TD=10, CP=4, ITW=4), between 6 and 16 years of age underwent gait analysis, including orthopaedic examination, 3D movement analysis with the Oxford Foot Model (OFM) and EMG of lateral and medial gastrocnemius and soleus. Dynamic muscle-tendon lengths and moment arms were calculated using kinematic data and a matched OpenSIM model incorporating 3DoF at the ankle/subtalar joint. A standard implementation was used for the Hill muscle model and activation dynamics. Optimal control was performed by Direct Collocation (2). Optimisation was used to estimate the values of tendon slack length and maximum isometric force to achieve the best fit of the dynamic ankle joint moment.

Results: Children with CP and ITW had reduced passive ankle dorsiflexion with the knee straight (CP = -12.5 ± 13°, ITW = -2.5 ± 2.5°) in comparison to TD children (13.4 ± 7.1°) and reduced peak ankle dorsiflexion during gait (ITW 1.7 ± 5.8°, CP 6.4 ± 9.8°, TD 12 ± 4.7°). Predicted ankle moment showed a good match to those measured experimentally. Mean RMS errors for the group were (CP = 3.2 ± 2.1Nm, ITW = 2.7 ± 1.2Nm, Normal = 4.8 ± 1.15Nm).

![Comparison of simulated (blue) and experimental (red) ankle moments for 3 individual test subjects.](image)

Figure 1 Comparison of simulated (blue) and experimental (red) ankle moments for 3 individual test subjects.
<table>
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<tr>
<td><strong>Mean</strong></td>
<td><strong>SD</strong></td>
<td><strong>Mean</strong></td>
<td><strong>SD</strong></td>
<td><strong>Mean</strong></td>
<td><strong>SD</strong></td>
</tr>
<tr>
<td>CP</td>
<td>800</td>
<td>283</td>
<td>1600</td>
<td>566</td>
<td>2900</td>
</tr>
<tr>
<td>ITW</td>
<td>550</td>
<td>260</td>
<td>1100</td>
<td>520</td>
<td>2200</td>
</tr>
<tr>
<td>TD</td>
<td>440</td>
<td>84</td>
<td>880</td>
<td>169</td>
<td>1820</td>
</tr>
</tbody>
</table>

**Discussion**: The small differences between the predicted and experimental data give confidence that the approach is feasible. The optimal values for the muscle parameters were not as expected from our understanding of the pathologies. We expect the estimates of the parameters to improve as the limitations are addressed. We only optimised two muscle parameters, assumed normal skeletal geometry and did not have access to imaging data. The Hill model may also be insufficient to capture the pathological changes in the muscle. Future work will seek to address these limitations through baseline measurements (eg ultrasound), more extensive optimisation and tailoring of the Hill model.

**References**:
Is it feasible to use an automated system to recommend orthopaedic surgeries?

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Introduction:

Clinical decision making in orthopaedics from gait analysis may be complex. It primarily depends on the perceived impairment(s) that may be addressed with surgery. These impairments are assessed objectively from data such as kinematics, kinetics and physical examinations. The decision making process is complex because of the volume, and specificity of the data involved. Clinical decision making may be easier and improved if an automated system could pre-process these data and even recommend potential surgeries, based on past decisions. Hence, using our clinical database of surgery performed in the past, we developed an automatic recommendation system and assessed its feasibility for clinical use by evaluating its ability to predict the administered surgery.

Research Question:

Can automated system achieve sufficient performance when recommending orthopaedic surgeries?

Methods:

Using a clinical dataset which consist of 1265 occasions of service (834 children with Cerebral Palsy), we developed two systems which use clinical and gait analysis data to predict the five most frequent orthopaedic surgical procedures in children with Cerebral Palsy at our centre. The first system detects features from the kinematics curves using deterministic rules developed from expert knowledge (similar to [1]). The pre/absence of these features, in combination with the physical examination data, are then used by several machine learning algorithms to predict the surgical procedures required. In contrast, the second system only uses the identified impairments as predictors. Since in the context of recommending an operation, a false positive could be more damaging than a false negative, the model selection metric is specificity. Sensitivity is also monitored but it only serves as secondary measure.

Results:

The system which uses kinematics features and physical examination data generally performs better than the system that uses identified impairments alone. Average specificity: 0.90 vs 0.85, Average sensitivity: 0.79 vs 0.78. The table below shows the specificity and sensitivity for both systems, for the predicted surgeries.

<table>
<thead>
<tr>
<th>metric</th>
<th>Adductor lengthening</th>
<th>Femur derotation osteotomy</th>
<th>Hamstring transfer</th>
<th>Gastrocnemius (Strayer)</th>
<th>Rectus transfer</th>
<th>Tibia derotation osteotomy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Features Spec</td>
<td>0.89</td>
<td>0.87</td>
<td>0.88</td>
<td>0.83</td>
<td>0.92</td>
<td>0.88</td>
</tr>
<tr>
<td>Features Sens</td>
<td>0.70</td>
<td>0.70</td>
<td>0.74</td>
<td>0.70</td>
<td>0.84</td>
<td>0.78</td>
</tr>
<tr>
<td>Impair. Spec</td>
<td>0.75</td>
<td>0.77</td>
<td>0.79</td>
<td>0.72</td>
<td>0.87</td>
<td>0.78</td>
</tr>
<tr>
<td>Impair. Sens</td>
<td>0.71</td>
<td>0.67</td>
<td>0.73</td>
<td>0.68</td>
<td>0.90</td>
<td>0.69</td>
</tr>
</tbody>
</table>

Conclusion:
The results show that an automatic system can achieve a fair level of predictive performance. In the context of surgical recommendations, the challenge remains for the system to achieve both a high level of specificity and sensitivity.

References:

Rectus femoris transfer has a limited effect on stiff knee gait for individuals diagnosed with cerebral palsy.

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Introduction: Rectus femoris transfer (RFT) is a common surgical procedure performed for the treatment of individuals with cerebral palsy (CP) who walk with a stiff knee gait characterized by reduced knee flexion during swing phase. Previous work has shown average improvements in swing phase knee flexion of approximately 6° for individuals with a stiff knee gait when a RFT is performed within a single event multi-level surgery (SEMLS) [1]. However, previous studies lacked a properly matched control group, which is essential to understanding the improvements in stiff knee gait directly attributable to the RFT, independent of other procedures included in a SEMLS.

Research Question: Does the rectus femoris transfer produce improvements in swing phase knee flexion?

Methods: In this retrospective analysis, individuals with a diagnosis of CP who had undergone a SEMLS with an RFT (SEMLS+RFT) were compared to a matched group of individuals with a diagnosis of CP who had undergone a SEMLS without an RFT (SEMLS-RFT). Drawn from a large database of CP patients, the SEMLS-RFT control group was matched to the SEMLS+RFT case group on three basic knee kinematic metrics: peak knee flexion, minimum knee flexion, and knee flexion range of motion. Individuals who underwent patellar tendon advancement as part of their SEMLS were excluded from this study. Changes in swing phase peak knee flexion between the two groups were examined to determine the impact of the RFT on swing phase knee flexion.

Results: Overall, the SEMLS+RFT group (N = 318, Age: 10.3±3.2) and SEMLS-RFT group (N = 130, Age: 9.3±3.3) were well matched. Prior to intervention, differences in peak knee flexion, minimum knee flexion, and knee flexion range of motion between groups were less than 1°. Surgical interventions included as part of the SEMLS procedures were also reasonably well matched except for intramuscular psoas and hamstrings lengthening procedures, which were performed at an increased rate for the SEMLS+RFT group (2.6 and 1.4 times as likely, respectively). For individuals who exhibited a stiff knee gait pattern (swing phase peak knee flexion < 50°) only psoas lengthening was performed at an increased rate for the SEMLS + RFT group (3.2 times more likely).

After SEMLS, individuals walked with 4.2° more swing phase knee flexion, on average. The SEMLS+RFT group walked with 5.2 ° more swing phase knee flexion, compared to 1.8° for the SEMLS-RFT group (p = .01). Overall, knee flexion improvements scaled with the magnitude of
pre-SEMLS stiffness (see Figure). For individuals who exhibited a stiff knee gait pattern, the SEMLS+RFT subgroup (n = 111) improved knee flexion by 12.7° while the SEMLS-RFT subgroup (n = 41) improved knee flexion by 9.0. The difference in improvement between the two groups (3.7°) was statistically significant (p < .05).

Discussion: The results of this study indicate that, on average, more than 70% of the total improvement possible in a SEMLS+RFT was due to other interventions in the SEMLS, and not due to the RFT itself. The addition of an RFT to a SEMLS provided less than 4° of additional swing phase knee flexion compared to SEMLS without an RFT, regardless of swing phase knee flexion function. For a subgroup of individuals with a stiff knee gait preoperatively, the RFT provided only 3.7° of the 12.7° of overall improvement. Overall, it appears that the benefit of RFT for improving stiff knee gait is minimal. However, the increased prevalence of intramuscular psoas lengthening for the SEMLS+RFT group remains a potential confounder in this analysis.

Functional power training in children with CP: Does increased sprinting capacity lead to improvement in gait kinematics?

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Introduction: Muscle weakness is one of the most prevalent symptoms in children with cerebral palsy (CP) [1,2]. In particular, weakness of the ankle plantar flexors may limit daily activities such as walking and running [2,3]. It has been argued however, that it is not strength alone which limits function, but rather the ability to rapidly generate power [4]. Although different studies showed that children with CP can improve strength by means of resistance training, effects on gait remain unclear [1-4]. Therefore, the MegaPower program was set up: a progressive resistance training, with the focus on ankle push-off power and exercises that are directly translational to children’s daily life activities such as running and playing.

Research Question: What are the effects of functional power training in children with CP on gait kinematics and walking and sprinting capacity?

Methods: Ten children with spastic cerebral palsy (age 5-10, GMFCS I-II) participated in the training program. All children followed a functional power training at the rehabilitation centre, which comprised three 1-hour training sessions per week for a consecutive period of 14 weeks. At the beginning and the end of the program, children performed several functional tests, including the 1-min walk test, Shuttle Run Test and Muscle Power Sprint Test (MPST). In addition, children underwent 3D gait analysis on an instrumented treadmill. During gait analysis children walked at different velocities, including comfortable walking velocity. Joint kinematics and spatiotemporal parameters were calculated using the Human Body Model (HBM) [5], for at least twenty representative strides of the most affected leg. Sagittal kinematics of ankle and knee were compared between pre- and post-measurements, at matched velocity (pre-training CWS).

Results: Children improved significantly on the 1-min walk test (pre: 69.7±14.1m vs. post: 84.5±9.8m; p<.000), Shuttle Run Test (pre: 7.3±2.1 stages vs. post:12.5±4.1 stages; p=.001) and mean power during MPST (pre: 24.6±22.0W vs. post 58.7±51.3W; p=.003). Self-chosen comfortable walking velocity during gait analysis increased with on average 21% (mean pre: 0.71±0.25 m/s; post: 0.85±0.24 m/s; p=0.046). Although not significant (p=.138), a tendency was found towards more knee extension (±3deg) during stance phase after training (see figure). No changes were observed for maximal ankle dorsiflexion during stance, knee angle at initial contact or ankle/knee range of motion during stance.

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Sagittal Knee Angles

![Sagittal Knee Angles Graph](image-url)
Discussion: This study demonstrates that functional power training can be effective to improve function in children with spastic cerebral palsy, but these effects are not necessarily reflected in gait kinematics. Although comfortable walking velocity improved significantly, no effects were found for knee or ankle kinematics, which is in agreement with previous studies [1-4]. The increase in self-chosen comfortable velocity implies that children might have adapted their gait pattern, but walking at pre-training comfortable velocity might not be challenging enough for changes to become apparent. Therefore, the next step is to compare effects of different walking velocities taking into account ankle push off power.

Mid-term results after distal femoral extension osteotomy in children with cerebral palsy (CP) – a musculoskeletal analysis

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Introduction: Flexed knee gait is a common gait deformity in children with CP and is surgically treated by hamstring lengthening or distal femoral extension (shortening) osteotomy (DFEO) with or without additional patellar tendon advancement (PTA). While previous studies showed that hamstring lengthening might lead to an increased anterior pelvic tilt and genu recurvatum in the long-term follow-up (more than 4 years postop) after satisfying short-term results, long-term data after DFEO (+PTA) are still missing. DFEO (+PTA) is preferred in many centres for ambulatory children.

Research Question: How do both kinematics and muscle tendon length (MTL) and velocity of hamstrings change in the mid-term follow-up (2-5 years postop) after DFEO?

Methods: 10 limbs of 8 children [12 ± 4 years] with bilateral spastic CP that received a DFEO with (4 limbs) or without (6 limbs) additional PTA in the context of SEMLS were retrospectively included in the study. Inclusion criterion was a pre-, one year postoperative and mid-term (3 ± 1 year postop, [24-55months]) gait analysis without assistive walking devices. Exclusion criteria were an additional hamstring lengthening and any botulinum toxin injections in the lower limbs. Kinematic data of 3D gait analysis were determined with the Plugin-gait model. Subject specific musculoskeletal models were created with OpenSim 3.3 using the generic musculoskeletal model 2392. The ‘Thelen 2003 muscle model’ [1] was used to determine peak muscle tendon length (MTL) and peak velocity of the hamstrings (M. semitendinosus, M. semimembranosus). Normal distribution of all parameters was confirmed by Shapiro-Wilk test. Significance level was set at p < 0.05.

Results: (↑ = significant increase, ↓ significant decrease, ↔ no significant change)

<table>
<thead>
<tr>
<th></th>
<th>Peak MTL (hamstrings)</th>
<th>Peak Velocity (hamstrings)</th>
<th>Max knee flexion in stance phase</th>
<th>Max knee flexion in swing phase</th>
<th>Mean hip flexion in stance phase</th>
<th>Mean pelvic tilt in stance phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>preop postop</td>
<td></td>
<td></td>
<td>↓ (p&lt;0.001)</td>
<td>↓ (p=0.001)</td>
<td>↓ (p=0.004)</td>
<td>↑ (p=0.129)</td>
</tr>
<tr>
<td>postop mid-term</td>
<td>↓ (p&gt;0.394)</td>
<td></td>
<td>↑ (p=0.017)</td>
<td>↑ (p=0.060)</td>
<td>↑ (p=0.211)</td>
<td>↑ (p=0.980)</td>
</tr>
<tr>
<td>preop mid-term</td>
<td></td>
<td></td>
<td>↑ (p=0.001)</td>
<td>↓ (p=0.002)</td>
<td>↑ (p=0.071)</td>
<td>↑ (p=0.111)</td>
</tr>
</tbody>
</table>

In the mid-term follow-up a decreased knee flexion in stance and swing phase and faster and longer hamstrings were seen compared to the preoperative assessment. There was no change in pelvic tilt and hip flexion.

Discussion: To our knowledge, this is the first study assessing mid-term outcomes after DFEO. In contrast to former studies [2,3] who described increased anterior pelvic tilt after DFEO with additional PTA, we saw no change in pelvic tilt over the whole period. This might have two reasons: In the present study, patients with and without PTA were included and besides all gait analyses were performed without walking devices, which themselves can lead to increased pelvic tilt [4]. This study suggests that DFEO leads to longer hamstrings immediately and also faster...
hamstrings over the time. Similar results were described by Healy [5] after a follow-up of 7 – 36 months. Although the results of this study have limitations due to the small number of patients and the relatively “short” period of follow-up (only 24-55 months), it can be concluded, that recurrence of flexed knee gait and increased pelvic tilt are less probable after DFEO than after hamstring lengthening. The results are even more surprising, as the last follow-up in this study is performed during or past the pubertal growth spurt and the children gained 15 ± 14 cm in body height and 8 ± 9 cm in leg length between the first and last exam.

Case study: The effects of two different Chopart-prostheses during level walking on gait parameters, socket and plantar pressure.

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Introduction:
When it comes to partial foot amputations at the Chopart line (Articulatio tarsi transversa) usually two kinds of prostheses (e.g. Bellmann (BP) or clamshell-type prostheses (CSP)) [1] are frequently used to restore the foot and regain an adequate foot lever arm [2]. For one particular subject it had to be decided which device suits best. The BP is a slipper socket which allows full ankle joint range of motion (ROM). Whereas the SCP is a semi-rigid, shin high device with a fixed ankle joint and a carbon fibre footplate (e.g. Chopart-Plate, Ossur, Iceland). So far the device decision is mostly based on the patients remaining ROM in the ankle joint, present stump status, level of daily activity and cosmetic aspects rather than evidence based literature [3]. Therefore objective data were acquired through clinical gait analysis including socket and plantar pressure, to determine which device provides the most advantages for this certain subject.

Research Question:
The aim of this study was to determine which of the two different Chopart-prostheses is more beneficial for one particular subject, by comparing differences in gait pattern, plantar and socket pressure during level ground walking.

Methods:
One subject (male, 92 kg, 1.79m, left side affected (Chopart)) underwent 3D motion analysis including pressure measurement, with two different prostheses (CSP/ BP) during level ground walking. Plug-in-Gait model (Vicon, UK) was used. The pressure was measured by pressure insoles (Novel, GER) inside the shoe for both devices. Only for the CSP three additional socket sensors (Novel, GER, size: 4x4 cm) were aligned in a row and placed along the shin edge. To determine changes in gait parameters, plantar pressure and socket pressure a paired T-Test was used to compare effects between these two prosthetic designs.

Results:
The BP enabled the user to perform a higher Ankle-ROM (34±1°) during level walking than the CSP (8±0.5°; p<0.001). The ankle joint moment during terminal stance with the CSP was significantly higher (1.2±0.03 Nm/kg) than the moment with the BP (0.5±0.03Nm/kg; p<0.001). In terminal stance the total ground reaction force (GRF) was significantly higher in CSP (11.5±0.5N/kg) compared to BP (10.2±0.2N/kg; p<0.001). The insoles showed less toe force wearing the BP (30±16N) as measured with the CSP (758±42N; p<0.001). The pressure at the shin, wearing the CSP, increased during the stance phase and reached its peak during terminal stance.

Discussion:
The BP has the advantage of a higher range of motion in the ankle joint, however was not able to create a proper ankle joint moment due to an incapability of producing a toe lever during terminal stance. In contrast the CSP allowed the wearer to “load” the carbon fibre plate by
applying force at the anterior shell, through the forward progression of the tibia, to create a proper toe lever. For level walking the CSP seemed to be the appropriate device for this particular patient. The results were quite similar to the subjects’ first hand report. The subject described the BP as “too flexible and unable to load the toe lever” for adequate walking compared to the CSP, and would rather use the CSP device. In the end the patient received the CSP device due to comparing subjective and objective data, to suit his needs. Based on these findings a controlled cohort study will be performed for further investigation.

References:
A new kinematic model associating functional calibration and inverse kinematic designed to assess the effect of a unilateral torsion splint on a 5 years old young girl with hemiplegia

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Introduction:

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 has a therapeutic test purposed 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. A specific functional motion capture protocol has been developed in order to overcome those difficulties.

Research Question:

What is the effect of an unilateral torsional splint on gait and how to measure it with CGA ?

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 rR=0.0055 rL=0.0167—with rR=0.0187 rL=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.

<table>
<thead>
<tr>
<th>Torsion splint</th>
<th>Inter hip dist. (mm)</th>
<th>R thigh (mm)</th>
<th>L thigh (mm)</th>
<th>R shank (mm)</th>
<th>L shank (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>without</td>
<td>142.4</td>
<td>244.9</td>
<td>265.5</td>
<td>216.8</td>
<td>220</td>
</tr>
<tr>
<td>with</td>
<td>146.2</td>
<td>246.1</td>
<td>266.2</td>
<td>215</td>
<td>229.7</td>
</tr>
<tr>
<td>difference</td>
<td>-3.8</td>
<td>-1.2</td>
<td>-0.7</td>
<td>1.8</td>
<td>-9.7</td>
</tr>
</tbody>
</table>
Discussion:

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.

References:

Case report: running analysis in hemiplegia affects surgical decision making

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Introduction: A 12-year-old girl with unilateral spastic infantile cerebral palsy and GMFCS II, was presented to the outpatient clinic. Visually a stiff knee gait, foot drop and in-toeing of the involved left side was observed. She complained of frequent tripping.

In-toeing can result from abnormal rotational alignment at the pelvis, femur, tibia, or foot. Quantifying the contribution of each anatomic area to this gait abnormality is difficult to determine from observational gait analysis alone. Therefore, the patient was referred to have an instrumented gait analysis.

Research question: Identify the rotational malalignment causing the In-toeing and additional reasons for frequent tripping.

Methods: manual muscle testing and instrumented gait analysis was performed using a modified Plug-In-gait model [1]. In addition to walking, a running analysis was performed to assess the risk of tripping under a highly dynamic situation.
**Results:** In the sagittal plane (figure), the patient showed a remarkable stiff knee walking pattern and reduced ankle dorsiflexion in swing. The knee and foot progression were internally rotated. Increased rectus EMG activity during swing phase and increased rectus tone (MAS 2) was identified and interpreted as primary reason for the stiff knee gait and the cause of reduced foot clearance and tripping. However, during running, despite increased EMG activity, the stiff knee pattern disappeared completely (figure).

**Discussion:** Due to the gait- and clinical analysis surgical rectus transfer [2] and tibia derotation osteotomy [3] were indicated. However, running considerably improved the knee flexion in swing. Therefore, the patient did not receive rectus transfer in addition to derotation osteotomy of the tibia. Following surgery, the foot progression angle improved and the patient did not complain about tripping anymore. Therefore, rather internal foot progression than stiff knee gait was the reason for tripping, since the patient was able to increase knee flexion when required. Similar observations have been made by walking on uneven surface where the patient was able to improve knee flexion without surgical intervention [4]. Summarized, running analysis was important and it changed invasive therapeutically interventions suggested from walking classification.

**References:**


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Introduction: Ankle joint hyper-resistance in cerebral palsy (CP) is thought to be caused by spasticity (neural, velocity-dependent hyper-active stretch reflex) and by non-neural morphological muscle changes that alter tissue stiffness. To target both components, treatment often combines Botulinum Toxin-A (BTX) injections with a period of stretching by means of lower leg casts. Given the heterogeneity in response to such treatment, it is worthwhile to quantify the separate effects of BTX and casting on the components of ankle joint hyper-resistance and measure how these relate to treatment outcome as measured by 3D gait analysis (3DGA). Such a unique combination of assessments could highlight the underlying mechanisms leading to treatment outcome, thereby helping us to improve treatment efficacy.

Research Question: How are medial gastrocnemius (MG) spasticity, muscle belly length, and gait as measured with objective instrumented assessments affected by BTX and by casting in a child with spastic cerebral palsy?

Methods: An 11 year old boy with spastic right hemiplegia due to CP (GMFCS level I) was treated with multilevel BTX injections (including 6u/kg body weight in the MG) and 2 weeks later with lower-leg casts applied for 2 weeks. Instrumented spasticity assessment (ISA)1, and 3D freehand ultrasonography (3DfUS)2 were assessed pre-treatment, after 2 weeks (post-injection), and after 4 weeks (post cast-removal). ISA was used to quantify the neural and non-neural contributions of the work measured at the ankle joint during slow and fast passive movement1 while 3DUS assessed the MG muscle length at rest.2 3DGA including assessment of joint kinematics, kinetics and EMG was carried out pre- and at 4 weeks post-treatment. To maximize the influence of spasticity, during the 3DGA, the child was asked to walk at self-selected walking speed and then as fast as possible without running. The effect of increasing walking speed on the ankle movement analysis profile (MAP)3 in the sagittal plane was calculated pre and at 4 weeks post-treatment.

Results: Two weeks post-BTX, both the neural (-96%) and non-neural (-92%) components decreased (see bar chart). At 4 weeks post-treatment, the neural component was still decreased by 88% and the non-neural by 60%. MG muscle length at rest (15-25° plantarflexion) decreased by 0.2mm 2 weeks post-BTX, but increased by 2.8mm at 4 weeks post-treatment. There were no changes in passive ankle range of motion (ROM). Improvements in ankle kinematics, kinetics, and power generation 4 weeks post-treatment were most marked at the fast walking speed (see figure). The ankle MAP pre-treatment was 10° at self-selected walking speed and 14° at fast walking speed. At 4 weeks post treatment, these values decreased to 3° and 5°, respectively.
Discussion: Surprisingly and in contrast to previous findings, the neural and non-neural components of joint hyper-resistance improved 2 weeks post BTX. The increase in non-neural hyper-resistance at 4 weeks may have been due to the assessment being carried out on the same day as the cast removal. Given the limited effect on MG muscle length, and the lack of improvement in passive ankle ROM, improved ankle motion and power generation during high velocity gait is most probably due to decreasing the neural component.

Patient centred rehabilitation: three years of gait recovery in a child affected by hemiplegia

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Introduction: The aim of this report was to illustrate and to discuss a method capable of improving the person-oriented decision-making process during three years of gait rehabilitation based on the integration of: i) the fundamental principles of motor learning; and ii) the outcomes made available by both clinical standardized assessment tools (SAT) and measures made available by a gait analysis system (GA).

Research Question: Can gait analysis (GA) improve the decision making processes during motor recovery in comparison with standardized functional assessment tools (SAT)?

Methods: A six-year-old child affected by hemiplegia after arterial ischemic stroke (Fig. 1) that had limited upper and lower right-limb function but unaffected sensory and cognitive skills was studied beginning from 22 days after the stroke. Four different rehabilitative treatments were chosen during recovery. A training centred on the equilibrium point hypothesis (T1), a cognitive approach (T2), segmental exercises (T3) and a proposal based on the ecological hypothesis (T4) were sequenced. Measurements of motor performance before and after the selected treatments using PEDI and GMFM (SAT) and kinematic and kinetic parameters (GA) were assessed along three years.

Results: Gait pattern and inter- and intra limb-joint coordination changed over time during the three examined years (Fig 2, A baseline, B 60 days, C 240 days, D 360 days; and Fig 3, A and B, solid line and dot dashed one, highlighted by the arrows, represents 240 days and 360 days, respectively, dashed line the controls). The changes in Fig 3A was determined by the reduction of pelvic tilt ante-version (Fig 3B) without any changes of ankle initial contact angle. The tilt variation allowed heel contact. However, after the first eight months of recovery, gait pattern modifications were detected by GA measures but not by SAT, Fig 4. Moreover, the two pattern depicted in Fig 2 (C and D) and in Fig 3 were alternated during the last two years in relationship to the selected training: T3 or T4, respectively. The recovery ended with the stabilization of the pattern in Fig 2D.

Discussion: While the SAT assessments show a ceiling effect, gait analysis was able to follow functional changes. Treatment T1 seems to be correlated with an improvement of muscle recruitment; treatment T2 is associated with gait recovery; and, finally, treatment T4 is related with functional pattern change. Ho et al. [1] suggested that there is a mutual relationship between
the post-injury neural pattern and mechanical properties of soft and contractile tissue in children; thus, we hypothesize that changes in the foot rocker (on toe or heel) can influence the future development of the walking pattern. Furthermore, a biomechanical redundancy contribution emerged. Where the system encountered the ankle control limit the pelvic regulation allowed the recovery of a more adaptive foot-terrain coupling induced by the treatment based on the ecological approach.

Clinical Case: Simulation-based evaluation of post-operative gait function to support clinical decision making in cerebral palsy

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Introduction: Three-dimensional gait analysis is typically used to inform clinical decision-making in children with cerebral palsy (CP). Musculoskeletal modelling and simulations, however, enable additional musculoskeletal analyses, which might provide further guidance when selecting the treatment. In this study, we evaluated the ability of simulations to inform on post-intervention gait performance in a child with CP.

Research Question: Can pre-intervention motion capture data together with a subject-specific musculoskeletal model be used to inform on post-intervention gait performance in a child with CP?

Methods: A 10-year old female, diagnosed with mild spastic triplegic CP (GMFCS II), underwent a single-event multilevel surgery including bilateral psoas lengthening, rectus femoris transfer, tibia derotation, femur derotation and extension osteotomy, and patella distalisation. This treatment was selected based on the gait and clinical assessment reporting a triple flexion gait pattern with increased femoral anteversion and increased muscle tone in hip flexors, hip adductors, rectus femoris, hamstrings, soleus, and gastrocnemius bilaterally. Marker trajectories, EMG, and ground reaction forces were measured during pre- and post-intervention gait analyses. A pre-intervention musculoskeletal model with subject-specific geometry was built based on magnetic resonance images [1] and experimental patient joint kinetics (red waveforms in Fig. 1) were calculated in OpenSim [2]. Muscle forces were subsequently calculated, while imposing a kinematic gait pattern from a typically developed (TD) child, using a synergy-constrained static optimization, hence taking the patient motor control capabilities into account [3]. The resulting model-based joint moments (dashed blue waveforms in Fig. 1) therefore give an indication of the motor capacities of the patient to perform a typical gait motion. The pre-intervention model was then modified based on the performed surgical interventions and a similar workflow was used. Experimental and model-based CP joint kinetics were compared to the experimental kinetics of a TD child (green waveforms in Fig. 1). Note that the post-intervention data were collected one year after the intervention, therefore slightly influencing the imposed TD kinetics due to the increase in bodyweight. The root mean square difference (RMSD) between 1) the experimental patient and the TD child joint kinetics and 2) the model-based and the TD child joint kinetics were then calculated pre- and post-intervention.

Results: The pre- and post-intervention joint kinetics for a representative degree of freedom, left hip adduction, are shown in Fig. 1. The post-intervention RMSDs were smaller for six out of eight analysed joints when comparing patient and TD child joint kinetics (average over all joints: 0.28±0.18 Nm/kg and 0.17±0.10 Nm/kg for pre- and post-interventions, respectively) and for seven out of eight joints when comparing model-based and TD child joint kinetics (average over all joints: 0.14±0.06 Nm/kg and 0.10±0.03 Nm/kg for pre- and post-intervention, respectively).
**Discussion:** These results suggest that the model-based evaluations were clinically meaningful since they provided similar information in terms of post-intervention gait performance as the post-intervention gait analysis. Note that this approach is independent of the availability of post-intervention data. This therefore opens perspective for model-informed treatment planning where multiple interventions might be simulated while evaluating their impact on the gait performance. In future work, we will refine the models by including subject-specific muscle-tendon properties [4] and extend this study to different patients and types of interventions.

Effects of Botulinum Toxin-A and casting treatment on assessed spasticity, muscle morphology and gait kinematics in spastic paresis.

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1VU, Amsterdam, The Netherlands, 2VUmc, Amsterdam, The Netherlands, 3TU Delft, Delft, The Netherlands, 4KU Leuven, Leuven, Belgium

Introduction: Spasticity as part of a central neurological disorder is characterized by a ‘velocity dependent hyperactive stretch-reflex’ [1]. Secondary, morphological adaptations of the muscle-tendon complex reduce the passive joint angle-moment relationship (i.e. passive ROM) [2]. Potentially, joint hyper-resistance, as a result of either the neurological disorder, muscle morphology or both, can be clinically assessed [3]. Botulinum Toxin-A (BoNT-A), in combination with casting and physiotherapy are regularly used as conservative treatment in children with a spastic paresis to improve gait. While in some studies improvements resulting from this approach are reported, large treatment-response variability persists [4]. Heterogeneity in treatment effectiveness may be due to a clinical focus at the joint impairment level rather than on the contributing mechanisms of joint hyper-resistance. In recent years great advances have been made in standardized, objective assessments of stretch reflexed induced joint hyper resistance [5]. 3D ultrasound (3D-US), allows morphometry of the muscle-tendon complex in children with spastic paresis [6]. The combination of instrumented assessments of neurological, muscle morphology and gait characteristics following treatment has not been carried out.

Research Question: What are the effects of BoNT-A treatment on spasticity, muscle morphology and gait in spastic paresis?

Methods: A 6.5 year old girl diagnosed with hereditary spastic paraplegia (functional level: GMFCS II) participated. Treatment started with ultrasound guided multi-level BoNT-A, 3 weeks after which serial casting was applied below the knee for 4 weeks. Intensive physiotherapy was carried out 12 weeks post treatment, while the use of ankle-foot orthoses continued after casting. The following assessments on her right (most affected) leg were carried out 1 week pre- and 9 and 26 weeks (w) post-treatment (Fig. 1): 1) motorized Instrumented spasticity assessment (ISA), quantifying m. gastrocnemius medialis (GM) reflexive response via EMG during standardized slow (15°/s) and fast (150°/s) passive stretches; 2) 3D-US morphometry of GM to assess muscle volume, and muscle belly and tendon lengthening between footplate angles corresponding to externally applied 1 and 4 Nm dorsal flexion (dfl) moments 3) Barefoot gait analysis (GA) aimed at assessing ankle and knee kinematics during gait.

Results: ISA showed that in all measurements EMG during fast stretches were higher compared to slow stretches, indicating the presence of spasticity. Post-treatment, fast stretch induced EMG reduced by 62% at 9w and 43% at 26w. 3D-US morphometry showed marginal post-treatment changes in GM muscle volume normalized for body mass (by 2% at 9w and 5% at 26w). However, passive normalised lengthening between 1 and 4Nm dfl moments increased post-treatment (muscle belly from 2.2% pre- to 4.3% at 9-w and 5.3% at 26w post-treatment; tendon from 1.3% pre- to 2.2% at 9w and 3.5% at 26w post-treatment). GA showed a decrease in stride time from 0.94s pre-treatment to 0.84s at 9w and 0.82s at 26w post-treatment. In addition at 9w post-treatment 10° (-4° pre to 6° post 9w) more ankle dorsiflexion and 6° (18° pre to 12° post 9w) less knee flexion were observed during mid-stance. However, after 26w ankle dorsiflexion improvement was reduced by 5° (-4° pre to 1° post 26w) and knee flexion angle deteriorated by -10° (18° pre to 28° post 26w).

Discussion: At 9w post-treatment, the velocity dependent hyperactive stretch-reflex was smallest and gait kinematics were most improved. However, muscle and tendon compliance to externally
applied footplate moments continued to increase until 26w post-treatment. Therefore, deterioration in gait after 26w may be explained by a mildly recurved velocity dependent hyperactive stretch-reflex. To the best of our knowledge, there is no previous literature available describing the combined effects of BoNT-A treatment on spasticity, muscle morphology and gait characteristics. This combination of assessments allows clinicians to estimate contributions of various components to joint hyper-resistance and their effects on gait, which in turn, can be used to fine-tune and individualize treatment.

References:
Are medial gastrocnemius and tibialis anterior morphology indicative of kinematic and kinetic impairment during gait in children with spastic cerebral palsy and a control group of typically developing peers?

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Introduction: Children with spastic cerebral palsy (SCP) present with impaired muscle growth compared to typical development (TD), where the deficits in muscle volume lead to lower force-generation, and reduced functional capacity. With respect to gait, moderate associations in the stance phase were found between plantar flexor work and muscle volume in unilaterally impaired SCP adolescents [1], whilst similar findings were reported between the sagittal plane ankle angle at initial contact and pennation angle of the tibialis anterior [2]. Neither investigation compared these findings to data of a control cohort. It is also unknown to what extent the proliferation of non-contractile tissue within SCP muscles [3] influences muscle function.

Research Question: To what extent can muscle volume and echo-intensity of the medial gastrocnemius and tibialis anterior explain ankle impairments in the stance phase of gait?

Methods: Two cohorts were recruited for this investigation (TD n=12; SCP n=33). The cohort of SCP children was naive to previous orthopaedic and/or neurological surgery, or BTX-A injections six months prior to measurement. Using 3D freehand ultrasound (combination of an ultrasound and motion-tracking system [4]), 3D reconstructions of the medial gastrocnemius (MG) and tibialis anterior (TA) were created. Muscle volume and echo-intensity (EI) were extracted using OsiriX (www.osirix-viewer.com). EI was calculated as the mean for the entire muscle, Whilst muscle volume was also expressed relative to body-mass. A Vicon system and AMTI force-plates collected kinematics and kinetics of the ankle at a self-selected walking speed. The mean of three good trials for peak ankle power generation during the stance phase, and the sagittal plane ankle angle at initial contact were extracted. Ankle power was also normalized to body-mass. T-tests were used to compare the differences between cohorts, whilst the Pearson correlation coefficient was used to evaluate correlations between variables. Significance was set to p≤0.05.

Results: Cohort characteristics with means and standard deviations for all outcome parameters can be found in table 1.

<table>
<thead>
<tr>
<th></th>
<th>Age (years)</th>
<th>Mass (kg)</th>
<th>norm. MV (ml/kg)</th>
<th>Mean EI (256 bit)</th>
<th>norm. Ankle Power (W/kg)</th>
<th>ankle @ IC (°)</th>
<th>ankle @ IC (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MG</td>
<td>TD n=12</td>
<td>10.6±2.2</td>
<td>36.9±9.3</td>
<td>2.0±0.3</td>
<td>100.9±6.7</td>
<td>4.1±0.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SCP n=33</td>
<td>9.4±2.8</td>
<td>30.4±11.2</td>
<td>1.2±0.4</td>
<td>124.4±8.9</td>
<td>2.2±0.9</td>
<td></td>
</tr>
<tr>
<td>TA</td>
<td>TD n=11</td>
<td>10.4±2.7</td>
<td>36.1±11</td>
<td>1.9±0.2</td>
<td>89.8±12.7</td>
<td>-</td>
<td>1.5±2.1</td>
</tr>
<tr>
<td></td>
<td>SCP n=21</td>
<td>9.3±2.9</td>
<td>31.0±12.5</td>
<td>0.7±0.1</td>
<td>107.9±9.6</td>
<td>-</td>
<td>-5.4±11.2</td>
</tr>
</tbody>
</table>

The SCP cohort had deficits in mean normalised MG and TA volume of 40% and 63%, respectively (p≤.001), increased mean EI of 23.3% and 20.2%, respectively (p≤.001), deficit in mean peak ankle power generation of 46% (p≤.001) and increased plantar flexion at initial contact (p=0.1). Significant correlations were found between MG volume and peak ankle power generation (TD r=.63 p=.03; SCP r=.85 p≤.001), MG mean EI and normalised peak ankle power.
generation (TD $r = -0.79 \ p \leq 0.001$; SCP $r = -0.40 \ p = 0.02$) and normalised TA volume and sagittal plane ankle angle at initial contact (TD $r = -0.69 \ p = 0.03$; SCP $r = -0.72 \ p \leq 0.001$).

**Discussion:** The investigation confirmed the presence of alterations to MG and TA volume and mean EI in SCP children, and their sensitivity relative to gait impairments. Gastrocnemius volume was shown to increase following a home-based strength training program [5], so it is of clinical interest to determine if this may also translate into an increased ankle power generation during gait. The impact of strength training on the TA is less clear, so investigating the extent of hypertrophy and its effect on the ankle at initial contact would be worthwhile. Future investigations should include the soleus muscle, whilst a measure of neurological control may provide a more complete picture. Finally, the inclusion of Mean EI provided additional insight beyond muscle volume alone, and should be investigated further.

Accurate measurement of human soleus morphological parameters using diffusion tensor and T1 magnetic resonance imaging

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Introduction: Morphological parameters of a muscle, e.g. fascicle length (FL) and pennation angle (PA), impact the muscle’s force generation capacity. These parameters vary between individuals and can be modified due to neurological pathologies. Accurate measurement of human muscle morphological parameters in vivo is still a challenge, nevertheless clinically relevant. The approach presented in the study aims to tackle the inaccuracy of conventional 2D ultrasonographical measurement by using 3D diffusion tensor imaging (DTI). FL and PA of the soleus muscle from three subjects after stroke are presented.

Research Question: The aim of the study was to accurately measure FL and PA of the posterior and anterior compartment of the soleus muscle in the post-stroke subjects using diffusion tensor and T1 magnetic resonance imaging.

Methods: Two male and one female hemiplegic subjects after stroke (age: 50.7 ± 16.3 yrs, body weight: 81 ± 7.9 kg) were scanned using a 3T MRI scanner (Siemens Trio) while the subjects were lying in a supine position with 30° knee flexion and 80° ankle plantarflexion. The reconstruction of muscle fascicles and calculation of morphological parameters (FL and PA) were conducted using a previously reported method [1]. The post-processing protocol consisted of several steps [2]: 1. Muscle segmentation from T1-weighted images; 2. Diffusion tensor and T1-weighted image registration; 3. Region of interest (ROI) identification and fascicle tracking from DTI images; 4. FL and PA determination.

Muscle parameters were identified in three ROIs for each muscle compartment (lateral, central and medial location of the posterior compartment; anterior, central and posterior location of the anterior compartment). FL was defined as the length of fascicles from the superficial/anterior aponeurosis to the deep aponeurosis or median septum and it was assumed that all fascicles ended at the muscle surface of the segmented volume. PA was determined as the angle of the fascicles relative to superficial/deep aponeurosis (posterior soleus) and relative to anterior aponeurosis and median septum (anterior soleus).

Results: In the affected leg, mean FL of all three locations was 4.28 ± 1.03 mm longer in the posterior compartment and 4.51 ± 1.63 mm longer in the anterior compartment compared to the...
less affected leg. PA was not significantly different between affected and less affected side. The mean values of FL and PA for the posterior compartment are presented in Table 1.

**Table 2:** Mean values of FL and PA over all three subjects for the posterior soleus compartment at each ROI.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Location</th>
<th>Less affected leg (mean ± S.D.)</th>
<th>Affected leg (mean ± S.D.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FL [mm]</td>
<td>Lateral</td>
<td>39.67 ± 1.76</td>
<td>43.97 ± 0.55</td>
</tr>
<tr>
<td></td>
<td>Central</td>
<td>39.12 ± 4.52</td>
<td>43.24 ± 4.23</td>
</tr>
<tr>
<td></td>
<td>Medial</td>
<td>33.94 ± 2.85</td>
<td>38.36 ± 1.52</td>
</tr>
<tr>
<td>PA [°]</td>
<td>Lateral</td>
<td>22.13 ± 3.91</td>
<td>22.82 ± 6.66</td>
</tr>
<tr>
<td></td>
<td>Central</td>
<td>19.29 ± 4.63</td>
<td>21.43 ± 7.10</td>
</tr>
<tr>
<td></td>
<td>Medial</td>
<td>18.55 ± 2.73</td>
<td>21.75 ± 6.07</td>
</tr>
</tbody>
</table>

**Discussion:** The estimated parameters agree with previously reported values [3] and it has been shown that the proposed method can be successfully used for the measurement of muscle morphological parameters in vivo. Furthermore, our preliminary results have indicated that the morphological parameters of the soleus may differ between the affected and less-affected side after stroke, though further investigation is necessary.

Medial gastrocnemius muscle in children with Spastic Paresis show growth defects for muscle volume and altered normalized muscle and tendon length compared to typically developed children.

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\textsuperscript{1}VU, Amsterdam, The Netherlands, \textsuperscript{2}VUmc, Amsterdam, The Netherlands, \textsuperscript{3}KU Leuven, Leuven, Belgium, \textsuperscript{4}TU Delft, Delft, The Netherlands

Introduction: Typically, Spastic Paresis (SCP) causes morphological changes of m. gastrocnemius medialis (GM) that may change its mechanical characteristics. An enhanced resistance to dorsal flexion may in part be explained by such changes.

Research Question: Are morphological parameters of GM in SCP and typically developing (TD) children different? And if so what are its functional consequences, measured or predicted.

Methods: Subjects: 13 SCP children (aged 9.7 ± 2.1 years; GMFCS: I-II 9 (i.e. considerably less serious afflicted than in our previous work [1]; body mass 33.1 ± 9.6kg) and 14 typically developed (TD) children (aged 9.3 ± 1.7 years; body mass 33.2 ± 8.8kg). For SCP, inclusion criteria were no Botulinum Toxin-A treatment for at least 6 months and no lower-limb orthopaedic surgery whatsoever. GM morphology (e.g. belly, fascicles and tendon length) were measured using 3D ultrasound imaging [2]. Results presented: for footplate angles corresponding to 4 Nm dorsiflexion (DF) moment. Muscle volume was assessed at footplate angle corresponding to 0Nm. Physiological cross-sectional area (Af) was calculated from muscle volume and fascicle length. EMG was used to verify muscle excitation was limited to ~2.2%MVC. Pearson’s correlation was used to test for correlation between 4Nm footprint angle and (normalized) variables of muscle morphology in both groups.

Results: Body mass, body length and lower leg length were not different between the SCP and TD groups. In TD, GM volume increased with age(r=0.78, p<0.01), however, in SCP no such effect could be shown (r=0.56, p=0.08).

Muscle belly and fascicle length normalized for segment length were lower in SCP (muscle belly: SCP 59±6% vs. TD 65±4%, p<0.01 and fascicle: SCP 16±3% vs. TD 19±2%, p<0.001). In contrast, in SCP normalized tendon length was higher (SCP 49±7% vs TD 43±3%, p<0.05). In SCP, muscle volume normalized for body mass was 57% smaller in SCP children (1.65±0.25 ml/kg) versus TD children (2.79±0.3ml/kg) (p <0.001).

In TD, a negative correlation was found between normalized muscle belly volume and 4Nm DF footprint angle (r=-0.89, p<0.001), however, no correlation was shown for SCP (see figure). For
TD, also $A_v$ was correlated negatively with 4Nm DF footplate angle ($r=-0.83$, $p<0.001$), for this variable also, SCP did not show such correlation and can thus be considered to be fairly constant despite increasing age.

In both TD and SCP groups normalized fascicle length did not correlate to 4Nm DF footplate angle.

**Discussion:** This study shows that GM morphology in SCP children differs from that of TD children. In particular GM muscle volume is smaller in children with SCP and, in contrast to TD, does not increase with age, indicating growth defect. As muscle volume is considered a measure for maximal muscle power [3], GM muscles in SCP children are lacking in maximal power, compared to TD. In TD children, GM volume was correlated with ankle dorsiflexion angle attained at externally exerted 4Nm, however in SCP children GM morphological variables do not solely explain functional limitations seen clinically. We suggest the clinical importance of interventions that improve muscle volume and physiological cross-section in spastic paresis. Further research is indicated toward explaining the source of mechanical limitations seen clinically for SCP children.

**References:**


An innovative solution to reduce muscle deformation during 3D freehand Ultrasonography

Francesco Cenni1,2, Simon-Henri Schless2,3, Davide Monari1,2, Lynn Bar-On2,3, Erwin Aertbeliën1, Herman Bruyninckx1, Kaat Desloovere2,3

1KU Leuven, Department of Mechanical Engineering, Leuven, Belgium, 2Clinical Motion Analysis Laboratory, University Hospital, Leuven, Belgium, 3KU Leuven, Department of Rehabilitation Sciences, Leuven, Belgium

Introduction: 3D freehand ultrasonography (3DFUS) can provide 3D datasets of anatomical regions [1], previously being used to assess morphological alterations in children with spastic cerebral palsy (SCP) [2]. Using a water tank (WT), the validity of 3DFUS for estimating medial gastrocnemius (MG) muscle volume revealed satisfactory results [3]. In routine use, the WT is substituted with a direct US probe-on-skin (PoS) approach, leading to an increase in subcutaneous tissue and muscle deformation (Figure 1). The extent of errors in estimating MG muscle volume due to these deformations was larger than using the WT [4]. These can be critical for longitudinal studies, where volume differences are small. Using a copious amount of gel is a possible solution to partly reduce deformation, but requires an experienced operator and may be unpleasant for the child. In an effort to maximally minimise tissue and muscle deformations due to linear US probes, a concave-shaped mount aptly on the US probe head, named ‘Portico’, was developed. The Portico is combined with a custom cut gel pad (Figure 1).

Figure 1. Cross-sectional area US images of the MG muscle acquired by using the US probe-on-skin (A) and the Portico (B) approaches. The portico mount (C) and custom cut gel pad (D)

Research Question: Can the Portico reduce the extrinsic errors when estimating MG muscle volume using 3DFUS in cohorts of TD and SCP children, with respect to the traditional PoS approach?

Methods: The MG was acquired in prone lying in 10 TD (age: 9.4±1.3y) and 10 SCP (age: 9.3±3.0y) children. US images (Telemed, Lithuania) were collected at 30Hz, whilst US probe pose (Optitrack, USA) was recorded at 120Hz. In-house developed software and MeVisLab were used for 3D MG reconstruction and volume computation [1,4]. Two repetitions were acquired for each acquisition condition (WT, PoS, Portico) to provide reliability analysis, whilst only the TD cohort had a WT measurement. The 3D datasets acquired using PoS and Portico were registered with respect to the ones corresponding in the WT. For the TD cohort, the muscle volume estimation, subcutaneous tissue and muscle deformation in the PoS and Portico conditions were compared to those in the WT (non-deformed measurement). For all analyses in both cohorts, the minimal detectable change (MDC) was calculated.

Results: Estimating MG volume using the PoS and Portico revealed differences in module of 3.4ml (4.2%) and 2.3 ml (2.8%), respectively. Lower MDCs were found using the Portico than PoS in both TD and SCP cohorts (Table 1). Subcutaneous tissue and muscle deformations using the PoS were 8.6 and 5.0, respectively, and 4.2 mm and 2.3mm for the Portico, respectively.
## Water Tank

<table>
<thead>
<tr>
<th>TD</th>
<th>MDC</th>
<th>Volume 1</th>
<th>Volume 2</th>
<th>Volume 1</th>
<th>Volume 2</th>
<th>MDC</th>
</tr>
</thead>
<tbody>
<tr>
<td>80.7 ± 19.8</td>
<td>3.5</td>
<td>80.5 ± 19.2</td>
<td>81.3 ± 17.9</td>
<td>80.9 ± 20.3</td>
<td>81.6 ± 21.7</td>
<td>5.7</td>
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<table>
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<tr>
<th>SCP</th>
<th>MDC</th>
<th>Volume 1</th>
<th>Volume 2</th>
<th>Volume 1</th>
<th>Volume 2</th>
<th>MDC</th>
</tr>
</thead>
<tbody>
<tr>
<td>38.1 ± 21.7</td>
<td>5.9</td>
<td>38.2 ± 20.0</td>
<td>38.7 ± 20.5</td>
<td>38 ± 19.7</td>
<td>1.9</td>
<td></td>
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</tbody>
</table>

**Table 1.** Average ± SD for volume [ml]. Between brackets: the percentage value with respect to the corresponding volume.

**Discussion:** Using the Portico yielded more valid and reliable MG muscle volume estimations than the traditional PoS approach. This can be further improved by optimising the fitting between the gel pad inside the portico and the curvature of the limb, using a larger range of portico geometries. Combining multiple 3DUS sweeps to provide a larger 3D reconstruction with several muscles may also benefit from the use of the portico, providing better matching between sweeps.

Can muscle morphology and internal composition of lower limb muscles explain strength and gait deficits in children with spastic cerebral palsy?

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1Clinical Motion Analysis Laboratory, UZ Leuven, Leuven, Belgium, 2Department of Rehabilitation Sciences, KU Leuven, Leuven, Belgium

Introduction: Three dimensional freehand ultrasonography (3DfUS) is an imaging technique for measuring morphological and structural parameters of skeletal muscles. In children with cerebral palsy (CP), muscle alterations are a secondary effect of a non-progressive brain lesion. Such changes are decreased muscle volume (MV) and muscle belly length [1], whilst echo-intensity (EI), a parameter representative of internal muscle composition, is increased [2]. However, most US research has focused on the medial gastrocnemius (MG). Next to this, changes in muscle strength, rate of force development (RFD) and functional measures, like gait, have also been reported extensively [3,4]. This study aims to define the relation of muscle morphology and internal composition of four lower limb muscles with muscle strength and gait performance.

Research Question: Can the morphology and internal composition of four lower limb muscles provide insight in known strength and gait deficits in children with cerebral palsy?

Methods: 9 typical developing (TD) children (10.4±3.3 yrs, 35.0±11.7 kg) and 8 CP children (9.5±3.0 yrs, 32.9±11.5 kg) were recruited. 3DfUS acquisitions with an US (Telemed, Lithuania) and motion tracking system (Optitrack, USA) were used to extract MV (ml) and EI (expressed in a grey-scale of 256 values). This was performed for the MG, tibialis anterior (TA), semitendinosus (ST) and rectus femoris (RF) muscles. Maximal voluntary isometric contractions (MVICs) were collected for plantar flexion (PF), dorsiflexion (DF), knee flexion (KF) and knee extension (KE) with a handheld dynamometer (Microfet, USA) from which maximal joint torques (MJT) and RFD were defined as strength parameters. 3DGA data were collected at a self-selected walking speed from which gait profile scores (GPS) and movement analysis profile scores (MAPS) were calculated for the assessed side. Associations between muscle properties, strength and gait were defined with the Spearman’s rank correlation coefficient and classified according to Altman [5].

Results: On average, MV was 40% smaller in CP children whilst EI was 15% increased. Joint torques and RFDs were in general lower in CP, while the average GPS was 12.5°±4.7°. Significant moderate to strong correlations between MV and MJT were found in the TD group for all muscles (r=0.65-0.91, p≤0.057). KF RFD and DF RFD strongly correlated with MV of the same muscle groups (r=0.87-0.88, p=0.002). EI showed no associations with MJT and RFD. The CP group showed weak, non-significant correlations of MV with either MJT or RFD, except for the strong correlation with KF RFD (r=0.667, p=0.071). For EI, moderate to strong correlations were found for the TA with MJT (r=0.69, p=0.058) and RFD (r=0.50, p=0.21) of DF. An average EI value for all four muscles showed a strong correlation with GPS (r=0.619, p=0.10), and the MAPS for the sagittal plane at the knee correlated moderate to strong with the EI of the MG, TA and ST (r=0.52-0.62, p≤0.18).

Discussion: This investigation revealed weaker associations between MV and muscle strength in CP children than seen in TD children, emphasizing the influence of non-muscular aspects possibly found in impaired neural control. The presence of stronger associations with EI in CP children reveals the influence of changed internal muscle composition besides morphological alterations. Overall, these preliminary explorations on a small sample size show trends towards moderate or strong correlations for EI and MV with strength parameters of the respective muscles groups. While previous research indicated only weak to moderate relations between MVIC joint torques and alterations in gait [6], results of this study suggest that EI, as a measure of internal muscle composition, may provide additional insight into the lack of this relationship. Further work is required to determine the influence of muscle morphology and internal muscle composition on functional deficits in a larger sample of children with CP.

References:
Alterations in lower limb muscle morphology in Cerebral Palsy with different GMFCS levels and varying age

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Introduction: Muscular pathology in CP progresses with growth and affects muscle morphology of the lower limbs [1]. Little is known about how this morphology is altered in children with different GMFCS levels. Moreover, it is not known how the relationship between muscle morphology and age is affected in children with CP.

Research Question: How are lower limb muscles altered in children with GMFCS levels I & II with varying age?

Methods: 18 spastic children with CP (group GMFCS I: N=10, GDI: 80±13; group GMFCS II: N=8, GDI: 64±13; age: 12±4 years [7-19]), with no orthopaedic history, and 17 age-matched typically developing children (TD group) underwent MRI acquisition of the lower limbs. Semi-automatic 3D reconstructions of the belly muscles were performed [2]. Normalized belly muscle volumes and lengths were calculated for 17 muscles bilaterally. For each muscle, the 20th and 5th percentile in TD were used to classify the spastic muscles as subnormally (class1) or abnormally (class2) low, respectively. Differences in distribution between classes in the different groups were studied using Fisher’s test and the effect size was quantified by Cramer’s V (CV) coefficient. Linear regressions between muscle volumes and age in TD children were displayed with their 95% Confidence Interval (CI). Then, in order to assess whether the relationship between CP muscle volume and age was similar to that of TD, muscle volumes of children with GMFCS levels I and II were plotted on the graph of the TD linear regressions. 2 classes were defined: inside or below the 95%CI. Differences in distributions between classes in the different groups were assessed.

Results: Hamstrings, rectus femoris, adductor longus, gastrocnemii, soleus and anterior tibialis showed more subnormally and abnormally low volumes in children with GMFCS I and II compared to TD children (CV: [0.3-0.6], p<0.05). The largest difference was noted for the rectus femoris (100% abnormal and subnormal volumes in GMFCS level II). As for muscle lengths, adductor longus, gracilis and anterior tibialis showed more subnormally and abnormally low lengths in children with GMFCS levels I and II compared to TD children (CV: [0.3-0.5], p<0.05). The largest difference was noted for the gracilis (80% subnormal and abnormal in GMFCS II). Although muscle volumes showed an increase with age in both CP and TD groups (i.e. $R^2=0.2$ for biceps brevis and 0.7 for adductor magnus), muscles in CP showed a slower increase in volumes with age when compared to TD. This was noticed for the rectus femoris, soleus, gastrocnemius medius and semimembranosus (fig.1), which showed significantly more CP subjects below the 95% CI of the regression line between muscle volume and age in TD (CV: [0.3-0.5], p<0.05).

Discussion: Subjects with GMFCS levels I and II have a significantly higher prevalence of abnormally small and short muscles compared to TD children, which could account for the known reduction in force generation during gait [3]. This cross-sectional study is the first to show that volume growth with age is altered in children with CP. This might explain the deterioration of walking abilities of these subjects with increasing age.

Semimembranosus

CV: 0.46
p = 0.001
TD: $R^2 = 0.56$

Rectus Femoris

CV: 0.38
p = 0.007
TD: $R^2 = 0.59$

- CP GMFCS I
- CP GMFCS II
- TD
- Conf. interval in TD (Obs 95%)
Assignment of Gross Motor Function Classification (GMFCS) Level Using an Algorithm Based on GMFCS Descriptors and Functional Skills

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Introduction: The Gross Motor Function Classification System (GMFCS) for children with cerebral palsy (CP) provides a description of a child’s or youth’s present abilities and limitations in gross motor function.[1,2] It is used extensively by clinicians, families, and researchers alike to communicate usual performance in mobility across a range of environments. The system is inclusive of mobility other than ambulation which was the focus of previous functional scales.[3]

The widespread use of the GMFCS among clinicians has created a need to be as consistent as possible in assigning the appropriate level. Similarly, use in research has created a need to retrospectively classify individuals for whom functional information is available but no GMFCS assignment was made. Currently, there is no objective decision tree or algorithm that captures the principles of GMFCS level assignment.

Research Question: Can an algorithm based on distinguishing descriptors of the GMFCS provide an accurate assignment of GMFCS level?

Methods: The Gillette Functional Assessment Questionnaire [4,5] (walking level and selected skills) (FAQ) and a modified Hoffer functional ambulation scale [3] along with a walking video were used to devise an algorithm to assign GMFCS levels I-IV based on GMFCS descriptors and distinguishing characteristics. Individuals with a diagnosis of CP and a pre-assigned GMFCS level were queried from our database. A test set of 500 individuals were randomly chosen for algorithm assignment in proportion to GMFCS levels in the database population (29% GMFCS I; 35% GMFCS II, 28% GMFCS III, 8% GMFCS IV).

Results: Initial database query yielded 2215 visits of individuals with a diagnosis of CP, pre-assigned GMFCS level, and seen for an initial, spasticity, or pre-surgery evaluation. Two thousand one hundred forty-six had complete information from which the random test set was chosen. Five of twenty-two skills from the FAQ were utilized in the algorithm in addition to the modified Hoffer scale and video: step up/down curb without assistance, jump off a single step, run, walk up/down stairs with railing, and walk up/down stairs without a railing. Accuracy of the algorithm was 87% [Figure 1]. The true positive rate (TPR) ranged from 82% to 90%, and the positive predictive value (PPV) ranged from 81% to 95%. The rate of misclassification by more than one level was 0.2%.

Discussion: The algorithm based on GMFCS descriptors provides an accurate method to assign levels retrospectively. Utility in concurrent clinical situations is apparent as well. Observation of walking abilities of the individual and conversation with the family regarding abilities on particular skills would lead to a common, collaborative assignment of level, and would enhance consistency.
of assignment among clinicians and family alike. The positive rate and predictive value are comparable (and in some cases better) to the levels of agreement reported in the original study.[1] Dependence on direct observation of walking ability or use of video presents a limitation in situations where retrospective assignment is necessary for large numbers of individuals. The construction of the algorithm using the distinguishing features of the GMFCS allows the clinician more objectivity in level assignment.

Jumping Ability in Young Adults with Spastic Cerebral Palsy – a Comparative Study of Controls

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Introduction: Cerebral palsy (CP) is caused by damage to the immature brain and affects approximately 2 out of 1000 children in Sweden. Persons with CP have restricted motor function and it is particularly impaired in terms of explosive movements. The vertical jump on one leg is an example of an explosive movement, which has been tested with good reliability in healthy persons and patients with knee ligament injury. No published papers on jumping in persons with CP have been found.

Research Question: How does the ability of young adults with spastic CP to jump on one leg differ from that ability of typically developed individuals in the same age range?

Methods: Measurements of kinematics and kinetics were made with three-dimensional motion analysis and force plates. Data analysis was carried out on jump height and power generation from the hip, knee and ankle level when jumping on the stronger and the weaker leg respectively. The study population was ten young adults (four women, six men) with unilateral or bilateral spastic CP, with unsupported walking-ability and age 25.6 (20.8-30.1). The reference group was ten healthy, typically developed individuals (five women, five men), age 25.2 (18.6-30.4).

Results: In the study population mean jump height was 21.1 cm (6.3-34.1 cm) on the stronger leg and 12.8 cm (6.3-22.4 cm) on the weaker. Mean jump height in the reference group was 29.3 cm (19.6-37.0 cm) on the stronger leg and 28.0 cm (19.3-34.3 cm) on the weaker. The difference in jump height between the study and the reference group was found significant for jumping, both on the stronger (p 0.028) and the weaker leg (p 0.001). In the study population mean power generation from the hip was 7.33 W/kg (4.20-11.23 W/kg) when jumping on the stronger leg and 7.62 W/kg (4.99-10.05 W/kg) jumping on the weaker leg. Mean power generation from the knee was 7.36 W/kg (4.48-11.67 W/kg) on the stronger leg and 4.09 W/kg (0.31-7.39 W/kg) on the weaker. Mean power generation from the ankle was 9.45 W/kg (4.89-12.05 W/kg) on the stronger leg and 5.00 W/kg (0.80-7.40 W/kg) on the weaker. Mean power generation from the hip in the reference group was 7.17 w/kg (3.61-9.67 w/kg). Mean power generation from the knee was 10.42 w/kg (3.73-15.11 w/kg) and from the ankle 12.29 w/kg (9.09-15.67 w/kg) in the reference group. There was a significant difference between the two groups in power generation from the knee in the stronger leg (p 0.33) and in both knee (p < 0.001) and ankle (p 0.002) in the weaker leg.

Discussion: Results show that there was a greater variation both of jump height and of power generation profile between the different individuals in the study group compared to the reference group. Furthermore, the mean power generation profiles of the stronger and the weaker leg were significantly different in the study group. Whereas, the profiles were the same for both legs in the reference group. When jumping on the weaker leg the study group generated most power from the hip, in contrast to both their jumping on their stronger leg and to all jumping in the reference group where most power originated from the ankle. These findings suggest that the population with CP have less of a standardized way of generating explosive power in a jump.
PROOF-OF-CONCEPT OF A VIDEO ANALYSIS FOR THE DETECTION OF INFANT MOVEMENT GESTALTS

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Introduction: 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). The general movement assessment is a qualitative method that assesses gestalts in the infant movements (1). Previous studies have shown that fidgety movements (FMs) can be detected and cerebral palsy can be predicted by use of computer-based video analysis software (2). However, video-based movement analysis has only assessed infant movements as a center of motion and not assessed the gestalts as coordinative movements between the infant’s body segments.

Research Question: The aim of this study was to introduce a proof-of-concept of the validity of computer-based movement analysis capturing gestalts of FMs.

Methods: A typically developing term born infant with a normal motor repertoire was included. Video recording at 12 weeks post term age were observed and analyzed according to Prechtl’s General Movement Assessment by an experienced and certified observer. Three epochs with FMs (duration) and three epochs with non-FMs with similar duration was selected from the video. A video analysis based on fixed-reference multilevel optical flow estimation and principle component analysis was developed according to the IDLE modeling principle (3), where the different principle components (PCs) have the potential to capture the gestalts of the infant movements. 3D plot and video vector fields were used to display the movement gestalts.

Results: 93% of the movement variation was explained by 10 PCs. Figure 1C indicate that PC number 2, 4, and especially 7 was the most sensitive PCs to difference between FMs and non-FMs. The video vector field indicates that composite movements in both arms were most related to FMs which was confirmed by certified observer (see PC #7 in Figure 1B and 1D). Discussion: The PC number 7 had the potential to define the gestalt for the FMs periods that was most present in the upper extremities for this infant. However, more studies are needed(?) to validate the present proof-of-concept on a larger cohort of infants and identify specific measures of the PCs valid for the FM pattern and which could improve predict models of cerebral palsy and other movement disabilities.

References:
Using Posture Recognition to Characterize Real Life Slipping in YouTube Videos

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Introduction: Numerous studies have attempted to characterize dynamic balance using margin of support (MOS), center of mass (COM) motion, or other means. While most falls occur due to tripping (34%), the second most common mode of falling is slipping (25%) [1]. Although there has been some lab-based research in this area [2], the lack of work involving realistic falls is of some concern. This has lead to a focus on measures which may not be applicable in real-life scenarios involving falls [3].

Research Question: How can we characterize balance in real life slipping – and can this inform our analysis of laboratory assessment of balance?

Methods: After obtaining IRB approval, de-identified slipping videos were gathered from YouTube. Fallers in 16 videos were manually tracked using OpenTrack2d to mark right and left heel, toe, knee, hip, shoulder, elbow, and wrist markers as well as a head marker. Using posture recognition code, a three-dimensional stick figure was matched to the two-dimensional data. From this 3D representation, COM, normalized deviation of COM (Dₜ) [4], and fall directionality were calculated. Fall directionality at initial instability and terminal fall were determined from COM position with respect to hip orientation and characterized by clock directions where 12 o’clock is forward and 6 o’clock is backward. In calculating Dₜ, the direction of the perpendicular from the ground projection of the COM to the line joining the foot centers (aka: interfoot line, IFL) was calculated [4]. The length of this vector was normalized to half the foot length to give Dₜ. Direction of subjects’ intended body motion was also noted.

Results: The body motion throughout the falls was forward in 68.75% of cases, lateral in 6.25% of cases, and stationary in 25% of cases. However, the fall direction was backwards in most cases. While initial instabilities were identified to be somewhat lateral in 50% of cases, terminal falling motion was lateral in only 12.5% of cases. The majority of falls ended with backwards falls (62.5%) with forward falls occurring in 25% of cases. There was only one fall in which the fall direction corresponded to the direction of the body motion. Direction of the IFL vector coincided with fall direction for forward and backward falls, and Dₜ quickly exceeded unity as fallers became more unstable.
Discussion: This study is the first to our knowledge to track real slipping without artificial constraints. While our results confirm previous notions that backwards slipping is most common, new insights are available from the consideration of body motion. In all but one case, the fall direction was independent of body motion. This was often due to both feet sliding on the ground prior to the onset of instability. A consequence of this is that metrics such as MOS which consider COM velocity to be integral to predicting stability are not necessarily valid under slipping conditions. This result is reinforced by Yang & Pai’s work [3]. However, _DN_ which determines when the COM deviates outside of an idealized base of support, can be estimated from posture alone. Likewise, as instability becomes apparent in the videos, _DN_ exceeds unity making it a clear indicator of balance loss. Finally, the IFL vector from which _DN_ is derived has some correlation with fall direction which should be further explored as a balance metric.

Skeletal and anthropometric determinants of gait balance in asymptomatic adult subjects

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Introduction: Maintaining balance allows subjects to minimize energy expenditure and avoid falls during gait. The relationship between the center of mass and center of pressure during gait has been recently shown to reflect dynamic gait balance [1,2]. However, there are currently no studies evaluating the determinants of balance during gait in asymptomatic adult subjects.

Research Question: What are the determinants of dynamic balance during gait in asymptomatic adult subjects?

Methods: 130 asymptomatic subjects (age: 29.5 ±11 years [18-59], 63F) underwent 3D gait analysis followed by full body biplanar X-rays. The center of mass (COM) was determined as the vector sum of the individual segment mass vectors, estimated from the kinematic centroid obtained from the Plug-In-Gait model. The center of pressure (COP) was determined as the application point of the ground reaction force. The COM-COP angle with the vertical was calculated in both the frontal and sagittal planes during the gait cycle. The maxima, averages and standard deviations of the absolute values of the COM-COP angles in the frontal and sagittal planes were considered as parameters of gait balance and were calculated over the whole gait cycle of each subject. An increase in any of these parameters would indicate increased imbalance. Full body 3D reconstructions were obtained from biplanar X-rays and skeletal parameters of the spine, pelvis and lower limbs were calculated: sagittal vertical axis, thoracic kyphosis, lumbar lordosis, pelvic incidence, pelvic tilt, femoral head diameter, neck length (NL), neck shaft angle, femoral anteversion, tibial torsion, vertical center edge angle (VCE), anterior (AASA) and posterior (PASA) acetabular sector angles. Stepwise multiple linear regression models (SMLR) were computed with the maxima, averages and standard deviations of the COM-COP angles as dependant variables and the skeletal and anthropometric (age, sex, weight and height) parameters as independent variables.

Results: Maximum (5.1±1.3˚; R²= 0.35) and average (3.3±0.9˚; R²= 0.28) of the frontal COM-COP angle were found to be determined by age (β= 0.23 and 0.24; respectively), weight (β= 0.34 and 0.20; respectively) and sex (β= 0.25 and 0.33; respectively). Standard deviation of frontal COM-COP angle (1.1± 0.3˚; R²= 0.32) was found to be related to age (β= 0.20) and weight (β= 0.50). Maximum sagittal COM-COP angle (19.6± 2.6˚; R²= 0.24) was found to be determined by height (β= -0.54), AASA (β= -0.27), NL (β= 0.27) and VCE (β= -0.17). Average (7.0± 0.9˚; R²= 0.20) and standard deviation (5.0± 0.7˚; R²= 0.19) of the sagittal COM-COP angle were found to be determined by height (β= -0.41 and -0.39; respectively) and AASA (β= -0.20 and -0.23; respectively). All SMLRs were statistically significant with p<0.01 (figure 1).

Discussion: Dynamic gait balance in the frontal and sagittal planes was found to be determined by both anthropometric and skeletal parameters in asymptomatic adult subjects. Frontal imbalance was found to increase with increasing age and weight as well as male sex but was independent of all skeletal parameters. Sagittal imbalance was found to decrease with increasing height, anterior and lateral acetabular coverage and decreasing neck length. These results suggest that the morphology of the proximal hip, which forms the anatomical hinge between the COM (located at the level of the trunk) and the lower limbs, is the most significant determinant of gait balance in asymptomatic adults.

COM-COP inclination angle in the frontal and sagittal planes (Paul et al., 2014)

Skeletal determinants of the COM-COP inclination angle

- Anterior Acetabular Sector Angle
- Vertical Center Edge angle
- Neck length
Use of a Pain Coping Assessment to Enhance Understanding of Pain in Individuals with Physical Disabilities

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Introduction:

Understanding the experience of pain in children and youth with physical disabilities has been identified as an important factor in predicting function later in life.[1,2] Pain is often best evaluated using a “battery” of tools to capture its multidimensional nature and identify which aspect has the greatest influence for a particular individual. As part of an institutional initiative to improve chronic pain measurement, a pain coping assessment was initiated to supplement current pain assessments for individuals undergoing 3-D gait analysis at a tertiary care institution for children with disabilities. Coping tools assess an individual’s ability to complete activities of daily living when in pain.

Research Question: The purpose of this study was to 1) describe the prevalence of chronic pain in a group of individuals undergoing 3D gait analysis; and 2) describe the ability of these individuals to cope when in pain.

Methods: The Child Self-Efficacy Scale-parent version [3] (CSES) was administered to families of all individuals who were seen for 3-D gait analysis at a tertiary care institution between January–June 2016. The Pediatric Outcome Data Collection Instrument [4]-pain & comfort subscale (PODCI-PC) was also collected as part of routine assessment. Total scores on the CSES range from 7 meaning the parent is “very sure” of the child’s ability to complete activities of daily living while in pain to 35 meaning the parent is “very unsure” of the child’s ability to complete activities while in pain. Scores on the PODCI-PC range from 0 to 100 and describe how much pain interfered with individual’s ability to participate in activities. Retrospective analysis was conducted after IRB approval was obtained.

Results: CSES completion rate was 91% (227 of 248 patients). Participants (58% male, mean age = 11.0 years, SD= 4.7 years) had a diagnosis of cerebral palsy (CP) (59%), orthopaedic conditions (19%), other neurologic conditions (16%), and miscellaneous diagnoses (5%). Musculoskeletal pain was present for 82 of 227 of participants (36%). Prevalence of pain was 51% in those with orthopedic conditions compared to 32% in those with CP. Average CSES total score among those who reported pain was 17.5 (SD 7.2; range 7-35). Average PODCI-PC score was 66.3 for those in pain and 88.1 for those who did not report pain. Scores for CSES and PODCI-PC assessments were negatively correlated ($r= -.49$).

Discussion: This initial assessment adds to the growing literature supporting the presence and prevalence of pain in children with orthopedic conditions and cerebral palsy. These data suggest that despite the presence of pain, individuals in this sample demonstrate a moderate ability to engage coping strategies in order to complete activities of daily living while in pain. The moderate negative correlation between PODCI-PC and CSES scores indicates that the characteristics and severity of the pain experience are not necessarily related to a child’s ability to complete activities of daily living. These measures are assessing different components of pain. This reinforces the need to continue to monitor the multiple dimensions of the pain construct.
This work was supported in part by the Transformative Practice Award of American Academy for Cerebral Palsy and Developmental Medicine to use the Holland Bloorview Chronic Pain Assessment Toolbox for Children with Disabilities.

References:

Does real-time feedback on ankle power alter dynamic motor control in children with cerebral palsy?

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Introduction: A common gait limitation in cerebral palsy (CP) is a reduced ability to generate power at the ankle during push off. This may be due a number of factors, such as muscle weakness or disrupted neuromuscular control. It has been shown that with the use real-time feedback, children with CP can improve key gait parameters such as knee and hip extension [1]. However, it is not known if children can improve ankle power, or, how they would achieve this change at the neuromuscular level. The use of synergy analysis to describe dynamic motor control (DMC) in CP is growing and has been shown to be predictive of treatment outcomes [2].

Research Question: Does real-time feedback on ankle power alter dynamic motor control in children with CP?

Methods: Twelve children with CP (age: 10±2.8, GMFCS: I–II) received 3D gait analysis at comfortable walking speed (CWS) on an instrumented treadmill (GRAIL, Motekforce Link). Gait kinematics and kinetics were recorded in real-time using the Human Body Model [3]. Electromyography (EMG) of 8 muscles (gluteus medius, rectus femoris, vastus lateralis, semitendinosus, tibialis anterior, peroneus longus, gastrocnemius medialis and soleus) were recorded following SENIAM guidelines. Children then underwent a two minute walking trial, at the same prior CWS, in which they were provided with real-time feedback on ankle power at push off for the most affected leg. Feedback was visualised by a colour coded ‘power-bar’ (Fig.1). Visual and auditory rewards were given when ankle power reached the target improvement of at least 10%. EMG data were band-pass filtered at 20-400Hz, rectified, and low-pass filtered at 10Hz. EMG envelopes were normalised to gait cycles and to peak dynamic activity (PDA) during baseline walking. Peak activations were calculated for gastroc. & soleus. EMG data were concatenated over all strides for all muscles and input to a non-negative matrix factorization algorithm (NNMF) to calculate synergistic activation of muscles.

Results: In response to feedback children achieved significant improvements in peak ankle power at push off from 0.98±0.45 to 1.42±0.6W/Kg (effect size: 0.81, p<0.001). Peak activation of the gastroc. and soleus increased significantly (p<0.001, Fig.2). While there were changes in activation of muscles, there was no significant change in the variance accounted for (VAF) by one synergy (0.79±0.06 vs. 0.79±0.03) and no clear changes in synergy pattern or weighting of muscles towards this synergy.

Discussion: Children with CP show the ability to greatly improve ankle power generation at push off with real-time feedback. This is coupled with an increased activation of the gastroc. and soleus muscles. Although there was a change in the level of activation of muscles there was no change in the VAF by one synergy. This result suggests that in the short term at least, DMC is not altered in response to feedback on ankle power and that increased power generation is driven by overall increased activation of muscles. Further studies are needed to clarify whether feedback training will promote refined control of the novel gait pattern with isolation of calf muscle action and reduced co-contraction.
Fig 1 Real-time feedback of ankle power

Fig 2 Group mean muscle activation at baseline vs. feedback

The effect of orthoses on biomechanical gait parameters in medial knee compartment osteoarthritis: Comparison of KO and AFO principles

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Introduction:
Knee orthoses (KO) to offload the medial compartment are one of the conservative treatment options in osteoarthritis of the knee. They use a 3-point pressure principle to generate a counteracting moment that reduces the natural external knee adduction moment. A novel ankle foot orthosis (AFO) shifts the center of pressure of the ground reaction force laterally, resulting in offloading the knee joint by a direct reduction of the external adduction moment.

Research Question:
Based on biomechanical measurements, KO and AFO - both successfully used in the treatment of patients - are compared with respect to their total effect on knee offloading.

Methods:
Two patient groups were tested during level walking. The first group (n=16, age 56±12y, BMI 27.9±4.5kg/m², KELLGREN grade 2-3) was fitted with a KO (GenuArthro, Ottobock), the second group (n=12, age 64±12y, BMI 29.3±5.0kg/m², KELLGREN grade 2-3) with an AFO (Agilium Freestep, Ottobock). For the KO group, the orthotic counteracting moment was defined by a specific calibration [1]. The gait analysis data were determined in the situations without (WOB) and with orthosis (WB). For the measurements, an optoelectronic camera system (27 passive markers, 12 Bonita cameras, VICONPEAK, Oxford, GB), coupled to two force plates (9287A, KISTLER, Winterthur, CH), was used.

Results:
For the KO group, the mean maximum knee adduction moment was 0.62 Nm/kg for WOB and WB. At the time of the first maximum of the knee adduction moment, the orthosis produced a compensatory abduction moment of 0.06 Nm/kg (10%). The pain as assessed on a 10-point VAS was reduced from 6.4 without to 3.3 (p≤0.01) with the orthosis. For the AFO group, the mean maximum of the knee adduction moment was reduced from 0.72 Nm/kg to 0.63 Nm/kg (p≤0.01) in WB. With the orthosis, pain was reduced from 7.7 to 3.8 (p≤0.01) on the VAS. In the AFO group, the 3D kinematics of the knee showed a reduction of the internal rotation of the tibia with the orthosis, reflected by 6° (p≤0.01) difference in the transversal knee angle.

Discussion:
The rigid bridging of the subtalar joint by the AFO limits eversion resulting in a lateral shift of the COP and thus in a reduction of the knee adduction moment. Based on the results of this and previous studies with KO [e.g. 2] and AFO [e.g. 3], the knee offloading can be estimated at about 10-15% for both mechanisms. Therefore, both principles may be considered biomechanically equivalent.

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Evolution of the gait pattern in adolescents and young adults with Cerebral Palsy who underwent SDR as children: a 10 year follow-up study

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Introduction: Selective Dorsal Rhizotomy (SDR) is a neurosurgical procedure aimed at eliminating spasticity in the lower limbs and thereby improving walking ability of patients with Cerebral Palsy (CP). Short-term benefits of SDR on the gait pattern have been demonstrated [1], but there is a need for long-term follow-up studies in order to analyse the gait pattern when patients become adolescents and young adults [2].

Research Question: How is evolution of the gait pattern in patients with CP who underwent SDR as a child, and what is the outcome after 10 years?

Methods: 23 patients with CP (7 females, 16 males) who underwent SDR between 1998 and 2007 were included in this study. Mean patients’ age at SDR was 6.3±3.3 years, 9 patients were classified as GMFCS I level, 6 as GMFCS II and 8 as GMFCS III. Patients’ assessment was performed four times: pre SDR, 2 years post SDR, 5 years post SDR and 10 years post SDR. From 2D video recordings, Edimburg Visual Gait Score [3] (EGAS) was calculated and lower limb joint angles at initial contact (IC), mid-stance (MST), opposite initial contact (OIC) were measured. For each subject, the mean EGAS value between left and right leg was considered. For analysis of the lower limb joint angles, the two patient’s legs were considered separately. Statistical analysis for repeated measures (General Linear Model) and post-hoc analysis was performed using SPSS (time as within-subjects effect, GMFCS as between-subjects effect, statistically significance was set at p<0.001).

Results: EGAS significantly improved after SDR and continued to improve up to 10 year follow-up (Figure 1, Table 1). In particular, patients with GMFCS level I and GMFCS level II showed a similar trend of continuous improvement over time, whereas the trend for patients with GMFCS III was different (Figure 1, p<0.001). Regarding lower limb joint kinematics, improvements at knee and ankle joints during follow-up were found, which were maintained or even improved at 10 year follow-up. No significant changes at pelvis and hip were found (Table 1).
### Table 1

<table>
<thead>
<tr>
<th></th>
<th>pre SDR</th>
<th>2 years post</th>
<th>5 years post</th>
<th>10 years post</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EGAS</strong></td>
<td>18.7±2.5</td>
<td>15.3±3.9*</td>
<td>13.8±5.6*</td>
<td>10.6±3.4*</td>
</tr>
<tr>
<td>Ankle at IC (°)</td>
<td>-20.9±9.5</td>
<td>-16.9±12.6</td>
<td>-12.2±11.1*</td>
<td>-8.2±10.2*</td>
</tr>
<tr>
<td>Ankle at MST (°)</td>
<td>-9.7±15.2</td>
<td>-2.9±11.4</td>
<td>-0.4±10.4*</td>
<td>4.5±8.3*</td>
</tr>
<tr>
<td>Ankle at OIC (°)</td>
<td>-16.1±14.7</td>
<td>-10.7±16.6</td>
<td>-3.2±14.5*</td>
<td>0.7±8.6*</td>
</tr>
<tr>
<td>Knee at IC (°)</td>
<td>43.2±10.9</td>
<td>30.4±13.8*</td>
<td>28.1±14.5*</td>
<td>22.1±10.0*</td>
</tr>
<tr>
<td>Knee at MST (°)</td>
<td>22.0±16.0</td>
<td>15.1±15.3</td>
<td>22.6±19.8</td>
<td>18.0±13.9</td>
</tr>
<tr>
<td>Knee at OIC (°)</td>
<td>24.4±16.7</td>
<td>16.8±13.9</td>
<td>16.0±17.2</td>
<td>15.2±15.2</td>
</tr>
</tbody>
</table>

*: statistically significant for time as within-subjects factor, *: statistically significant compared to pre SDR value

**Discussion**: 10 years after SDR, patients with CP still demonstrated improvement in their gait pattern. As previously reported [4,5,6], patients with GMFCS I and II improved more after SDR compared to patients with GMFCS III. 10 years after SDR, EGAS of patients with GMFCS I and II was on average half their preoperative value. After SDR part of the patients underwent additional bone or soft tissue surgery. This has to be taken into account, because for many patients the gait pattern in follow-up is a consequence of a combination of SDR, orthopaedic surgery and overall development due to age and regular treatment. Considering the lower limb joint kinematics, the gait pattern of patients during stance was characterized by improved knee extension and reduced ankle plantar flexion. The lack of improvement at pelvis and hip joint could be due to gluteus muscle and hamstrings weakness [2]. In conclusion, lasting benefits in gait pattern can be obtained with SDR, even when patients with CP become adolescents or young adults.

Arthroereisis for the treatment of flatfoot in children: a kinematic comparison of in-and outside sinus tarsi implants

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Introduction: The flexible flatfoot is a common disorder in children and subtalar joint arthroereisis is a popular procedure. It uses a subtalar extra-articular implant to limit excessive eversion of the hindfoot without restricting inversion. We distinguish techniques inside (IST) and outside (OST) the sinus tarsi. In OST a 6.5 mm cancellous screw is inserted into the calcaneus and motion is limited by the head of the screw contacting against the lateral aspect of the talus [1]. In IST a spacer is implanted into the sinus tarsi and bones were by contact on either side of the implant. Since outside the entrance of the sinus tarsi more free nerve endings were located than in the deeper situated canalis tarsi ligament [2], there may be differences in the stimulation of proprioceptive foot receptors between techniques.

Research Question: The aim of the study is to compare the effect of inside and outside sinus tarsi implants on foot motion and muscular energy absorption during walking.

Methods: 19 children with idiopathic flexible flatfeet 8-14 years received subtalar joint arthroereisis, 9 patients (17 feet) received OST and 10 patients (20 feet) received IST (Arthrex ProStop®). Foot analysis during walking was done using the Oxford Foot Model, pre- and 13 (SD=2) months postoperatively. A two factor ANOVA with group (OST, IST) and time (pre, post) was performed.

Results: The ANOVA showed no significant differences between groups in all parameters investigated. This suggests similar baseline and surgery effects in both groups. In the frontal plane subtalar eversion was significantly reduced (p<0.001) whereas inversion at push-off was not altered. In the sagittal plane midfoot dorsiflexion in stance remained unchanged, whereas medial arch height increased significantly (p=0.018). However, a significant interaction effect showed...
that the improvement was greater in the IST group. In the transversal plane the tibia internal rotation and midfoot abduction were significantly decreased. Muscular energy absorption at the ankle was significantly increased \((p=0.007)\) whereas a significant interaction effect indicated a greater increase in the OST group.

**Discussion:** As expected, both techniques reduced excessive eversion without restricting the inversion during walking. Improvement in medial arch height (elevation of talus) was greater in IST suggesting a mechanical blockade, whereas muscular absorption was more increased in OST indicating stimulation of proprioceptive receptors. In conclusion for the choice of implants, both systems are able to correct the flatfoot. However, IST may be preferred when the medial arch height is extremely low, and OST implants may provide a greater training effect of the muscles that may better stabilize the foot in the long term.

Reference:

Are baseline joint patterns in the sagittal plane indicative for the success of botulinum toxin injections in children with cerebral palsy?

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Introduction: A recently developed gait classification system for children with spastic cerebral palsy (CP) [1] has previously been proven to be able to detect change in joint patterns after botulinum toxin (BTX-A) injections for the ankle and knee patterns in the sagittal plane [2]. However, the ability of the joint patterns to predict treatment outcome has not yet been explored.

Research Question: Are sagittal baseline joint patterns predictive of BTX-A treatment outcome in children with CP?

Methods: The retrospective study sample consisted of 45 patients with spastic CP: 29 boys and 16 girls, 31 bilaterally affected. GMFCS I: 25, II: 12, III: 8. All patients underwent two 3DGA sessions, on average 1 month before and 2 months after intervention (administration of BTX-A for the 1st, 2nd or 3rd time, n=9, n=21 and n=15 respectively). At the baseline three-dimensional gait analysis (3DGA) the average age was 6 years(y) 11 months(m) old (range 3y9m - 12y4m). The injected muscles were: gastrocnemius (n=43), hamstrings (n=43), psoas (n=22), hip adductors (n=16), rectus femoris (n=7), tibialis posterior (n=4) and soleus (n=16). All but 3 children received casting from 7 days to 6 weeks, with the majority being immobilized for 2 weeks (n=22). Representative walking trials from 70 limbs were classified before treatment, according to the rules defined by a Delphi consensus and described by Nieuwenhuys et al. [1]. Subsequently, the trials of all treated children were grouped per joint pattern for the ankle, knee, hip and pelvis in the sagittal plane and in these groups the treatment outcome was evaluated by comparing the MAPS and the GPS [3] before and after treatment. No separate comparisons regarding which muscles were injected were made. All data were checked for normality using the Shapiro-Wilk test (p<.05). Normally distributed data were compared with paired t-tests, whereas, otherwise, the Wilcoxon signed rank test was applied.

Results: In this sample, all patterns but one (pelvic posterior tilt) were observed with sample sizes varying from 3 patients classified into a specific pattern up to 36 patients per pattern.

Table 1. Comparisons of the observed patterns with MAPS and GPS before and after BTX-A (*p≤.05, **p≤.01)

<table>
<thead>
<tr>
<th>Gait joint patterns pre BTX-A (n)</th>
<th>MAPSpre</th>
<th>MAPSpost</th>
<th>p</th>
<th>GPSpre</th>
<th>GPSpost</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankle stance equinus gait (10)</td>
<td>20.89 (8.22)</td>
<td>9.28 (3.8)</td>
<td>.003**</td>
<td>16 (4.52)</td>
<td>9.87 (10.36)</td>
<td>.203</td>
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<tr>
<td>Ankle stance calcaneus gait (9)</td>
<td>14.91 (5.13)</td>
<td>15.05 (5.36)</td>
<td>.916</td>
<td>12.81 (4.06)</td>
<td>11.79 (3.89)</td>
<td>.009**</td>
</tr>
<tr>
<td>Ankle swing minor deviations (25)</td>
<td>6.37 (2.35)</td>
<td>7.7 (3.64)</td>
<td>.150</td>
<td>10.25 (2.81)</td>
<td>9.48 (2.74)</td>
<td>.016*</td>
</tr>
<tr>
<td>Ankle swing dropfoot (24)</td>
<td>10.99 (12.16)</td>
<td>7.25 (4.85)</td>
<td>.001**</td>
<td>9.89 (8.44)</td>
<td>9.06 (6.10)</td>
<td>.1168</td>
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<tr>
<td>Knee flexion initial contact (4)</td>
<td>7.88 (1.47)</td>
<td>14.22 (2.83)</td>
<td>.011*</td>
<td>7.95 (1.86)</td>
<td>9.49 (2.23)</td>
<td>.069</td>
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<tr>
<td>Knee hyperextension (11)</td>
<td>13.39 (7.92)</td>
<td>14.91 (10.82)</td>
<td>.05*</td>
<td>7.94 (0.82)</td>
<td>7.96 (1.5)</td>
<td>.967</td>
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<tr>
<td>Knee increased knee flexion in midstance + flexion moment (28)</td>
<td>16.76 (10.5)</td>
<td>15.04 (9.16)</td>
<td>.043*</td>
<td>13.13 (4.26)</td>
<td>11.45 (4.19)</td>
<td>.002**</td>
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Knee increased knee flexion in midstance + extension moment (6)

<table>
<thead>
<tr>
<th></th>
<th>Mean (SD)</th>
<th>Mean (SD)</th>
<th>p-Value</th>
<th>Mean (SD)</th>
<th>Mean (SD)</th>
<th>p-Value</th>
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<tbody>
<tr>
<td></td>
<td>17.94 (7.32)</td>
<td>14.96 (6.95)</td>
<td>.059</td>
<td>11.43 (3.6)</td>
<td>9.76 (4.22)</td>
<td>.009**</td>
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</table>

Hip extension deficit (34)

<table>
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<th>Mean (SD)</th>
<th>Mean (SD)</th>
<th>p-Value</th>
<th>Mean (SD)</th>
<th>Mean (SD)</th>
<th>p-Value</th>
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<tbody>
<tr>
<td></td>
<td>11.47 (4.63)</td>
<td>9.39 (6.14)</td>
<td>.351</td>
<td>11.08 (5.39)</td>
<td>9.39 (3.67)</td>
<td>.003**</td>
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Pelvis increased ROM sagittal (16)

<table>
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<th></th>
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<th>Mean (SD)</th>
<th>p-Value</th>
<th>Mean (SD)</th>
<th>Mean (SD)</th>
<th>p-Value</th>
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<tbody>
<tr>
<td></td>
<td>3.74 (2.04)</td>
<td>3.06 (3.67)</td>
<td>.877</td>
<td>9.8 (3.27)</td>
<td>8.21 (2.0)</td>
<td>.038*</td>
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Pelvis posterior tilt + ROM (3)

<table>
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<th>Mean (SD)</th>
<th>p-Value</th>
<th>Mean (SD)</th>
<th>Mean (SD)</th>
<th>p-Value</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>6.55 (0.68)</td>
<td>3.22 (2.04)</td>
<td>.156</td>
<td>13.48 (7.02)</td>
<td>12.00 (6.93)</td>
<td>.017*</td>
</tr>
</tbody>
</table>

Results in darker grey are normally distributed: mean (SD), results in lighter grey are not normally distributed: median (IQR)

**Discussion**: Out of the 29 sagittal joint patterns defined by expert consensus [1], only 11 baseline patterns showed a significant change in either MAPS or GPS after BTX-A. Nine out of these patterns displayed an improved treatment outcome (3 on a joint level and 6 overall). For example, for children with increased plantar flexion in both stance and swing, local improvements were observed after injections on the gastrocnemius. Interestingly, children with an increased knee flexion at initial contact or a knee hyperextension, showed a deteriorating MAPS after treatment. These descriptive analyses suggest that children with equinus during stance and swing, knee flexion in stance, hip extension deficit in stance and increased pelvic sagittal motion are most likely to profit from a multilevel BTX-A treatment.

Assessment of the effect of Hydrotherapy on postural alterations in Parkinson disease patients.

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Introduction: Hydrotherapy (HT) has been proposed as an innovative rehabilitative strategy for the treatment of motor symptoms and the improvement of quality of life in Parkinson disease (PD) patients [1,2]. In particular water buoyancy abolishes gravity thus reducing the body weight, consequently, an underwater (UW) environment allows early active mobilization, dynamic strengthening and represents a therapeutic setting where the patient motor disabilities and the fear of falling decreases.

Research Question: to assess the effect of HT on both balance and posture (spine alignment and mobility) in PD patients.

Methods: For this study 19 PD subjects and 10 controls were recruited. PD subjects were divided in two groups: the first composed by 10 patients (group A - mean age: 64.4, SD 8.8 years; H&Y<3; BMI: 26.8 ± 4.2 kg/m²) was engaged in 10 HT sessions; the second including 9 patients (group B - mean age: 67.4, SD 8.1 years; H&Y<3; BMI: 25.9 ± 4.2 kg/m²) performed 10 sessions of out-of-water therapy. The control group (group C) was composed by 10 healthy persons (mean age: 69.4, SD 8.2 years; BMI: 27.3 ± 2.24 kg/m²) and did not perform any physical training. Both PD groups underwent posture and spine mobility assessment pre (T0) and post (T1) therapy treatment as follows: group A performed the test both in UW and in a gravity (out-of-water - OW) environment in the gait lab; group B was tested only in OW. For the posture tests, subjects were asked to stand in upright position with eyes open (EO) for 60 seconds and then with eyes close (EC) for 60 seconds. For the spine mobility tests in OW, subjects performed 3 maximal flexion-extension tasks on sagittal plane and 3 in the coronal plane. OW data were acquired with a stereophotogrammetric system (BTS, 300Hz) and a force plate (BTS, 1000 Hz) while UW data were registered with 4 cameras (GoPro Hero3, 30Hz). For UW 3D postural analysis the center of mass trajectory was recorded and extracted as in [3] while in OW the center of pressure displacement was recorded through the force plate. Both postural data were analyzed according to [4] by extracting center of pressure spatio-temporal parameters. Spine vertebrae 3D motion was reconstructed through a motion analysis protocol [5] and maximum flexion angles excursions were calculated. The following clinical scales were also administered to the PD subjects: BBS, PDQ-39, UPDRS. For comparisons between groups, independent T-Test and Anova were used. For comparisons between T0 and T1, dependent T-test was used.

Results: In figures some results of posturography (first), of clinical scales (second) and of spine alignment and mobility tests (third- for one subject of group A) are reported.
Discussion: Results of both clinical and instrumental analysis showed a greater efficacy of HT compared to the physical activity protocol performed OW. The UW environment appears to be a safer, proprioceptive and ideal environment for the body postural awareness. Indeed, both the posturographic results and the spine alignment and mobility assessment showed a better performance of group A PD subjects. Future developments will include a longer follow up in order to define the HT effects duration and the necessary frequency over the year.

Tibialis anterior muscle in swing phase of gait before and after tendon shortening with simultaneous Achilles tendon lengthening in patients with hemiplegic cerebral palsy

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Introduction: In severe equinus deformity due to spastic hemiplegic cerebral palsy we described a surgical correction by simultaneously lengthening the Achilles tendon (ATL) and shortening of the tendon of the tibialis anterior muscle (TAS). The results are clinically satisfying proven by gait analysis [1] and remain so even at the long term [2].

Research Question: Is tibialis anterior activity more normal with a powerful dorsiflexion especially during swing after ATL and TAS?

Methods: All patients from the first cohort study (n = 12) were included and their data anonymised. Patients with too poor data were excluded (10 patients remained). The data before and at the time for the long-term follow-up study were considered. The gait data were imported in a slightly changed Lower Leg extremity Model of AnyBody Technology software. The mean of five trials for every patient was compared pre- to postoperative and to normal data (which was equally handled, n=10). Not overlapping standard deviation was considered significant.

Results: Ankle joint dorsiflexion increases postoperatively by about 15 degrees. The shape of the curve in swing phase remains similar compared to preoperative with a drop in the second half of swing. This indicates a shift of this part of the curve only. Musculoskeletal modelling shows no change of tibialis anterior force pre- to postoperatively but an increase of the muscle moment almost to normal values during swing.

Fig. 1: Shift of kinematic curve in swing postop. To dorsiflexion but premature plantarflexion remains.

Fig. 2: Muscle force of the tibialis anterior remains unchanged postop.

Fig. 3: Muscle moment of the tibialis anterior reaches normal values postop.

Discussion: In spite of a clinical improvement of gait due to the increased dorsiflexion postoperatively the function of the tibialis anterior muscle remains unchanged. This is shown by the unchanged foot dropping in swing and the missing change of force production of this muscle. Our hypothesis thus is rejected. However, the moment of the tibialis anterior in swing gets almost normal due to the improved foot position (change of lever arm and direction of action).

We conclude that tibialis anterior tendon shortening does not improve the function of the muscle also the patients show good active dorsiflexion in clinical exam. In spite of the lack of improved active (dynamic) function, however, there is a static tenodesis function with the same force as preoperatively. This tenodesis nevertheless is sufficient to improve the foot position in swing phase. Weakness of the tibialis anterior due to tendon overlength is not the only reason for the dropfoot in hemiplegic cerebral palsy.

References:

Walking with big steps to test the ability to lengthen the hamstrings during gait in children with spastic cerebral palsy

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1 Institut Régional de Réadaptation, Nancy, France, 2 Université Lorraine -EA3450, Nancy, France

Introduction: During spontaneous gait, short hamstrings have been shown to be a factor of excessive knee flexion at initial contact (IC) in children with cerebral palsy (CP) [1]. Indeed, the hamstrings length is maximal just before IC when the difference between hip flexion and knee flexion (DHKF) is maximal [2]. Increasing step length during walking is associated with an increase of DHFK [3]. Knowing the functional ability to lengthen hamstrings during gait appears to be of importance in children with CP to help taking decision about surgical hamstrings lengthening.

Research Question: Could walking with big steps compared to free walking increase the DHFK at IC in children with CP?

Methods: In 47 children with CP, GMFCS I and II, diplegic (n=34) or hemiplegic (n=13) who were 12(3) (mean(SD)) and in 10 children with typical development (TD) who were 9(1), the popliteal angle at low and high speed were measured to estimate hamstrings retraction and spasticity. A 3D gait analysis of free walking and walking with big steps was performed to assess adimensional step length (aSL), hip flexion, knee flexion and DHKF at IC. All variables were averaged over 3 gait cycles.

Results: The results are summarized in the following table.

<table>
<thead>
<tr>
<th>Variable</th>
<th>CP (n=47)</th>
<th>CP (n=17)</th>
<th>CP (n=30)</th>
<th>TD (n=10)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All together</td>
<td>△DHKF&lt;5°</td>
<td>△DHKF≥5°</td>
<td></td>
</tr>
<tr>
<td>Popliteal angle (PA) at low speed (°)</td>
<td>32 (17) *</td>
<td>31 (21) *</td>
<td>32 (15) *</td>
<td>81 (5)</td>
</tr>
<tr>
<td>Popliteal angle (PA) at high speed (°)</td>
<td>19 (17) *</td>
<td>18 (20) *</td>
<td>20 (15) *</td>
<td>79 (6)</td>
</tr>
<tr>
<td>PA at low speed – PA at high speed (°)</td>
<td>12 (8) *</td>
<td>13 (9) *</td>
<td>12 (7) *</td>
<td>3 (3)</td>
</tr>
<tr>
<td>Adimensional step length (aSL) with free steps</td>
<td>0.67 (0.16) *</td>
<td>0.68 (0.13) *</td>
<td>0.67 (0.18) *</td>
<td>0.84 (0.08)</td>
</tr>
<tr>
<td>Adimensional step length (aSL) with big steps</td>
<td>0.88 (0.22) *</td>
<td>0.86 (0.21) *</td>
<td>0.90 (0.22) *</td>
<td>1.32 (0.17)</td>
</tr>
<tr>
<td>aSL with big steps – aSL with free steps</td>
<td>0.21 (0.15) *</td>
<td>0.18 (0.15) *</td>
<td>0.23 (0.15) *</td>
<td>0.48 (0.22)</td>
</tr>
<tr>
<td>Hip flexion (HF) with free steps (°)</td>
<td>41 (9)</td>
<td>40 (9)</td>
<td>42 (9) *</td>
<td>35 (5)</td>
</tr>
<tr>
<td>Hip flexion (HF) with big steps (°)</td>
<td>47 (11) *</td>
<td>44 (12) *</td>
<td>48 (10) *</td>
<td>61 (11)</td>
</tr>
<tr>
<td>HF with big steps – HF with free steps (°)</td>
<td>6 (9) *</td>
<td>4 (9) *</td>
<td>7 (9) *</td>
<td>28 (14)</td>
</tr>
<tr>
<td>Knee flexion (KF) with free steps (°)</td>
<td>24 (11) *</td>
<td>24 (14) *</td>
<td>24 (10) *</td>
<td>5 (5)</td>
</tr>
<tr>
<td>Knee flexion (KF) with big steps (°)</td>
<td>23 (11)</td>
<td>27 (12)</td>
<td>20 (10)</td>
<td>19 (11)</td>
</tr>
<tr>
<td>KF with big steps – KF with free steps (°)</td>
<td>-1 (8) *</td>
<td>3 (9) *§</td>
<td>-3 (7) *</td>
<td>14 (11)</td>
</tr>
<tr>
<td>Delta hip-knee flexion (DHKF) with free steps (°)</td>
<td>17 (10) *</td>
<td>15 (11) *</td>
<td>18 (9) *</td>
<td>30 (5)</td>
</tr>
<tr>
<td>Delta hip-knee flexion (DHKF) with big steps (°)</td>
<td>24 (12) *</td>
<td>17 (11) *§</td>
<td>28 (11) *</td>
<td>42 (5)</td>
</tr>
<tr>
<td>DHKF with big steps – DHKF with free steps (°)</td>
<td>7 (6) *</td>
<td>1 (4) *§</td>
<td>10 (4)</td>
<td>12 (4)</td>
</tr>
</tbody>
</table>
Discussion: In the studied CP children with retracted and spastic hamstrings, about one third of them had very low ∆DHKF with increased knee flexion during big steps. The remaining two third, although they had similar popliteal angles compared to the other subgroup of CP children, had a ∆DHKF comparable to TD children with decreased knee flexion during big steps. Walking with big steps is a simple walking condition which tests the dynamic ability to lengthen hamstrings. This physiological ecologic condition may be useful to orientate the therapeutic decision about hamstrings since the clinical examination of popliteal angles at low and high speed was not informative enough about hamstrings lengthening ability.

The challenge of using statistical models to predict gait outcomes of orthopaedic surgery

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Introduction: After deciding on which orthopaedic operations to conduct on a patient, there are several reasons why we would like to predict the effect of the operation on the patient's gait. For example, if the prediction shows an improvement is unlikely, then it might be prudent for the clinical team to reconsider their decision. On one hand, the rise of sophisticated data modelling techniques would suggest that predicting gait variables, such as kinematics curves, should become increasingly feasible. On the other hand, gait curves are inherently challenging to model given the high dimensionality. Therefore, this study evaluates the feasibility of predicting post-surgery kinematic variables, using statistical models.

Research Question: Can statistical modelling techniques predict the post-surgery kinematic curves with sufficient accuracy?

Methods: Our data consists of 359 patients with Cerebral Palsy, who i) had a Single-Event-Multi-Level Surgery (SEMLS); and ii) had at least one 3DGA session within 2 years, both before and after the operation. We used the patients' pre-surgery kinematic data, as well as the types of operations they received at the SEMLS, to predict 3 sets of post-surgery variables. Listed in order of decreasing difficulty, they are: the kinematic curves, the Gait Variable Score (GVS), and a categorical variable which indicates whether the surgery was successful, neutral, or unsuccessful, based on the change in GPS. In all models, we also produced a constant (or random for the categorical case) model which simply uses averages of the post-surgery data as prediction, for a comparison benchmark.

Results: Predicting the kinematic curves proved to be difficult. Across the different angles (joint-plane combinations), the statistical model scored an average Root Median Squared Error (RMiSE) of 4.6° (range: 2.0-7.7°), when the constant prediction scored a 5.2° (2.2-8.4°). When we directly modelled the GVS, a statistical model scored a mean RMiSE of 2.5° (0.9-4.4°), whereas a constant model scored a mean of 2.9° (1.0-4.7°). Finally, predicting the categorical outcomes scored a mean accuracy of 72%, whereas a constant prediction (always predict "improved") would score an accuracy of 60% (% majority class).

The detailed results are shown below:

Table: GVS. Sag = sagittal. Tra = transverse. Cor = coronal

<table>
<thead>
<tr>
<th>Modelling (RMiSE, °, better)</th>
<th>Pel</th>
<th>Pel</th>
<th>Hip</th>
<th>Hip</th>
<th>Hip</th>
<th>Knee</th>
<th>Ankle</th>
<th>Foot</th>
<th>Progress</th>
</tr>
</thead>
<tbody>
<tr>
<td>statistical</td>
<td>4.6</td>
<td>3.7</td>
<td>2.0</td>
<td>4.2</td>
<td>4.8</td>
<td>2.9</td>
<td>6.4</td>
<td>5.9</td>
<td>4.1</td>
</tr>
<tr>
<td>constant</td>
<td>5.2</td>
<td>5.1</td>
<td>2.2</td>
<td>4.5</td>
<td>6.1</td>
<td>3.3</td>
<td>6.4</td>
<td>7.1</td>
<td>4.7</td>
</tr>
<tr>
<td>statistical</td>
<td>2.5</td>
<td>2.6</td>
<td>0.9</td>
<td>1.9</td>
<td>2.9</td>
<td>1.4</td>
<td>2.8</td>
<td>2.7</td>
<td>2.3</td>
</tr>
<tr>
<td>constant</td>
<td>2.9</td>
<td>4.3</td>
<td>1.0</td>
<td>2.4</td>
<td>4.2</td>
<td>1.6</td>
<td>2.8</td>
<td>3.5</td>
<td>2.3</td>
</tr>
</tbody>
</table>

Confusion Matrix for the categorical outcome models.

<table>
<thead>
<tr>
<th>%Predicted ↓ \ %Observed →</th>
<th>deteriorated</th>
<th>unchanged</th>
<th>improved</th>
</tr>
</thead>
<tbody>
<tr>
<td>deteriorated</td>
<td>0.1</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>unchanged</td>
<td>2.0</td>
<td>22.6</td>
<td>10.5</td>
</tr>
</tbody>
</table>
Conclusion:

The results show that directly modelling kinematic curves is difficult. Modelling the GVS is easier, but predicting the categorical outcomes gives the best gain over a random/constant prediction.
How does pain influence running in individuals with patellofemoral pain?

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Introduction:

Patellofemoral pain (PFP) is the most frequently diagnosed condition in patients with knee complaints and describes a disorder with aching or diffusing pain in the peripatellar or retropatella regions. Beside pathophysiological factors, the pain itself is believed to play a crucial role in the aetiology and progression of PFP. Previous studies reported that pain in individuals with PFP relates to several factors, such as alterations of the lower limb biomechanics, muscle coordination and muscle strength. However, to date in individuals with PFP the isolated effect of pain on these factors has not been investigated.

Research Question:

How does pain influence lower limb biomechanics and muscle activation of the hamstrings and quadriceps muscles in individuals with PFP?

Methods:

19 individuals with PFP, 10 males and 9 females (age: 28.8± 5.7years, height: 1.74± 0.09m, mass: 70.27± 8.98kg) were recruited. Participants were tested at two different occasions: when not experiencing acute pain; standard baseline pain (NPRS: 1.42±2.01), and when experiencing acute pain (NPRS: 4.00±1.98). Each individual was asked to run on a 15m walkway at their own selected speed until five successful trials were collected. Three-dimensional motion analysis was conducted with ten Qualisys OQUS7 cameras and three AMTI force plates and muscle activity was collected with surface electromyography (sEMG). Co-activation ratios and the net activity of the quadriceps and the hamstrings muscles were calculated. The normality was assessed using the Shapiro-Wilk test and paired sample t-tests were performed at the 95% confidence interval.

Results:

The lower limb biomechanics were not significantly different during the early stance phase (ESP) with pain, however the co-activation was shifted towards an increased hamstrings activity (p=0.027) (table 1). During the mid stance phase (MSP) the participants showed a decreased external knee flexor moment (p=0.015) and decreased knee flexor activity (p=0.031) when they experienced pain. During the late stance phase (LSP) the individuals had an increased knee flexor angle (p=0.024) and a decreased external knee flexor moment (p=0.024) when experiencing pain.

Discussion:

The decreased external knee flexor moment during MSP and LSP in acute pain during running is in accordance with findings in individuals with artificially induced knee pain and might be caused by a quadriceps avoidance strategy. This assumption partly conflicts with the sEMG results, because the activation ratio was shifted towards an increased knee extensor activation during the stance phases. However, the net activation showed a tendency for an overall reduced activation of the quadriceps and hamstrings activity. This indicates a possible inhibition of the quadriceps as well as the hamstrings muscles, which might cause knee instability during the loading response and also might be responsible for the development of pain.

References:


Effect of leg alignment on knee and hip adduction moments in unilateral hip osteoarthritis patients.

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Introduction: In order to reduce pain caused by the affected hip joint, unilateral hip osteoarthritis (OA) patients adopt characteristic gait patterns with changed loads in both the non-affected limb and affect limb [1]. Reduced knee ROM and an outwardly rotated foot position are factors which contribute to a lateral shift of the knee joint load in the affected limb.

Research Question: The aim of this study was to analyze whether clinical parameters such as leg length and radiological leg alignment are predictors for a change in the knee and hip joint loading in unilateral hip OA patients.

Methods: 11 OA patients (5 m and 6 w; age = 60.2±13.1 yrs.; height = 1.70±0.09 m; weight = 80.3±11.4 kg; BMI = 27.9±3.1) were recruited. A 3D gait analysis was performed to obtain kinematic and kinetic data. As joint loading parameters the peak knee and hip adduction moments of the affected leg (KAM and HAM) were selected.

All patients had a full leg standing biplanar EOS® radiographic assessment (EOS imaging, France) before total hip arthroplasty [2]. The prosthesis was planned via the hipEOS® software based on the 3D reconstruction. Afterwards four clinical parameters were extracted: anatomical leg length (ALL: sum of the femoral length and the tibial length) the Hip-Knee-Ankle-Angle (HKA) in the frontal plane (equals the varus/valgus angle), the mechanical femoral angle (MFA: angle in the frontal plane between the femoral mechanical axis and the center of the trochlea and the axis crossing the most distal points of the medial and lateral condyles) and the Hip-Knee-Shaft-Angle (HKS: angle between the femoral mechanical axis and the femoral diaphysis axis).

Joint moments were compared to norm data to confirm the abnormal joint loading. Regression analyses were performed to identify predictor variables (ALL, HKA, MFA and HKS) that best explain alterations in joint loading of OA patients. Based on Pearson correlation analyses, only independent variables that correlate with HAM and KAM were included into the regression analyses.

Results: The second KAM in terminal stance (KAM2) was significantly lower in the patient group compared to the values of the norm population (0.30 vs. 0.44 Nm/kg, p = 0.01). The other loading parameters at the knee and hip joint were lower but not significantly.

All three leg alignment angles showed a significant correlation with the knee loading parameters in mid and terminal stance (KAM1 and KAM2), whereas only the MFA showed a significant correlation with the hip loading parameters (HAM1 and HAM2). Regression analyses revealed HKS as the best predictor variable for KAM1 (F = 16.1, r = 0.801, β = 0.096, p = 0.030) and KAM2 (F = 19.8, r = 0.829, β = 0.059, p = 0.020). Hence, HKS explained 64% and 69% of the KAM alterations.

Regarding the hip joint, the MFA explained 39% and 46% of respectively the HAM1 and HAM2 alterations (F = 5.7, r = 0.624, β = -0.060, p = 0.040; F = 7.7, r = 0.678, β = -0.066, p = 0.022).

Discussion: The loading characteristics of the affected limb showed similar results to previous studies [1,3], KAM2 being significantly lower compared to healthy controls. This change indicates a shift in the medial-to-lateral load distribution and might cause degenerative changes in the lateral knee compartment.

Although the HKS is an angle not often used (the angle is also called the hip-center femoral shaft angle) the predictive value to the knee loads is a logical one. The HKS is negatively correlated to
the varus/valgus angle (HKA), indicating that with a positive HKA (valgus), the HKS decreases as does the KAM. Also the predictive value of the MFA for the HAM can be explained. The correlation between the MFA and the HKA is positive. This means that with more valgus, the MFA increases and the HAM decreases.

The results of the present study suggest that abnormal loading of the hip and knee joint are affected by a valgus leg alignment on the side of the affected hip in patients with unilateral hip OA. Also Bendaya [4] found an increased MFA on reconstructed EOS® images in OA patients compared to orthopedically healthy persons. The results are also in line with the study of Fujimaki [5] who found that the alignment of the affected leg in OA patients was more valgus than the unaffected leg before total hip arthroscopy.

Gait symmetry in walking and running after unilateral total knee replacement: Is there a relationship between walking and running symmetry?

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Introduction: Gait symmetry is a characteristic of interest in unilateral conditions, such as hip arthroplasty and it has been suggested that this can lead to gait asymmetry [1]. Gait symmetry is increasingly assessed after stroke [2] and is a measure of motor control in walking to inform treatment [3]. However, the use of gait symmetry transfers to other unilateral conditions and has been used after ankle arthroplasty [4]. Therefore, it is assumed it can also be used after total knee replacement (TKR). The aim of this study is to investigate if the symmetry ratios (SR) reported in TKR participants whilst walking, correlate to the SR whilst running. This contributes to a larger investigation currently being conducted by the authors on a new generation of TKR, involving more demanding activities not previously assessed in this patient group (such as running).

Research Question: Are symmetry ratios of TKR participants related between walking and running?

Methods: NHS ethical approval (15/SC/0725) was gained for this study. Six (4 female, 2 male) TKR participants implanted with the Physica KR TKR (LimaCorporate, Italy), a minimum of 12 months post-operative were recruited.

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Height (m)</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>69</td>
<td>5</td>
<td>1.69</td>
</tr>
</tbody>
</table>

Gait analysis was performed using a 3D 10 camera motion capture system (VICON, Oxford), synchronised with two Kistler force plates. Marker data was sampled at 250Hz and force data at 2000Hz. Six successful trials were recorded and three were selected for processing once reviewed. Three-trial averages were used for each parameter (V), and then SR was calculated. The parameters investigated included peak knee flexion (PKF), peak knee extension (PKE), range of motion (ROM), swing time and stance time.

Symmetry ratio (SR) = \( \frac{V_{op}}{V_{non-op}} \)

Perfect gait symmetry equates to 1. Pearson's correlation coefficients determined relationship for the SR (for each parameter) between walking and running.
Results:

<table>
<thead>
<tr>
<th></th>
<th>PKF (°)</th>
<th>PKE (°)</th>
<th>ROM (°)</th>
<th>Swing time (s)</th>
<th>Stance time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking</td>
<td>Op</td>
<td>43.94</td>
<td>-3.50</td>
<td>47.44</td>
<td>0.48</td>
</tr>
<tr>
<td></td>
<td>Non-op</td>
<td>40.26</td>
<td>-4.58</td>
<td>44.84</td>
<td>0.47</td>
</tr>
<tr>
<td></td>
<td>SR</td>
<td>1.27</td>
<td>-0.32</td>
<td>1.10</td>
<td>0.98</td>
</tr>
<tr>
<td>Running</td>
<td>Op</td>
<td>69.97</td>
<td>2.66</td>
<td>67.04</td>
<td>0.42</td>
</tr>
<tr>
<td></td>
<td>Non-op</td>
<td>68.69</td>
<td>-1.03</td>
<td>68.53</td>
<td>0.40</td>
</tr>
<tr>
<td></td>
<td>SR</td>
<td>1.02</td>
<td>0.87</td>
<td>1.00</td>
<td>1.04</td>
</tr>
</tbody>
</table>

Discussion: A symmetry ratio of 1 would denote perfect symmetry between the operated and non-operated leg. It was found that many of the SR values were close to perfect symmetry, implying that the TKR performs in a similar way to the healthy knee. This in turn suggests positive results from the TKR surgery. There were no significant correlations between the results reported whilst walking and running, therefore there is no relationship in the symmetry ratio knee kinematics and gait phases for walking and running in TKR patients.

References:

Asymptomatic femoro-acetabular impingement affects gait strategies during fast speed gait

Fares Yared¹, Ziad Bakouny¹, Joeffroy Otayek¹, Aren Joe Bizdikian¹, Abir Massaad¹, Joe Ghanimeh¹, Chris Labaki¹, Ismat Ghanem¹, Gaby Kreichati¹, Wafa Skalli², Ayman Assi¹,²

¹Faculty of Medicine, University of Saint-Joseph, Beirut, Lebanon, ²Institut de Biomécanique Humaine Georges Charpak, Arts et Métiers ParisTech, Paris, France

Introduction: Femoro-acetabular impingement (FAI) is a condition characterized by alteration in the osseous morphology of the hip joint, which could lead to hip osteoarthritis. This pathology can be seen in asymptomatic subjects [1]. However, it is not known whether asymptomatic FAI affects self-selected and fast speed gait.

Research Question: Are there differences in gait patterns between asymptomatic FAI and non-FAI subjects in self-selected and fast speed gait?

Methods: 130 asymptomatic adults (29.5±11.4 years, 65F) with no prior orthopaedic treatment underwent full body EOS® biplanar X-rays with 3D reconstruction of the pelvis and the lower limbs. The following 10 hip parameters were calculated in 3D: acetabular anteversion, abduction and tilt, coverage of the femoral head by the acetabulum (in %), modified Wiberg angle, Idelberg & Frank angle, neck-shaft angle, femoral anteversion, neck length (in mm) and femoral head diameter (in mm) (figure 1). The hip parameters were classified as normal or abnormal (in favor of FAI) using pre-established norms [2-4]. Then 2 groups were created: non-FAI subjects (gr.1: 63 subjects having 0 or only 1 abnormal hip parameter in favor of FAI) and asymptomatic FAI adults (gr.2: 67 subjects having ≥2 abnormal hip parameters in favor of FAI). All subjects underwent 3D gait analysis at self-selected and fast speed, from which pelvic, hip, knee, ankle and foot kinematics in the 3 planes as well as spatio-temporal parameters were generated. Kinematic parameters such as means, maxima, minima and ROM were calculated on the waveforms [5]. In order to assess gait adaptations from self-selected to fast speed, the difference between fast and self-selected speed gait was calculated for each kinematic and spatio-temporal parameter. Demographic and hip skeletal parameters were compared between both groups using t-test. Kinematics at self-selected speed, fast speed and the gait adaptations between both speeds were compared between the 2 groups using ANCOVA while controlling for confounding demographic factors.

Results: Significant differences were found (p<0.05) between both groups in the modified Wiberg angle (gr.1:29°; gr.2:33°), coverage of the femoral head by the acetabulum (gr.1:42%; gr.2:44%), acetabular tilt (gr.1:24°; gr.2: 19°), acetabular abduction (gr.1:55°; gr.2:53°), acetabular anteversion (gr.1:19°; gr.2:16°) and femoral anteversion (gr.1:18°; gr.2:14°). There were no differences in kinematics at self-selected speed gait between both groups. However, ROM pelvic rotation differed between both groups at fast speed gait (gr.1:20°; gr.2:17°, p=0.017). Significant differences in gait adaptations from self-selected to fast speed were found between the 2 groups (p<0.05): ROM pelvic rotation (gr.1:7°; gr.2:4°), ROM hip flexion/extension (gr.1:10°; gr.2:7°), maximum hip extension in stance (gr.1:-4°; gr. 2:-2°), hip rotation at initial contact (gr.1:-2°; gr.2:2°) and step length (gr.1:16cm; gr.2:13cm).

Discussion: This is the first study to show that subjects with asymptomatic FAI have moderately altered gait kinematics compared to non FAI subjects. As expected, subjects with asymptomatic FAI had increased acetabular coverage, decreased acetabular abduction and anteversion as well as femoral anteversion. When adapting their gait from self-selected to fast speed, subjects with asymptomatic FAI seem to limit pelvic rotation, hip flexion/extension, maximal hip extension and to increase hip internal rotation, which might have led to a decrease in step length. Interestingly, these kinematic limitations are similar to those found in subjects with symptomatic FAI [6].

A protective effect in females with alkaptonuria: relationships between gait deviations and ochronosis

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Introduction: Alkaptonuria (AKU) is a genetic metabolic disease resulting in elevated levels of homogentisic acid. When oxidised, ochronosis develops in connective tissues, including cartilage, resulting in a gradual tissue deterioration over time. Subsequently, gait becomes altered, with deviations from normality increasing with advancing age and disease, in parallel with deterioration of typical clinical outcome measures [1]. Qualitative investigations into disease progression suggests apparent gender differences with symptoms developing earlier in males, indicating females are somehow protected from the effects of the disease [2].

Research Question: Is there a relationship between gender, ochronosis and gait deviations in patients with AKU?

Methods: 3D gait analysis was performed on a total of 34 patients (age range; 19 – 72 years, 14 females) with AKU as part of their standard clinical assessments. Reflective markers were affixed to the lower limbs according to the Helen-Hayes model and patients were asked to walk at a self-selected pace along a 10m walkway. The Movement Deviation Profile (MDP) [3] quantified the deviation of AKU patients’ gait from normality by passing mean-corrected marker coordinate data normalised to unit standard deviation of both AKU patients and 10 healthy controls to the self-organising neural network. MDP mean values were then derived for each patient and used for further analysis.

Results: To visualise changes over age, data were median filtered with windows ranging between 5-9 samples. Ochronosis levels in ear cartilage showed broadly similar disease progression in males and females. In contrast, the increase of MDP mean was slow in females between the 3rd and 5th decades, and accelerated mid-way through the 6th decade. Males demonstrated a more continuous increase in MDP mean throughout the lifespan.

Discussion: Deviation of gait from normality, as measured by the MDP mean, provides a more faithful measure of movement function than ochronosis level on its own. Our findings provide
some functional evidence to support previous qualitative reports of a protective effect in females with AKU [2]. Gait deviation from normality was minimal until ~55 years, coinciding with the typical onset of menopause although it is unclear how the onset of menopause affects gait mechanics in healthy females. However, it could be suggested that the subsequent effects on bone mineral density and bone loading, particularly in those with AKU, would also impact joint loading and lead to altered walking patterns. Total joint arthroplasties have been reported to occur in more than 50% of patients around 50 years of age [4] and the present findings indicate that females experience a greater and, more importantly, rapid change in gait mechanics between the ages of 50-60 years. Hormonal status was not investigated as part of this study, but the data suggests that therapies aiming to prolong the seemingly protective effect of oestrogen might be advocated. Certainly, female patients in particular must be closely monitored during this 6th decade for signs of sudden functional impairments.

References:


Changes in knee joint kinetics of transfemoral amputee's intact leg: An osteoarthritis indication?

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Introduction: The prevalence of lower limb amputation is increasing significantly all around the world. Knee osteoarthritis (KOA) is one of the secondary physical conditions that occur because of altered knee mechanical loading in the intact limb. Esposito et al. reported, the increase rate of KOA in transfemoral intact limb is 10 times more than non-amputees [1].

Research Question: Using an inverse dynamics-based musculoskeletal model in AnyBody™ (v6.1, AnyBody Technology A/S, Aalborg, Denmark), we aimed to investigate the difference in knee medial force (KMF) and knee adduction moment (KAM) between non-amputee’s dominant leg and amputee’s intact leg.

Methods: 4 healthy subjects (mean (SD): age 21.3 (0.4) years, body weight (BW) 72.2 (5.9) kg, height (Ht) 175.7 (6.0) cm) and 3 transfemoral amputees (mean (SD): age 52.7 (11.14) years, BW 80.0 (16.8) kg, Ht 169 (7.1) cm) participated in this study. Motion and ground reaction data were captured during self-selected walking speed. Musculoskeletal analysis was performed using the anatomically scaled model set up [2]. Prior to performing inverse dynamics, there were three steps to generate subject-specific model: 1) First, a stick-figure model was generated based on a standing reference; 2) Over-determinate kinematic analysis was performed over the dynamic trial and the joint angles were calculated over the entire trials; and 3) The stick-figure model and the base musculoskeletal Twente Lower Extremity Model (TLEM) were loaded together and the TLEM morphed to match the size and joint morphology of the stick-figure model using radial basis functions. Subsequently, the inverse dynamic analysis can be performed by driving the joint angles using those obtained in step 2) and the kinetic boundary conditions. The obtained KMF and KAM were compared between healthy and amputee subjects by a two-sample t-test statistical parametric mapping (SPM). In the SPM analysis, the t-value is zero when there is no difference between the mean KMF and KAM of the two groups. The critical value then was calculated through inference based on random field theory.

Results: Figs. 1-A and 2-A illustrate healthy (black) and amputee (blue) KMF and KAM, respectively. In Figs. 1B and 2B, positive t-value means healthy > amputee and vice versa when it is negative. Furthermore, where t-curve exceeds the threshold (red lines) shows the statistically significant difference in KMF and KAM. At maximum 1st and 2nd peaks of KMF and KAM in healthy and amputee subjects, statistical difference was not observed (p – value > 0.05). However, KMF showed to be significantly different (p – value < 0.05) at early (0% - 5%), mid (36% - 60%) and terminal (78%-80%) stance. The statistical difference in KAM occurred only in early stance phase (0% - 7%).
Discussion: These results suggest the main differences between the two groups were during loading response, weight acceptance and single limb support of the intact leg. This could be due to changes in muscle synergies of amputees during various tasks [3-5]. Therefore, modifications in gait and orthopaedic interventions (laterally wedged shoes and valgus braces) may alter either of the KAM variables i.e. ground reaction force and lever arm which directly influence the KAM hence KMF.

Evaluation of morphomechanical interactions of the gastrocnemius medials during gait in patients after calcaneal fracture.

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Introduction: Patients with calcaneal fractures (CF) show severe impairments of dynamic foot function, such as a reduced ability of active push off and decreased ankle plantar flexion during gait [1]. It is strongly believed that insufficiency of the gastrosoleus complex is one of the main factors of this issue [2]. In this context, ultrasound measures of the morphology in lower limb muscles such as the gastrocnemius medialis (GM) are a feasible tool to evaluate muscle efficacy [3]. However, potential adaptations of the GM morphology and relations with gait mechanics in patients after CF still remain unknown. This study aims to investigate the muscle structure of the GM in the early stage after surgically treated CF in order to provide new insights about the morphological interaction with ankle joint biomechanics during gait.

Research Question: Is there a causal link between the structural morphology of the GM and altered ankle joint mechanics during gait in patients with CF?

Methods: Eleven patients (4♀, 7♂, 51±11 years, BMI 24.9±3.5) who had a unilateral calcaneal fracture agreed to participate in this prospective study. Instrumented gait analysis (Vicon, UK) with embedded force plates (AMTI, USA) was used to measure ankle joint moments and power as well as plantar flexion angle during stance phase. For the affected side, simultaneous measurements of GM muscle structure parameters such as fascicle length (FL), fascicle angle (FA) and serial elastic element (SEE) length change were obtained by a portable ultrasound system (Telemed, LT). Measurements were performed three months post-surgery while a total of five walking trials were examined. To investigate interaction between gait parameters and muscle structure, a correlation analysis for maximum values at push off was conducted using Pearson’s correlation coefficient (p < 0.05).

Results: Compared to the contralateral side, the results generally showed reduced strength potential and ankle plantarflexion during push off. Morphomechanical analyses revealed a significant positive relationship for FA with ankle joint kinetics as well as for maximum plantar flexion angle (see Figure). In contrast, relatively low and non-significant correlations were found for FL and SEE (r < 0.3, p > 0.05).

Discussion: The investigation of muscle morphology provided feasible information regarding ankle mechanics during gait in patients with CF. In this context, increased ankle joint kinetics and kinematics were related to a larger FA. This clearly indicates that FA seems to be the main determinant of force production and ankle joint mobility during gait in those patients. In contrast, FL had no impact on dynamic foot function, which might potentially result from a reduced isometric contraction of fascicles during stance phase. In healthy subjects, the ability of the SEE recoil by a rapid shortening at the end of stance generally contributes to a large amount of push off energy generation at the ankle joint [4]. In patients with CF, the SEE showed no relation to any of the gait parameters, indicating an impaired shortening potential during gait. This would suggest, that the biomechanical deficits of the
gastrosoleus complex might be related to an inefficient contribution of passive structures to forward propulsion.

Assessment of sagittal and transversal kinematics of the lower body in patients with total knee arthroplasty affected by pain and limited range of motion

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Introduction: In recent years, total knee arthroplasty (TKA) has been of fundamental importance in the treatment of patients affected by osteoarthrosis. Despite improvements in the quality of available endoprosthesis up to 20% of patients with TKA are still not satisfied, i.e. they suffer from pain and a loss in range of motion (ROM) [1]. The current diagnostic procedure for these patients involves computed tomography (CT) scan to evaluate the rotational alignment of the TKA following the Berger protocol [2] considering that the large amount of these patients (56.4%) show an internal rotational mal-alignment [3]. Since the CT scan typically is performed in the supine position with unloaded legs this may not represent the loaded situation of the knee gait. Also data of the static CT scan may not be resembled in the clinical examination or the functional parameters determined via instrumented 3D gait analysis.

Research Question: Is there functional conspicuousness for the rotational alignment of the affected limb observed in instrumented 3D gait analysis in patients following TKA with constant pain and limitations in ROM?

Methods: This study included 12 patients [61 ± 11 years] provided with unilateral TKA enduring pain and limited knee ROM at minimum follow-up of 6 months after surgical treatment and with indication for CT scan to determine static rotational alignment. Excluding criteria were clinical, laboratory or radiological parameters indicating possible instability, infection, component loosening or material failure. To assess the functional aspects of the affected limb, an instrumented 3D gait analysis is performed determining kinematic data by using the Plug-in-Gait model. Maximum and minimum joint angles in the sagittal plane and mean joint angles in the transversal plane were calculated. The study group was compared to 12 retrospectively recorded subjects without TKA matched by age and sex as the reference group (RG). The Significance level was set at p = 0.05.

Results: There were significant differences between the groups concerning joint angles in sagittal plane as well as transversal plane (Table1). The maximum value of knee flexion during swing decreased significantly. Nonetheless the maximum value of knee extension during stance did not change significantly. Mean hip rotation during stance showed significant increase in external rotation. Foot orientation compared to walking direction did not vary between groups.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>TKA mean(std)</th>
<th>RG mean(std)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max_Knee_Flex(swing)</td>
<td>42.5(10.3)</td>
<td>57.7(6.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Min_Knee_Flex(stance)</td>
<td>5.1(11.7)</td>
<td>0.3(5.4)</td>
<td>0.217</td>
</tr>
<tr>
<td>Mean_Hip_Rotation(stance)</td>
<td>-11.5(8.1)</td>
<td>-1.1(6.6)</td>
<td>0.002</td>
</tr>
<tr>
<td>Mean_Foot_Prog(stance)</td>
<td>-9.9(2.5)</td>
<td>-9.2(4.7)</td>
<td>0.673</td>
</tr>
</tbody>
</table>

Table1. Joint angles in sagittal and transversal plane for TKA and RG groups.
Discussion: This preliminary study manifested that maximum knee flexion during swing decreased significantly nonetheless the maximum knee extension during stance showed no significant difference in discontent patients following TKA. This finding appears to reflect the major flexion problem of patients when climbing stairs or riding bike. TKA patients with constant pain and limited ROM showed typically increased mean external hip rotation during stance in instrumented 3D gait possibly reflecting rotational mal-alignment of the prosthetic joint. Further analysis of CT data and correlation with gait data may give indications for the association of functional deficits and pain with prosthetic mal-alignment.

Influence of a microprocessor-controlled prosthetic knee on responses to anteroposterior platform perturbations during walking: A randomized cross-over trial.

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Introduction:
Falling is highly prevalent in individuals with a transfemoral amputation. Because of its detrimental consequences it is of clinical importance to study the influence of interventions on balance of individuals with a transfemoral amputation. An example of such an intervention is the use of microprocessor-controlled prosthetic knee (MPK). MPKs are able to change their damping properties. This is in contrast with non-microprocessor-controlled prosthetic knees (NMPKs) which have fixed damping properties. Because of the adaptable damping properties, MPKs claim to increase stance stability. Research has shown that MPKs have been associated with a reduced self-reported number of falls and increased balance confidence.[1] A biomechanical explanation for these findings, however, is not available.

Research Question:
What is the influence of the Rheo Knee II, an MPK, on responses to anteroposterior platform perturbations when compared to the use of an NMPK.

Methods:
Seven individuals with a transfemoral amputation or knee disarticulation were measured twice, once with their own NMPK and once with the Rheo Knee II. The order in which measurements were performed was randomized. The low-profile Variflex with EVO prosthetic foot was used in both prosthetic knee conditions. In addition, a control group of ten individuals without an amputation was also measured. Measurements were performed on a CAREN platform. Anteroposterior platform perturbations (amplitude 20 cm, speed 20 cm/s) were applied during mid-stance and terminal-swing of the prosthetic leg. Outcome measures included the backwards margin of stability (BMoS), which was defined as the minimal distance between the extrapolated centre of mass (XCoM) and the base of support (BoS). An increased BMoS limits the chance of balance disturbances in the backwards direction and, thus, may reflect a reduced fall risk. Next to perturbed gait, we also collected 15 strides of non-perturbed gait.

Results:
The BMoS of the steps after the mid-stance perturbations in the Rheo Knee II condition was significantly increased when compared to the NMPK condition. This was mainly explained by a smaller foot forward placement (horizontal distance between the center of mass and the BoS) in the Rheo Knee II condition. No differences between prosthetic knees were found for the perturbations during terminal swing. Comparison of perturbed and non-perturbed gait showed that individuals without an amputation decreased foot forward placement to cope with the platform perturbations. This mechanism was also seen in the Rheo Knee II condition. In the NMPK few differences were found between perturbed and non-perturbed gait.

Discussion:
The use of the Rheo Knee II was found to lead to an increased BMoS during anteroposterior platform perturbations during mid-stance of the prosthetic leg when compared to the use of an NMPK. This was mainly the results of a smaller foot-forward placement in the Rheo Knee II condition. The increased BMoS is thought to be reflective of a reduced fall risk. The smaller foot-forward placement during perturbed gait was also seen in individuals without an amputation. In that light, the Rheo Knee II enabled individuals with an amputation to use the same strategies
that are also used by individuals without an amputation. This was not the case for the NMPK condition. Future research could focus on whether our findings can be replicated in a larger study sample and provide a biomechanical explanation as to why the Rheo Knee II enables a smaller foot-forward placement.

References:

An Offset-Corrected Movement Analysis Profile to study the offset component of deviation in gait features

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Introduction:

Gait Analysis (GA) allows the quantitative assessment of walking. Over the years, several descriptors have been developed with the aim to derive an overall GA assessment based on a synthetic score. Examples are the Gait Deviation Index (GDI) [1], and the Movement Analysis Profile (MAP) [2]. These indices are useful to assess the overall quality of gait patterns, but inherently do not provide information about the nature of the deviation (offset, scaling, time shift) or about the direction of the deviation (too much flexion or extension). It was observed that certain gait abnormalities corresponded to specific deviations in kinematic angles [3]. E.g. crouch gait is characterized by a persistent knee flexion that can be observed as a shift in the baseline of the knee flexion/extension angle.

Research Question:

The aim of this work was to design and test an extended synthetic index that takes into account the effect of offset in kinematic angles. Such an index may provide additional information about gait deviation and variation pre-/post-treatment.

Methods:

GA of nine children with bilateral CP and crouch gait (GMFCS ranks from II to III) were collected before and after SEMLS. In all children, 9 bilateral gait features were obtained: pelvic tilt, obliquity and rotation; hip flexion, abduction and rotation; knee flexion; ankle dorsiflexion and foot progression. A new index was designed as a modified MAP by separating out the deviation due to offset, defined as the distance between the time-average of gait features and the average value of the respective normality curve. MAP analysis was then computed on the gait features after removing the offset (named OC-MAP and OC-GPS as overall index). Results were averaged across the 18 legs. Offset scores were arranged as a separate profile and overall RMS average was computed. Pre-post differences were assessed using t-tests.

Results:

Fig. 1 shows an example of the knee flexion angle before and after intervention. The persistent bilateral knee flexion is represented by the offset between the curves and the reference. Both MAP and OC-MAP identified an overall improvement in gait (Fig. 2,3). Significant changes from pre- to post-intervention were also observed in the offset profile (Fig. 4). The offset profile identified an improvement in knee offset that remained towards flexion (positive value). The ankle was in plantarflexion (negative offset) in the pre- and the offset reduced to ~0° in the post. A posterior pelvic tilt was identified in the pre- (negative offset) that changed to anterior tilt in the post (positive offset), while MAP suggested a worsening in pelvic tilt with no indication of the direction.
Discussion:

The most notable improvement was in the offset of knee flex/ext. The offset profile provided important information about: (i) the influence of offset on gait deviation; (ii) the magnitude of its pre/post variation; (iii) the direction (sign) of the variation. High SDs in Offset indicated that the largest inter-subject variability was in terms of offset, confirming that offset plays an important role in gait deviation of these patients, having effect on MAP. OC-MAP keeps track of the deviation not due to offset. The OC-MAP/Offset analysis is therefore recommended to study GA in children with CP.

References:

The choice of hip regression equations has small effect on kinematic and kinetic outputs of the conventional gait model

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Introduction:

The hip joint centre (HJC) regression equations used by the Conventional Gait Model (CGM) [1] has been shown to provide inadequate results [2]. The location of the HJC has benefited from a large research effort in recent years, and new regression equations have been proposed [3,4]. Although the accuracy of the equations has been validated against medical imaging, the effects the new equations may have on kinematic and kinetic outputs are relatively unknown.

Research question: What is the effect of recent HJC regression equations on the outputs of the CGM?

Methods:

Gait analysis was performed on 16 healthy adults with a state of the art VICON system (VICON, Oxford UK). Calibration of the CGM used the Knee Alignment Device and ankle medial markers. We compared the native equations (PiG) and that of Harrington et al. [3], Hara et al. [4], with the benchmark position obtained with freehand 3D ultrasound (US, [2]). For the equations of Harrington et al., pelvic depth was used as predictor and measured from the pelvic markers.

An open-source software package (pyCGM2, [5]) that reproduces the outputs of PiG (VICON) was used to calculate kinematics and kinetics. Differences in kinematics and kinetics attributable to the difference in position of the HJC were calculated as the root mean square over the gait cycle.

Results:

The largest kinematic deviation (2.4°) occurred for hip abduction when using PiG. Hara’s regressions were the closest to the benchmark for the anterior/posterior axis. Consequently, difference in hip flexion deviation was small (0.6°). Harrington’s regressions provided the smallest difference for hip adduction (0.86°).

We found similar results for kinetics. With Hara’s regressions, difference in hip extensor moment was 0.02 N.m.Kg⁻¹ whereas it was 0.045 N.m.Kg⁻¹ in average for the other equations. Differences in hip abductor moment were 0.03 N.m.Kg⁻¹ with Harrington’s regressions. The largest kinetics difference was of 0.09 N.m.Kg⁻¹ when using PiG.

Discussion:

Recent results from the literature on the position of the hip joint centre legitimate updating the equations used to locate the HJC in the CGM. However, the effects of HJC position on kinematics and kinetics were small. Our results are similar to that of Kiernan [6], who employed an Optotrack model (Optotrack Motion Analysis Corporation, Santa Rosa USA).

References:

Relations between age, step-time parameters and margin of stability during gait in typically developing children

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Introduction: Immature balance control has been suggested to be an important rate limiter for maturation of gait. The spatial margin of stability (MoS) is a measure derived from biomechanics characterizing dynamic balance control (1). Because of its sound biomechanical basis (2), it might provide insights into the balance control strategies used by children during the developmental course of gait. We hypothesize there will be an age-dependent decrease in MoS in children with typical development. To understand the mechanics behind this, relations between MoS and step-time parameters of gait (STP) are investigated.

Research Question: How does MoS change with age? Can changes in MoS be explained by changes in STP?

Methods: Total body gait analysis of typically developing children (29 toddlers age 1 – 2 and 54 children age 3 – 10) were retrospectively selected from available databases in case of clear foot strikes on the force plates and full marker visibility for at least two consecutive strides. MoS is defined as the minimum distance between the extrapolated centre of mass (CoM) and the base of support (1). To explore the relation between the MoS, age and STP, Pearson correlation coefficients (r) were calculated. To eliminate size effects, MoS and STP were normalized to leg length (3). Variables showing a significant correlation (p < 0.05) with MoS were added to a stepwise linear regression model and the variable with the highest coefficient of correlation was entered first. Variables entered the model if p < 0.05. Variables were removed from the model if p >0.10. Goodness of fit was investigated by R² values.

Results: In toddlers, dimensionless MoS correlated with dimensionless stride length (r = .712, p < 0.001), step width (r = -.541, p < 0.001) and duration of swing (r = -.516, p < 0.01). The stepwise linear regression model indicated one predictor, stride length (r = 0.712, p = 0.047), explained 50% of the variance in MoS (R² = 0.507, F(1,6) = 6.17, p = 0.047). In children, MoS correlated with stride length (r = -.428, p < 0.001), age (r = -.352, p < 0.001) and duration of swing (r = -.310, p < 0.01). The stepwise linear regression model showed two predictors, stride length (r = -.569, p < 0.001) and duration of swing (r = -0.362, p = 0.014), explained 49% of the variance in MoS (R² = 0.491, F(2,27) = 13.03, p < 0.001).

Discussion: The hypothesis that MoS would be large at the onset of walking and would decrease with increasing age due to maturation of balance control could not be confirmed. However, age-dependent relations are found between dimensionless MoS, dimensionless stride length and...
duration of swing. This suggests that dynamic balance control strategies are different in toddlers and children. In toddlers, MoS is small suggesting a strategy of shifting weight from one foot to the other. MoS increases with increasing stride length, which might reflect gait maturation. In children, MoS decreases with increasing stride length and duration of swing. This relation is independent of age. An increased duration of swing means spending more time on one leg. It is easier to maintain balance in this situation if the CoM is brought closer to the supporting leg, which would result in a smaller MoS. Future research should compare the observed strategies in children to those used in adults and in children with altered balance control related to pathology.

AN APPROPRIATELY COMPLEX BIOMECHANICAL MODEL OF RUNNING

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Introduction: Mathematical models of running have the potential to provide insight into how and why humans run the way they do. Existing models can generally be categorised as either simple or complex. The simple models often use spring to model the elastic storage and return of energy [1, 2] and are used to explore the fundamental mechanics of movement. On the other hand, the complex models often aim to model the individual components of the musculoskeletal system, using musculotendon actuators and complex activation dynamics, and hence understand the way in which the individual muscles contribute to the movement [3].

Research Question: What level of model complexity is required to describe the biomechanics of normal distance running?

Methods: A series of three models (Figure 1), each with an increasing level of complexity, were developed using OpenSim. Forward simulations of each of the models were compared to experimental data. Model 1 (spring mass model), consisted of a point mass representative of the body’s centre of mass (CoM) connected to a fixed point on the ground via a massless linear spring of constant stiffness. Model 2 introduced a knee joint. A massless torsional spring connected two weighted segments and ground contact was modelled using a point constraint. Model 3 introduced a third segment and thus an ankle joint. Pin joints with torsional springs connected the segments and again ground contact was modelled using a point constraint.

Results: Agreement between experimental data and model simulations improved as the complexity increased. With Model 1, the mean(SD) RMSD between the CoM trajectories were 29(8), 27(7), 25(6) and 23(7) mm at speeds 1 – 4, respectively. Peak vertical displacement and peak anterior-posterior ground reaction force (GRF) were overestimated, whereas the peak vertical GRF was underestimated. Geometry restrictions with Model 2 meant only the middle ~50% of stance could be modelled. This middle portion matched well with the experimental CoM trajectory (RMSD_{CoM} = 5(2), 11(11), 15(15) and 14(20) mm at speeds 1 –
4, respectively). However, interestingly there was poorer agreement between predicted and experimental GRFs than with Model 1. Model 3 resulted in reasonable agreement between both the kinematics and the kinetics, mean(SD) RMSD between the CoM trajectories were 16(15), 14(8), 13(6) and 13(5) mm at speeds 1 – 4, respectively.

Discussion: These models provide potential rationales for the mechanical characteristics that contribute to how and why people run the way they do. For example, for the knee model, the agreement in the kinematics suggests that a passive torsional spring is sufficient to replicate mid-stance of running, but that to replicate early and late stance a combination of ankle and knee mechanisms is required.

O95

An instrumented treadmill shows excellent reliability and repeatability at a range of speeds to maximal walking speed over a range of inclines and declines.

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1St George's Hospitals University NHS Foundation Trust, London, UK, 2MSK Lab, Imperial College, London, UK

Introduction: The use of an instrumented treadmill for gait analysis offers an objective measure of gait for musculoskeletal disease assessment reproducing activities of daily living with standardised gait speeds necessary for group comparisons [1]. Notably, there is very little current data on gait analysis using an instrumented treadmill for the evaluation of uphill and particularly downhill walking at different speeds to maximal walking speed.

Research Question: Is an instrumented treadmill reliable and repeatable for measuring gait at different speeds and inclines?

Methods: Ten subjects each walked on two occasions at least five days apart on an instrumented Gaitway II treadmill (Kistler, Nussdorf-Traunstein, Germany) after an acclimatisation period. A range of speeds from 4.0 - 6.5 km/h were used rising in 0.5 km/h increments. Measurements were taken at treadmill inclinations of 0% (flat), then 5, 10, 15 and 20% (ascending) and -12% (descending). The intraclass correlation coefficients (ICC) and p-values for significant differences (alpha 0.05) were measured to assess the reliability and repeatability of the system.

Results: Over 80,000 steps were analysed. Measurements of all variables showed excellent reliability across all speeds and all gradients with ICCs ranging from excellent for maximum forces on the first and second peaks (0.996 and 0.995 respectively) to least reliable for gait width (0.844) (figure 1a). Results of between session repeatability did not show any statistically significant difference (p > 0.05) (figure 1b) thus confirming the validity of the treadmill data.

Figure 4(a) Bar graph showing excellent reliability of ICC for temporospatial variables, (N=normalised groups).
(b) Repeatability showing $p > 0.05$ for t-test comparisons (alpha 0.05 represented by the red dashed line for significance).

**Discussion**: Our results included higher maximum walking speeds than have previously been published, which has been shown to be relevant in musculoskeletal disease [2]. We also assessed gait parameters at different speeds and inclines, which have not previously been reported. Use of the Gaitway II instrumented treadmill to measure gait at different speeds and inclines shows excellent reliability and repeatability. These results provide an independent assessment of the validity of this treadmill in a clinical context which has been shown to be more reliable than different treadmills which have reported variable ICCs of 0.43 - 0.99 [3].

References:


Is it feasible to use an automated system to identify gait impairments?

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Introduction:

Gait impairments are typically identified by clinicians using data from physical examination and three-dimensional gait analysis (3DGA). The quantity of information the clinicians have to synthesize can be substantial. Therefore, it is probable that the efficiency and accuracy of this process can be improved, if an automated system can pre-process the data and postulate potential impairments. We assessed the feasibility of two systems for clinical use by assessing their predictive performance.

Research Question:

Can an automated system achieve sufficient performance when identifying gait impairments?

Methods:

Using a clinical dataset which consists of 614 occasions of service (395 children with Cerebral Palsy), we developed two systems which use clinical and gait analysis data to predict the ten most frequently occurring gait impairments, in children with Cerebral Palsy. The first, expert driven system, detects features from the kinematics curves using deterministic rules developed from expert knowledge (similar to [1]). The pre/absence of these features, in combination with the physical examination data, are then used by several machine learning algorithms to predict the gait impairments. The second, data driven system, uses the raw kinematics angles directly, in combination with the physical examination data, through a different set of machine learning algorithms to predict the impairments. The predictive performance was measured by the ROC, Sensitivity, and Specificity.

Results:

Both the expert driven, and data driven systems can achieve an average ROC of at least 0.8, Sensitivity and Specificity of at least 0.7. For Excessive External Tibial Torsion, Knee Flexion Deformity, and Plantarflexor Contracture, we found that the best predictive model is a simple logistic regression with a single physical examination variable. For the remaining 7 (of the top ten) impairments, the detail performance of each system is shown below:

<table>
<thead>
<tr>
<th>Metric</th>
<th>Type</th>
<th>Adductor Contracture</th>
<th>Increased Femoral Neck Anterversion</th>
<th>Gastroc Contracture</th>
<th>Hamstring Contracture</th>
<th>Hamstring Spasticity</th>
<th>Rectus Spasticity</th>
<th>Tibialis Posterior Spasticity</th>
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</thead>
<tbody>
<tr>
<td>ROC</td>
<td>Data</td>
<td>0.86</td>
<td>0.86</td>
<td>0.78</td>
<td>0.85</td>
<td>0.80</td>
<td>0.87</td>
<td>0.78</td>
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<tr>
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<td>0.87</td>
<td>0.79</td>
<td>0.88</td>
<td>0.83</td>
<td>0.85</td>
<td>0.78</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>Data</td>
<td>0.80</td>
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<td>0.80</td>
<td>0.73</td>
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<tr>
<td>Sensitivity</td>
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<tr>
<td>Specificity</td>
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<td>0.78</td>
<td>0.71</td>
<td>0.80</td>
<td>0.75</td>
<td>0.74</td>
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</tr>
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</table>

Discussion:
The results shows that the prediction of the automated system is generally good, although not perfect. Therefore, it can be used as a decision support system, which helps guide clinicians through the diagnosis process. Interestingly, the data driven system is no better than, and sometimes worse than, the expert driven system, indicating domain knowledge plays an important role in gait analysis.

References:

Identifying spasticity during gait by surface electromyography

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Introduction: Cerebral palsy (CP) results from abnormal brain development and/or brain damage that is non-progressive and occurs during very early development [1]. Dependent on the location of the lesion, there are spastic, athetoid, ataxic, and mixed types of CP; clinical symptoms vary largely. The majority of patients have the spastic type. The Modified Ashworth Scale is the most frequently used clinical method to assess spasticity. However, we don’t know how the measurement outcomes relate to spasticity during function, such as gait.

Research Question: Can patients diagnosed with the spastic type of CP be discriminated from patients without spasticity during gait by surface electromyography (SEMG)?

Methods: The SEMG signals of retrospective gait analysis data (2014-2017) of patients with the following diagnoses were investigated: hemiplegic CP (hemiCP, N=35), spastic diplegic CP (diCP, N=35), ataxic CP (N=19), and orthopaedic patients (N=35). The mean frequency over the active part of the SEMG signal during gait was calculated according to Von Tscharner [1] for the following muscles (bilateral): gastrocnemius medialis (GM), tibialis anterior (TA), rectus femoris (RF), and semitendinosus-/membranosus (STM). Also, an average value for the four muscles per leg (Surface EMG Spasticity Scale (SESS)) was calculated. Because hemiCP patients are more often spastic in the lower than upper leg, the SESS was calculated separately for this group. Results were compared using paired t-tests and ANOVA with post-hoc analyses. Significance level was set at p<0.05.

Results: Fig. 1 shows the results for the mean frequency of the SEMG signal calculated over the active part of the gait cycle. The SESS was 12 Hz (SD 7, p<0.001) higher for the affected than for the non-affected leg in the hemiCP group. Also, significant differences in mean frequencies between the upper and lower leg (Fig. 1C) were found for this group. Mean frequencies were higher for all muscles and SESS for the spastic diCP group compared to the ataxic CP and orthopaedic groups (Fig. 1A and B).

Discussion: The results show that the group of spastic CP patients could successfully be differentiated from the ataxic CP group and the orthopaedic group by SEMG during gait. The clinical diagnosis of hemiCP patients in this study was less specific in terms of CP type than of the spastic diCP patients. Also the SESS for the non-affected leg of the hemiCP group was higher than SESS of the ataxic CP and orthopaedic groups. Therefore, this group is of high interest to further explore the possibility of assessing spasticity by SEMG during gait. The results of this study may provide clinicians a basis for treatment of spasticity in specific muscles related to function.

Dynamic functional leg alignment in healthy young adults during a stair ascent and descent: an explorative pilot study

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FH Campus Wien, Vienna, Austria

Introduction: Osteoarthritis (OA) at the knee joint is one of the leading global burdens concerning disability [1]. OA does not only cause pain, functional impairment and declined quality of life but also comes along with a high economic impact for societies and health care systems. Raised body mass index (BMI), genetic disposition and mechanical overload have been identified as primary risk factors of OA [2]. Increasingly sedentary lifestyle is in this regard suspected to lack adequate stimuli for muscles, tendons, cartilage and the sensorimotor system. This may, as a consequence, be reflected by inadequate sagittal alignment and altered motor control. Changes in the lumbo-pelvic rhythm have, in this context, been reported recently [3]. Especially strenuous muscular activities such as single-leg weight bearing movements provide challenging conditions for an appropriate control of the dynamic functional leg alignment (dFLA). Loss of control of the frontal plane of the knee causes elevated stress on passive structures of the musculoskeletal system. Still there is insufficient evidence concerning the physiological range of the dFLA [4, 5].

Research Question: Can frontal knee angles and external moments serve for a classification of the dFLA during stair ascents and descents?

Methods: By means of a cross-sectional study design, 22 healthy participants (12 of which female) aged 18 to 30 years with a BMI between 18.5 and 29.99 kg/m² performed 7 trials of free stair ascents and descents. Following to an initial clinical examination, 3D kinematic und kinetic data were obtained for the stance phase of the 2nd and 3rd step on a 4-ary staircase with Kistler force plates mounted on the steps using an 18-camera Vicon system. Main outcome measures for both knees were the range of motion (ROM) of frontal knee angles (varus/valgus) and maximum frontal knee external moments. These 4 variables were processed in a hierarchical cluster analysis. One-way ANOVA was applied to test whether allocation to the identified clusters had a significant impact on the determining variables.

Results: Clusters have been defined for the ascent and descent. Type I is characterised by lower ROM and lower moments when compared to type II and III. Cluster allocations identified for the ascent and descent were significantly associated with a large effect size (Tab). Regarding the descent, cluster allocation had a significant impact on the ROM (right knee: F (2.19) = 42.5, p < 0.01, ω = 0.89; left knee: F (2.19) = 34.9, p < 0.01, ω = 0.87). In contrast, cluster allocation had no significant impact on the maximum external moments (right knee: F (2.19) = 0.9, p < 0.45; left knee: F (2.19) = 2.4, p < 0.12). Due to too little numbers of subjects in subgroups, no ANOVA was performed for the ascent.

Table: Allocation to clusters related to the dynamic functional leg alignment (dFLA)

<table>
<thead>
<tr>
<th></th>
<th>Type I</th>
<th>Type II</th>
<th>Type III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stair ascent</td>
<td>19</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Stair descent*</td>
<td>12</td>
<td>7</td>
<td>3</td>
</tr>
</tbody>
</table>

* Ascent and descent allocation associated significantly (X² (4) = 16.05, p < 0.01, Cramer-V = 0.60)

Discussion: In terms of kinematic characteristics, a statistically significant trend indicated a variability of the dFLA during stair descents among healthy young adults. In contrast, this was not the case for the kinetic dimension. Noteworthy, the majority of the participants were recruited amongst students in education for allied health science professions. In view of planning a longitudinal study, a minimum sample size of 150 (α=0.05; β=0.8; 3 pairwise comparisons) and more task characteristic parameters (e.g. moment impulse) should be taken into account. The
authors furthermore suggest analysing the impact of phases with elevated ground reaction forces and frontal knee moments as well as changes in frontal kinematics by means of 1D statistic parametric mapping.

Reducing knee joint crosstalk using PCA correction

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**Introduction:** Multiple marker protocols exist for analysing gait kinematics, however most models show crosstalk, particularly in the knee joint due to difficulties in aligning the flexion/extension (F/E) axis. These difficulties are enlarged in patient groups, such as children with cerebral palsy (CP) due to difficulties in palpation and deviations from model assumptions. Functional calibration might be effective in improving knee axes alignment\(^1\), but is time consuming and difficult to perform. Therefore post hoc optimisation methods are preferable. The aim of this study is to outline the effects of a newly proposed post hoc method based on principal component analysis (PCA) to reduce crosstalk\(^2\) in commonly used models for gait analysis.

**Research Question:** Can PCA be used to reduce crosstalk in the knee joint in gait kinematics of children with CP?

**Methods:** 19 children with CP (GMFCS level I-II, age 8-15) participated in this study. Data was collected by experienced gait analysts. 3D instrumented gait analysis was performed using a reflective marker set that included two models. Functional calibration\(^3\) was performed by 8 participants capable of independently performing the required movements. Knee kinematics were calculated using the Newington Model\(^4\), known as the Plug-in-Gait (PiG) model and the Calibrated Anatomical System Technique\(^5\) (CAST). Consequently PCA was performed using custom-made software to correct for cross-talk using a method proposed by Baudet et al\(^2\). The rationale behind this method is that the highest variance can be explained by movement around the F/E axis. Therefore the first axis is rotated towards the first principal component explaining the highest variance. The second and third axes are rotated along with this axis and new kinematic angles for the knee joint are constructed. Differences in knee angles between the two models were compared before and after PCA, and with/without functional calibration for comparison, using root mean square error values. Knee F/E, adduction, and rotation range of motion (ROM) for the original signals and corrected signals were compared using paired-samples t-tests to assess the effect of functional calibration and PCA correction.

**Results:** The knee joint coordinate system was rotated around the longitudinal axis by on average 15.3° and 9.4° for PiG and CAST. Differences between models decreased significantly due to PCA in frontal (p<0.001) and transversal (p=0.01) plane (see figure). Knee adduction ROM decreased (p<0.001) from 18.8° to 7.4° for PiG and 14.0° to 6.0° for CAST. F/E ROM increased significantly (p<0.001) for both models with on average 3.5° and 1.9° for PiG and CAST and for six people with more than 5°. Lastly, knee rotation angles differed less (p=0.01) between models after PCA correction. Functional knee calibration did not reduce adduction and rotation ROMs and differences between the models.
Discussion: PCA correction did improve outcomes by reducing the knee adduction and rotation ROM and reducing differences between models and outperformed functional knee calibration. It can therefore be considered a promising method to reduce cross-talk in the knee of children with CP. The PCA analysis explains most of the variation in the first dimension, to be considered as an F/E axis. From its orthogonal nature the two following axes are perpendicular, resulting in a rotation axis that does not align with the longitudinal axis of the femur. If that should be wanted, a hybrid approach resulting in a non-orthogonal decomposition might be considered. An independent component analysis could be used to determine these non-orthogonal axes. PCA was in this study performed post analysis and only influenced knee kinematics. The incorporation of PCA analysis in the different models should be further studied to analyse the effects on other joint and segment angles.

Validation of the precision of the Microsoft HoloLens augmented reality headset head and hand motion measurement

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¹MSKLab - Imperial College, London, UK, ²CARU - Newcastle University, Newcastle, UK

Introduction: Exergaming is an emerging vector for the delivery of physical exercises to patients to recover or maintain functional capabilities. Recent work has shown the promise of this developing field with a reach and grasp exergames to improve balance in clinical populations.¹ The Microsoft HoloLens is a lightweight augmented reality headset that projects holograms into the user’s view and allows the user to interact with the holograms using hand gestures. Advances in augmented reality technology such as the HoloLens promise new opportunities for researchers and clinicians interested in exergaming and motor control although its accuracy has not been externally evaluated.

Research Question: The aim of this study was to establish how accurately the HoloLens estimates the position of the headset in the global reference frame and the position of a hand relative to the headset (local reference frame).

Methods: To validate the position of the head and the hand measured by the HoloLens, the motion was compared with a reference marker based motion capture system composed of 18 infrared motion capture cameras. 5 retroreflective markers were taped to the HoloLens to enable accurate tracking of the headset relative to the room (global reference frame). To identify the feature point the HoloLens located the hand, a 3D printed hand, with accurate anthropometric dimensions, was used to avoid posture variations of a natural hand changing position. 4 retroreflective markers placed on the hand allowed tracking in the global and local reference frames. The motion of both the hand and the headset were recorded by with both the HoloLens and the marker based system (MBS). To register the HoloLens and the MBS referential and synchronize the two signals, the HoloLens was moved through the MBS capture volume in anterior-posterior, mediolateral and vertical axes to produce a cross formation. Each axis was tested in alternating order. This alternative signal was then synchronised with a cross correlation function. Corresponding points in time were then associated and with a Procrustes analysis, where the rotation and the translation between HoloLens and the MBS referential were computed. Once the registration was completed, a series of free movements in the sphere of arm length was done to test the calibration. To evaluate the precision of the HoloLens hand measurement system, the 3D printed hand position was compared with the position of the hand measured by the MBS. To this end, the position of the hand measured by HoloLens was projected into the reference frame of the hand which was static during measurements at different place in front the HoloLens.

Results: The correlation coefficient between the calibration signal from HoloLens and the MBS was above 0.999 on the calibration set with an error of (mean ± standard deviation) 0.000m±0.0056m on the lateral axis, 0.0000±0.0044m on the vertical axis, 0.0000±0.0052m on the anterior-posterior axis, on the validation set, the error was 0.0004±0.0097m, 0.0016m±0.0102m, -0.0009m±0.0109m respectively for lateral, vertical and anterior-posterior axis. The hand position feature recognised by the HoloLens is shown in figure 1. This feature has been computed by averaging measured hand position. The standard deviation of the error around the feature point was 0.0088m, 0.0148m, 0.0138m respectively for the lateral, vertical and anterior-posterior axis.

Figure 1: Hand feature's position
**Discussion:** This study introduces a method to synchronise and calibrate the HoloLens with a MBS and allow estimation of the position error of the head and the hand. The measurements were done on static hand position and future work would include a motion impact study, as well as the range of hand visibility. The results indicate that the HoloLens is accurate enough for use in reaching-based exergaming.

**References:** 1. Galna et al. Retraining function in people with Parkinson’s disease using the Microsoft kinect: game design and pilot testing. JNER, 2014 11:60
How spino-pelvic postural alignment influences gait kinematics?

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Introduction: Spino-pelvic alignment has been shown to be altered with increasing age [1]. Furthermore, gait kinematics are known to vary between subjects with different ages [2]. However, it is not known how spino-pelvic alignment components are related to gait kinematics. The aim was to assess the relationships between spino-pelvic postural alignment parameters and gait kinematics in asymptomatic adults with a large age range.

Research Question: how do spino-pelvic components relate to gait kinematics?

Methods: 145 asymptomatic subjects with a large age range (age: 29±11 years [18-59], 70F) underwent 3D gait analysis, from which kinematics of lower limb segments (pelvis, hip, knee, ankle and foot) were extracted in the 3 planes during the gait cycle with the calculation of specific parameters on the waveforms (minima, maxima, means, ROM) [3]. Subjects then underwent full body biplanar X-rays, from which skeletal 3D reconstructions were obtained and spino-pelvic postural alignment parameters were evaluated: sagittal vertical axis (SVA), thoracic kyphosis (TK), lumbar lordosis (LL), pelvic parameters (sacral slope, radiologic pelvic tilt rPT, pelvic incidence PI). In order to assess the influence of postural alignment on gait kinematics, stepwise multiple linear regression (SMLR) models were computed on each kinematic parameter, considered as dependent variables, with spino-pelvic and anthropometric parameters (age, weight, height and sex) as independent variables.

Results: Mean pelvic tilt was shown to be determined (R² adjusted = 0.14, p<0.001) by weight (β=0.43), height (β=-0.31) and TK (β=-0.17). ROM pelvic obliquity was shown to be determined (R² adjusted = 0.34, p<0.001) by rPT (β=-0.16) and sex (β=0.57). ROM pelvic rotation (R² adjusted = 0.12, p<0.001) was shown to be determined by PI (β=0.16), TK (β=-0.18) and sex (β=0.24). Maximal knee flexion during loading response was shown to be determined (R² adjusted = 0.13, p<0.001) by weight (β=-0.31) and SVA (β=0.18). ROM knee flexion/extension was shown to be determined (R² adjusted = 0.13, p<0.001) by weight (β=-0.31) and TK (β=-0.18) (see figure below).

Discussion: This study showed that subjects with larger SVA seem to have a larger knee flexion during loading response. Subjects with higher rPT seem to reduce their pelvic ROM frontally. Subjects with larger TK seem to have a smaller pelvic tilt during walking, a reduced ROM of pelvic rotation as well as a reduced ROM of knee flexion/extension. These results suggest that among spino-pelvic alignment parameters, alterations in SVA, TK and rPT, either due to ageing or postural alignment pathologies, would most affect gait kinematics.

Associations between trunk and gait performance after stroke

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University of Antwerp, Antwerpen, Belgium

Introduction: Evidence has shown that trunk performance after stroke is related to measures of balance, gait and functional ability [1]. Trunk performance, assessed by the Trunk Impairment Scale (TIS), is highly correlated to clinical measures of gait. Although clinical measures are a valid criterion to assess performance, they cannot explain the underlying mechanisms and interactions between body segments of the trunk and gait. Additionally, the trunk can now be examined as both a whole and a separate unit, consisting of the thorax and pelvis. Research Question: What is the biomechanical relationship between trunk and gait performance after stroke?

Methods: In total, 14 adult stroke patients were included in this ongoing study. Participants who had a haemorrhagic or ischaemic stroke diagnosis within five months of onset and no known history of previous stroke were included in this study. Gait performance was biomechanically assessed by spatiotemporal parameters (STP) of the paretic side, measured by a total body 3D gait analysis (Plug-In-Gait, Vicon), and clinically by Functional Ambulation Categories (FAC) and the Tinetti Test. Trunk performance was biomechanically assessed by the absolute angles in the thorax and pelvis during the paretic step in the frontal (F), sagittal (S) and transversal (T) plane, and clinically by the TIS. A Pearson's correlation was performed to investigate the relationship between trunk and gait parameters. Level of significance was set at p<0.05.

Results:

<table>
<thead>
<tr>
<th>Pelvis</th>
<th>Mean angle stance</th>
<th>Mean angle swing</th>
<th>Angle at foot strike</th>
<th>Angle at foot off</th>
<th>TIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stride Time</td>
<td>.31</td>
<td>.45</td>
<td>-.62</td>
<td>.64</td>
<td>.40</td>
</tr>
<tr>
<td>Stride length</td>
<td>-.35</td>
<td>-.34</td>
<td>.09</td>
<td>-.58</td>
<td>-.31</td>
</tr>
<tr>
<td>Stance %</td>
<td>.23</td>
<td>.39</td>
<td>-.05</td>
<td>.51</td>
<td>.40</td>
</tr>
<tr>
<td>Walking Speed</td>
<td>-.36</td>
<td>-.21</td>
<td>.38</td>
<td>-.56</td>
<td>-.14</td>
</tr>
<tr>
<td>FAC</td>
<td>-.57</td>
<td>-.21</td>
<td>.64</td>
<td>-.32</td>
<td>-.12</td>
</tr>
<tr>
<td>Tinetti Test</td>
<td>-.41</td>
<td>-.19</td>
<td>.55</td>
<td>-.41</td>
<td>.18</td>
</tr>
<tr>
<td>Thorax</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stride Time</td>
<td>-.16</td>
<td>.30</td>
<td>-.41</td>
<td>-.30</td>
<td>.24</td>
</tr>
<tr>
<td>Stride length</td>
<td>-.44</td>
<td>-.14</td>
<td>.08</td>
<td>.02</td>
<td>-.07</td>
</tr>
<tr>
<td>Stance %</td>
<td>.19</td>
<td>.34</td>
<td>-.02</td>
<td>-.20</td>
<td>.29</td>
</tr>
<tr>
<td>Walking Speed</td>
<td>-.26</td>
<td>-.09</td>
<td>.24</td>
<td>.07</td>
<td>-.00</td>
</tr>
<tr>
<td>FAC</td>
<td>-.06</td>
<td>-.54</td>
<td>.71</td>
<td>.44</td>
<td>-.50</td>
</tr>
<tr>
<td>Tinetti Total</td>
<td>-.18</td>
<td>-.45</td>
<td>.51</td>
<td>.39</td>
<td>-.45</td>
</tr>
</tbody>
</table>
Discussion: Concerning the biomechanical assessment, the pelvis, especially in the frontal plane, seemed to be the most important contributor to gait performance which is in contrast to the findings of Kim et al. [2] who found a strong relation with pelvic movements the sagittal and transversal plane. Differences in results might be due to a difference in population since the aforementioned study included chronic stroke patients, more than two years post stroke. Early after stroke, an ipsilateral pelvic hike is a frequently seen compensation for a lack of foot clearance. The presence of this compensation seemed to decrease gait performance, which might differ from compensatory movements seen in chronic stroke patients. Concerning clinical measures, the TIS showed to be moderately correlated with the FAC, but not the Tinetti test. Yet, Verheyden et al. [1] found a significant correlation between both the FAC and Tinetti Total with the TIS. However, submaximal Tinetti scores were found in our study population which could explain the observed differences.

Conclusion: Rehabilitation goals should focus on increasing foot clearance without allowing a pelvic hike since this compensation seems to decrease gait performance. It might be relevant to search for appropriate walking aids which could facilitate foot clearance.

References:


Association of self-report measures with objective measures of physical function in patients with symptomatic lumbar degenerative disease

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Introduction: Self-report measures are routinely used in the clinical setting to evaluate surgery outcome. However, these questionnaires assess patient perception and are not necessarily indicative of actual disabilities. Additionally, the associations between self-report measures and objective measures of physical function in patients with symptomatic lumbar degenerative disease are not well characterized.

Research Question: The aim of the present study was to determine the correlation between self-report assessments with objective biomechanical measures of function including gait analysis and trunk range of motion (ROM). Additionally, we evaluated the effect of a lumbar spinal fusion surgery on this relationship.

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 and 20 healthy subjects at the same age were prospectively evaluated. Before and approximately six month after mono- or bisegmental lumbar spinal fusion surgery patients completed self-report questionnaires as well as biomechanical assessments of gait analysis and trunk ROM during standing measured with a 3D Vicon motion capture system. The Oswestry Disability Index (ODI) was used to quantify disability for low back pain. A high score reflects a high rate of pain-induced limitations. A measure of health-related quality of life was assessed with the validated EQ-5D questionnaire. A high EQ-5D index score reflects a higher level of quality of life. Linear regression (Pearson product-moment correlation coefficient; r) was used to examine the association between self-report measures and objective measures of physical function. The significance level was set at p < 0.05.

Results: Before surgery the ODI and the EQ-5D questionnaire were not significantly correlated with any of the gait parameters. A high EQ-5D score was correlated with a greater forward flexion of the trunk during standing (r=0.547, p=0.010). Approximately six month after surgery a better ODI (r=0.464, p=0.026) and EQ-5D (r=-0.440, p=0.036) score were correlated with a reduced anterior thorax tilt during walking. The EQ-5D questionnaire was also positively correlated with walking speed (r=0.544, p=0.007) and step length (r=0.503, p=0.014). Maximum forward flexion of the trunk during standing was correlated with a better EQ-5D (r=0.684, p=0.001) and ODI (r=-0.560, p=0.008) score in the postoperative condition.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>EQ-5D Preoperative</th>
<th>p-Value</th>
<th>EQ-5D Postoperative</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trunk max. forward flexion - standing (°)</td>
<td>0.547</td>
<td>0.010</td>
<td>0.684</td>
<td>0.001</td>
</tr>
<tr>
<td>Walking speed (m/s)</td>
<td>0.038</td>
<td>N.S.</td>
<td>0.544</td>
<td>0.007</td>
</tr>
<tr>
<td>Step length (m)</td>
<td>-0.048</td>
<td>N.S.</td>
<td>0.503</td>
<td>0.014</td>
</tr>
<tr>
<td>Trunk max. forward flexion - gait (°)</td>
<td>-0.102</td>
<td>N.S.</td>
<td>-0.440</td>
<td>0.036</td>
</tr>
</tbody>
</table>

Discussion: The lack of association between self-report assessment of disability and objective measures of function before surgery was likely due to psychological distress [1], correlating with emotional and cognitive function rather than true functional capacities [2]. In particular, it is possible to have a high score of pain-induced limitations with a high objective measure of...
functionality. Moreover, it must be assumed that subjects over- or underestimate their disability or health-related quality of life. The influence of these psychological factors might be reduced after surgery due to a reduction of low back pain in patients with lumbar degenerative disease. In conclusion, to obtain an accurate assessment of impairment, there is a need to evaluate function by measuring objective physiologic parameters that are relatively unsusceptible to voluntary or affective influences. These objective measures can enhance the mechanism of differentiating pain from disability and impairment.

Does the assessor's experience matter when we evaluate the kinematics of the upper limb?

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Introduction: The reproducibility of scapular kinematics has already been tested in intra and inter-sessions and days. However, these evaluations were only performed by experienced assessors and the majority of studies included only one assessor. [2] Thus, the comparison between assessors with different levels of experience has not yet been explored, leaving doubts as to the accuracy of the evaluation results when performed by different assessors experience. The aim of this study was to analyze the repeatability of the three-dimensional kinematics of the trunk, scapula and arm between experienced and inexperienced assessor intra and inter-day during arm flexion and abduction movements.

Research question: The experience of the assessors may interfere with trunk, scapula and arm kinematics evaluation results and consequently in clinical interpretation and decision making?

Methods: 10 men and 10 healthy women participated in the study, all with right upper limb dominance, with a mean age of 25.1 (1.1) years. Each volunteer participated in six test sessions, four on the first day, two for each assessor and two on the second day, 1 for each evaluator with a 48-hour interval between days. The assessors were made by an evaluator with ten years experience as physiotherapist and five in motion analysis and a second examiner with three years as physiotherapist and no experience in the kinematic analysis. For each session (intra-day), the volunteers performed five repetition of unilateral arm flexion and abduction using dominant side. After an interval of one hour, the data was collected again and between each session all markers were replaced. A biomechanical model based on International Society of Biomechanics [1] was used and a Vicon® Nexus 2.5 were used for data collection and processing. Data from trunk, scapula and arm was analysed at 30, 60, 90 and 120 degrees of arm flexion and abduction using ICC, standard error of measurement and ANOVA test.

Results: The results (Table 1) refute our hypothesis and showed no difference between the results of the experienced and inexperinced evaluators, except for trunk rotation at all angles studied and for arm rotation only 120° of abduction.

Discussion: Our results suggest that a therapist previously trained in movement analysis marker placement demonstrate the same within-tester reliability as an experienced tester when marker placement accuracy is the variable of interest. This is, to our knowledge, the first study to compare the influence of tester experience on 3D upper limb kinematic reliability. The excellent in-tester
reliability values obtained by the inexperienced and experienced testers are in accordance with those observed in previous studies [2].

Asymmetry of lumbar muscle activity during sit-to-stand task in patients with chronic non-specific low back pain compared to healthy participants.

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1Willy Taillard Laboratory of Kinesiology, Geneva University Hospitals and Geneva University, Geneva, Switzerland, 2AGEIS, Univ. Grenoble Alps, Grenoble, France, 3Division of Rheumatology, Geneva University Hospitals, Faculty of Medicine, Geneva, Switzerland, 4Division of Orthopaedics and Traumatology, Geneva University Hospitals, Faculty of Medicine, Geneva, Switzerland, 5French University Institute, Paris, France

Introduction: Sit-to-stand (STS) represents a key determinant of independence in daily life with an average of 60 repetitions per day [1]. It has been shown that STS exacerbates pain and is greater energy demanding in individuals with non-specific low back pain (NSLBP) compared to healthy participants [2]. Trunk muscles electromyography (EMG) highlighted asymmetry in NSLBP compared to healthy participants in functional tasks [3,4]. To the best of our knowledge, few studies have investigated muscles activity during STS in NSLBP patients. Investigating trunk muscles EMG of NSLBP patients during functional tasks such STS would provide better understanding mechanisms of pain and enable to adapt therapeutic management. This study aimed to compare asymmetry of lumbar muscles between chronic NSLBP (CNSLBP) and healthy participants (HP).

Research Question: Do CNSLBP patients have a greater asymmetry of lumbar muscle activity than healthy participants during STS?

Methods: EMG of erector spinae (ES) at L1 level was measured bilaterally in 11 chronic NSLBP patients (age: 41.5 ± 10.0 years; BMI: 23.2 ± 3.7 kg/m²; with mean VAS> 3/10 ) and 11 HP (age: 35.5 ± 10.1 years; BMI: 22.5 ± 1.5 kg/m²). An endurance test task of back muscles (Sorensen test) was used as reference sub-maximal voluntary isometric contraction (RsubMVIC) to normalize ES EMG amplitude. Kinematics of the trunk was recorded with 3D system caption and calculated using Visual3D software (Version 4.0, C-Motion, Inc., Germantown, MD, USA). Each participant realized 3 times the STS movement from an adjusted stool (knee at 90°) with arms crossed on chest at self-select speed. For each STS movement, time of movement (s), mean ES amplitude (%RsubMVIC) and ES asymmetry (ΔES=|ESRight – ESLeft |), trunk kinematic amplitude (°), were computed. As sagittal plan is dominant in STS movement, trunk obliquity and rotation characterized trunk kinematic asymmetry [5].The mean of the 3 STS movement was used for statistical analysis. Mann-Whitney U test was used to compare groups with level of significance of 0.05(*)

Results:

<table>
<thead>
<tr>
<th></th>
<th>LBP (n=11)</th>
<th>HP (n=11)</th>
<th>p-value</th>
<th>95% CI</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time of movement (s)</td>
<td>2.73 (2.58-3.42)</td>
<td>2.44 (2.39-2.91)</td>
<td>0.116</td>
<td>0.03 to 0.89</td>
<td>.254</td>
</tr>
<tr>
<td>Trunk obliquity amplitude</td>
<td>2.9 (2.4-3.9)</td>
<td>3.7 (3.1-4.1)</td>
<td>0.332</td>
<td>-1.4 to 0.6</td>
<td>.093</td>
</tr>
<tr>
<td>Trunk rotation amplitude</td>
<td>4.7 (4.0-6.6)</td>
<td>5.4 (5.1-5.9)</td>
<td>0.365</td>
<td>-1.8 to 1.3</td>
<td>.07</td>
</tr>
<tr>
<td>Mean ES (%RsubMVIC)</td>
<td>22.7 (20.1-27.1)</td>
<td>17.9 (12.6-23.3)</td>
<td>0.133</td>
<td>-0.95 to 13.2</td>
<td>.237</td>
</tr>
</tbody>
</table>
Discussion: CNSLBP patients exhibit a higher asymmetry for ES activity as has been showed in other functional tasks [4]. This muscles asymmetry may be due to muscle characteristics imbalance and could contribute to chronicity of pain. Our results suggest that CNSLBP patients performed STS movement slower than healthy participants but the results failed to show significant difference contrary to a previous study [6]. A lower pain level of our NSLBP groups may explain this difference between both studies. Despite these differences, CNSLBP trunk kinematic asymmetry seems to be similar to healthy participant during STS. These results highlight the importance to include exercises on lumbar muscles asymmetry in clinical rehabilitation.

References:


<table>
<thead>
<tr>
<th>ΔES (%RsubMVIC)</th>
<th>15.5</th>
<th>9.1</th>
<th>0.022*</th>
<th>0.7 to 13.0</th>
<th>.429</th>
</tr>
</thead>
<tbody>
<tr>
<td>(12.3-18.9)</td>
<td>(3.9-12.9)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Locomotion detection and cadence estimation using 3D wrist accelerometer: an in-field validation

Abolfazl Soltani1, Hooman Dejnabadi1, Benedikt Fasel1, Anisoara Ionescu1, Cedric Gubelmann2, Pedro Manuel Marques-Vidal2, Peter Vollenweider2, Kamiar Aminian1

1EPFL, Lausanne, Switzerland, 2Department of Internal Medicine of CHUV, Lausanne, Switzerland

Introduction:

Automatic human activity recognition has been recently employed in many clinical applications where it is crucial to perform accurate detection of the activities [1-4]. An important issue is that, compared to an in-laboratory condition, the performance of activity detectors decreases when the validation is performed in real life circumstance [5]. Among all types of activity detectors for various sensor locations, single-sensor and wrist-based ones have a prominent importance due to their easy setup and possibility to be used in long-term real life condition [6-8]. However, independent free movements of the wrist make many challenges for reliable activity monitoring.

Research Question:

The aim of the study is proposing a novel method to classify locomotion and non-locomotion periods in everyday life context using a 3D accelerometer worn on the wrist. The proposed algorithm is validated on human free daily activities under real life condition.

Methods:

A data logger (GENEAActiv Original, ActivInsights Ltd, United Kingdom) is fixed to the wrist to measure 3D acceleration at 40Hz during daily living activities. The proposed classification method consists of three main steps. The first step is feature extraction where 3D acceleration is segmented into 8-second windows with a 7-second overlap. For each window, the following features are computed: mean and standard deviation of acceleration norm, dominant frequency of movement, between-axes cross-correlation, and the angle between each axis of 3D acceleration and the norm. The second step is classification where a C4.5 decision tree classifier is trained to classify locomotion and non-locomotion periods. The last step is cadence estimation during locomotion periods according to [8]. Using leave-one-out cross-validation, the method is validated on 37 subjects, 12 hours of free daily activities per person, against a previously validated reference system using inertial sensors attached to the trunk, thigh and shank [3]. For both locomotion detection and cadence estimation, the results of the proposed method and the reference are compared sample-by-sample with a resolution of 1 second.

Results:

A total 398 hours of free daily living activities, including 38 hours locomotion, are employed to evaluate the performance of the proposed method. The specificity, accuracy and sensitivity of the method for locomotion detection are 98.7±1%, 95.4±2%, and 64±15%, respectively. In addition, the relative error of cadence estimation is 6.3±3.2%.

Discussion:

The validation results show that our method provides an excellent performance in classifying non-locomotion periods. Nevertheless, the detection system is quite biased towards the non-locomotion class. The important point here is that our validation, in contrast to many previous works, is performed on people’s daily activities in real condition. In fact, locomotion in daily life context is characterized by short periods, e.g. a person who is working in the kitchen or similar indoor places has many short locomotion intervals that are difficult to be detected by wrist accelerometer. Moreover, activities like cycling, upper-body exercises, etc. are not detected by the reference system. Therefore, such activities impose negative effects on the training procedure of our proposed method. In addition, under real condition, there are imbalanced distributions of locomotion and non-locomotion periods in human daily activities, which leads to a biased
detection algorithm. Considering all these aspects, the proposed algorithm has achieved acceptable accuracy and sensitivity for detecting locomotion periods.

References:

Are static sagittal compensation strategies preserved during walking in adult spinal deformity?

Pieter Severijns¹,², Lieven Moke²,³, Thomas Overbergh²,³, Kristel Van de Loock², Kaat Desloovere¹,⁴, Lennart Scheys²,³

¹KU Leuven – Department of Rehabilitation Sciences, Leuven, Belgium, ²KU Leuven – Institute for Orthopaedic Research and Training (IORT), Leuven, Belgium, ³KU Leuven – Institute for Development and Regeneration, Leuven, Belgium, ⁴Clinical Motion Analysis Laboratory Pellenberg (University Hospitals Leuven), Pellenberg, Belgium

Introduction: To compensate for their aberrant sagittal malalignment, i.e. an important cause of pain and disability, patients with adult spinal deformity (ASD) use different musculoskeletal strategies. Although frequently described in static conditions, little is known about these compensations during dynamic conditions. Recently our research group reported that ASD patients with increased posterior pelvic tilt have decreased dynamic balance capacities, measured with the BESTest¹. We assumed that patients were not able to maintain this compensating pelvic retroversion during more dynamic conditions. Therefore, the goal of this study is to quantify to what extent previously described compensatory changes in sagittal profile during standing are preserved during more dynamic motor tasks, i.e. gait. A secondary objective is to document to what extent discriminative features of their dynamic sagittal profile relate to clinically assessed balance performance.

Research Question: To what extent are static sagittal compensation strategies preserved during walking in ASD patients?

Methods: 9 ASD patients and 7 healthy controls, not different in age (67,22 ± 2,52; 60,14 ± 7,71; p=0,143) and BMI (23,85 ± 2,73; 25,47 ± 2,09; p=0,45) were recruited for 3D motion analysis, using a 10 camera Vicon system, and balance assessment using the BESTest². One static trial and 6 walking trials were processed (full body Plug-In-Gait model, Vicon Nexus) for calculating spatiotemporal and sagittal kinematic data of the spine and lower limb and statistically analyzed between and within groups using one-way ANOVA, Mann-Whitney U, Wilcoxon signed rank test and Spearman correlation coefficient.

Results:

<table>
<thead>
<tr>
<th>1. Spatiotemporal parameters:</th>
<th>ASD (n=9)</th>
<th>Control (n=7)</th>
<th>Sig (p&lt;0,05)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step length (m)</td>
<td>0,55±0,04</td>
<td>0,65±0,04</td>
<td>0,002</td>
</tr>
<tr>
<td>Velocity (m/s)</td>
<td>1,05±0,11</td>
<td>1,34±0,06</td>
<td>0,000</td>
</tr>
<tr>
<td>Stride length (m)</td>
<td>1,1±0,06</td>
<td>1,31±0,07</td>
<td>0,000</td>
</tr>
<tr>
<td>Double support (s)</td>
<td>0,31±0,05</td>
<td>0,24±0,02</td>
<td>0,020</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>2. BESTest:</th>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Total BESTest (%)</td>
<td>78,70±7,95</td>
<td>93,78±6,96</td>
<td>0,006</td>
</tr>
<tr>
<td>Stability in gait (%)</td>
<td>78,84±6,35</td>
<td>93,88±7,64</td>
<td>0,027</td>
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</table>

3. Static vs dynamic sagittal profile:

<table>
<thead>
<tr>
<th>Pelvic angle (°)</th>
<th>ASD</th>
<th>Control</th>
<th>p-value</th>
<th>Spine angle (°)</th>
<th>ASD</th>
<th>Control</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static</td>
<td>-4,06±7,61</td>
<td>5,01±3,45</td>
<td>0,016</td>
<td>Static</td>
<td>11,95±11,56</td>
<td>-5,72±4,97</td>
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<tr>
<td>Dynamic(mean)</td>
<td>-0,04±5,86</td>
<td>7,62±2,43</td>
<td>0,008</td>
<td>Dynamic(mean)</td>
<td>13,58±11,34</td>
<td>-2,04±4,94</td>
<td>0,004</td>
</tr>
<tr>
<td></td>
<td>ASD</td>
<td>Control</td>
<td>p-value</td>
<td></td>
<td>ASD</td>
<td>Control</td>
<td>p-value</td>
</tr>
<tr>
<td>------------</td>
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<td>---------</td>
<td>------------</td>
<td>----------</td>
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</tr>
<tr>
<td>Knee angle (°)</td>
<td>8.85±9.38</td>
<td>0.80±2.80</td>
<td>0.008</td>
<td>Ankle angle (°)</td>
<td>8.91±4.52</td>
<td>3.26±4.10</td>
<td>0.016</td>
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<tr>
<td>Static</td>
<td></td>
<td></td>
<td></td>
<td>Dynamic</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>(midstance)</td>
<td>19.95±4.26</td>
<td>23.55±6.45</td>
<td>0.351</td>
<td>(max stance)</td>
<td>16.57±3.18</td>
<td>14.86±3.23</td>
<td>0.351</td>
</tr>
</tbody>
</table>

*Positive values mean pelvic anteversion, spinal flexion, knee flexion and ankle dorsiflexion*

4. Clinical balance assessment vs motion analysis: | BESTest | Total | Stability in gait |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic spine angle</td>
<td>r = -0.51</td>
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</tr>
<tr>
<td>p-value</td>
<td>0.045</td>
<td>0.026</td>
</tr>
</tbody>
</table>

**Discussion**: Results indicate that patients with ASD partially omit statically-used sagittal compensation mechanisms (pelvic retroversion, knee flexion and ankle dorsiflexion) during walking. Although these changes in dynamic versus static sagittal parameters resemble the changes observed in healthy controls, the persisting increase in sagittal spine angle, combined with reduced compensations at pelvis, knee and ankle, may explain the impairments during gait and balance assessment, as demonstrated by the correlation with, and lower scores on the BESTest as well as its ‘Stability in gait’ subscore. Furthermore, the observed reduced pelvic retroversion in ASD during walking confirms the recent literature. However, our results cannot confirm the previously reported crouch gait in ASD patients. Future research on more demanding or exhaustive motor tasks in larger study samples will lead to a better understanding of the dynamic impairments and compensations in ASD.

ESTIMATION OF 3D SPINE CURVATURE PROFILES FROM DIGITIZED MANUAL ANATOMICAL PALPATION: REPEATABILITY AND METHOD COMPARISON

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Introduction: Measurement of spinal curvature parameters is mainly obtained from medical imaging techniques [1]. Various technique and geometrical approaches are now available to determine similar parameters from external measurements using either markers directly glued on the skin [2] or the forefinger pulp previously calibrated in a marker cluster linked to this forefinger to digitize anatomical landmarks [3] but also, as an extension of this published method, trajectories on the body shape. In parallel, evaluation of protocols to determine if exercise can improve a pre-existing or acquired spinal deformities have been published [4]. Determining spinal curvature measurement uncertainties are a fundamental issue to enable reliable follow-up in various clinical conditions (post-operative rehabilitation, effect of spine muscle endurance training).

Research Question: Is there a difference in term of repeatability for determining whole spinal curvature profiles in optoelectronic environment between patients having undergone low back surgery and an asymptomatic group?

Methods: Fifty asymptomatic subjects (AS) and 40 patients having undergone low back surgery (LBS) were evaluated in an upright position with both feet on an AMTI force plate allowing external force measurement (GRF). Reflective markers were placed on each subject for further estimation of postural parameters (e.g. gait pelvic tilt (GPT), sacral slope (SS), knee flexum during standing and femoral head centre (FH) by regression. Anatomic manual digitization named A_Palp technique [3] was performed on the whole spine from the external occipital protuberance to the sacrum at S2 spinous process. Three measurements were performed on each subject. During the palpation, successive stops at the level of Th1, Th7 and Th12 spinous processes were used to allow spine regionalization, and to define knots for further spline approach adjustment. Many parameters (See Figure) were computed such as cervical lordosis (CL), upper and lower arc of thoracic kyphosis (UTK/LTK) and upper and lower arc of lumbar lordosis (ULL/LLL) angles and associated parameters (arrow,..). Tangential [5], Taubin best-circle fit [6] and trigonometric [7] methods were then applied on adjusted spine profiles, at inflection points. Repeatability assessment was performed using intra-class correlation coefficients while the Bland & Altman graphical method for limits of agreement was used to compare methods. A mixed model of ANOVA for repeated measurement was also used to determine the influence of method, session and group.

Results: For repeatability lordosis and kyphosis angle computation, ICC were above 0.75. Trigonometric method displayed significant difference with others. ANOVA showed difference between groups; no significant difference for the repetition of spine profile measurement; significant difference between angle calculation methods; no interaction between method * Repetition; group * Repetition and group * method.
Discussion: A novel approach for spine curvature digitization using the pulp of the index finger as a probe has been developed and tested in a control group and in patients. The method allows appreciating graphically modification of spine shape and offer a method for reducing the need for multiple radiographs. The technique is repeatable without group effect (Control – Patients), but spine angle estimations are method-dependent. Tangential and circle fit methods may be used together to allow tuning in the clinical decision. This non-invasive protocol in optoelectronic environment may offer new interesting perspectives in spinal curvature profile appreciation in upright standing but also during forward and/or lateral bending usually used in physical therapy. The combination of spine parameter with COP sway may add to our understanding of sagittal balance.

References:

O109

Differences in muscle tendon length and velocity of the hamstrings and vastus after distal femoral extension osteotomy with and without additional patella tendon advancement in children with cerebral palsy (CP)

Mirjam Niklasch1, Stefan van Drongelen2, Julia Wagner1, Julia Brosa1, Matthias Klotz1, Sebastian Wolf1, Firooz Salami1, Thomas Dreher1

1University Hospital Heidelberg, Heidelberg, Germany, 2Orthopedic University Hospital Friedrichsheim gGmbH, Frankfurt, Germany

Introduction: Flexed knee gait is a common gait deformity in children with CP and is surgically treated by hamstring lengthening or distal femoral extension (shortening) osteotomy (DFEO) with or without additional patellar tendon advancement (PTA). DFEO + PTA (without additional hamstring lengthening) as well lead to faster hamstrings and a larger muscle tendon length (MTL) [1]. Therefore, today DFEO (+PTA) is preferred in many centres for ambulatory children.

Research Question: How do MTL and velocity of hamstrings and vasti change after DFEO (+PTA) in children with CP?

Methods: 25 limbs of 19 children [13 ± 3 years] with bilateral spastic CP that received a DFEO + PTA (10 limbs) or DFEO (without PTA) (15 limbs) in the context of SEMLS were retrospectively included in the study. Inclusion criterion was a pre- and one year postoperative gait analysis without assistive walking devices. Exclusion criteria were an additional hamstring lengthening and any botulinum toxin injections in the lower limbs. Kinematic data of 3D gait analysis were determined by using the Plugin-gait model. Subject specific musculoskeletal models were created with OpenSim 3.3 using the generic musculo-skeletal model 2392. The ‘Thelen 2003 muscle model’ [2] was used to calculate peak muscle tendon length (MTL) and peak velocity of the vasti (medialis, lateralis and intermedius) and the hamstrings (M. semitendinosus, M. semimembranosus, M. biceps femoris long head). Normal distribution of all parameters was confirmed by Shapiro-Wilk test. A subgroup analysis of both subgroups (with and without additional PTA) was performed. The significance level was set at p < 0.05.

Results: Overall, the kinematic results confirmed previous studies [1,3-5]: For both subgroups mean and max hip flexion/extension and pelvic tilt in stance phase did not change significantly, knee flexion in stance phase (mean, min, max) and mean knee flexion in swing phase decreased significantly.

DFEO without PTA presented a significant increase of MTL and velocity of the hamstrings and vasti from pre- to postoperative. In contrast DFEO + PTA presented no significant change for vasti MTL and hamstring velocity. (The figures present peak MTL and peak velocity of M. semitendinosus and M. vastus intermedius representative for the hamstrings and the vasti respectively).

Discussion: Former studies [3,5] described an increased anterior pelvic tilt after DFEO with additional PTA. In this study, a larger increase in anterior pelvic tilt was seen with PTA compared to isolated DFEO. However in none of the subgroups the change in anterior pelvic tilt was significant. Due to musculoskeletal modelling only gait analyses without any walking devices were
included. Walking devices lead as well to an increased anterior pelvic tilt [6] and might explain the
difference to previous studies.

For the first time the vasti were assessed as well. DFEO + PTA allowed the vasti to sustain their
length, but increase their velocity. As the vasti operate as knee extensors, an additional PTA
therefore strengthens the upright body position and counteracts a flexed knee gait. Healy [1] described longer and faster hamstrings after DFEO + PTA. In contrast to this study, 50% of the patients received additional botulinum toxin injections in the hamstrings during surgery. Our results present longer and faster hamstrings after DFEO without PTA but only longer hamstrings after DFEO + PTA. Part of the effects described in [1] might be due to additional botulinum injections. The hamstrings might not work faster after DFEO + PTA, but after DFEO because the strengthened vasti counteract the hamstring lengthening velocity.

Simulation of passive gastrocnemius muscle-tendon properties in cerebral palsy and typically developing children.

Lynn Bar-On1,2, Barbara Kalkman4, Kaat Desloovere1, Jaap Harlaar3,2, Marjolein van der Krogt2

1KU Leuven, Leuven, Belgium, 2VU University medical center, Amsterdam, The Netherlands, 3Delft University of Technology, Delft, The Netherlands, 4Liverpool John Moores University, Liverpool, UK

Introduction: An altered joint moment-angle relationship is a common impairment in children with cerebral palsy (CP). Experimental data combining ankle joint kinematics and kinetics with ultrasound (US) imaging indicate that the lengthening properties of both the medial gastrocnemius (MG) and the Achilles tendon contribute to this impairment during both passive stretch1 and during gait2. Specifically, muscle fascicles are seen to lengthen relatively less, and Achilles tendons relatively more in CP compared to typically developing children (TDC). In the current project we compare experimental tissue lengthening data to optimized simulations to gain a better fundamental understanding of the possible structures and properties that contribute to alterations in MG fascicle and the serial elastic element (SEE – aponeurosis and free tendon) lengthening in children with CP and TDC during slow passive ankle movement; and to validate the model parameters.

Research Question: What contributes to an altered passive ankle joint moment-angle relationship in children with CP?

Methods: The ankle was passively moved over the full range of motion at slow velocity in 12 children with CP (GMFCS I-II) and 17 age-matched TDC. Ankle angle and net joint ankle moment were measured using 3D motion analysis and a hand-held dynamometer, respectively. MG muscle-tendon unit (MTU) and MG fascicle lengthening during the movements were measured using motion analysis and dynamic US imaging. A dedicated OpenSim3 model was created with one lumped plantar flexor (MG) and Tibialis Anterior muscle and a tibio-calcaneal anterior ligament. MG optimum fiber length (lopt) and anterior ligament stiffness were optimized such that the RMS error between measured and modelled moment-angle data was minimized. To prevent overfitting, other model parameters were kept as in the generic model. Thereafter, measured and modelled fascicle, MTU, and SEE (MTU minus projected fascicle) lengthening were statistically compared between each other for model validation, and between CP and TD using paired sample t-tests (p<0.05).

Results: Optimization of the MG lopt and ligament stiffness resulted in a good fit between modelled and measured moment-angle data in CP and TDC (Fig.1A). llopt was significantly shorter in children with CP vs TDC (3.4±0.8cm vs 4.0±0.7cm, p=0.02). Measured and simulated maximum normalized fascicle lengthening were reduced in CP (Table 1). Simulated SEE lengthening was grossly underestimated by the model, while fascicle lengthening was overestimated, with a trend towards a greater overestimation for CP (table 1 and Fig.1B-C).

Table 1. Average (SD) normalized maximum lengthening values (%MTU)

<table>
<thead>
<tr>
<th></th>
<th>TD</th>
<th>CP</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fascicle</td>
<td>7.9 (1.6)</td>
<td>4.5 (1.6)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>SEE</td>
<td>6.0 (2.4)</td>
<td>7.0 (3.1)</td>
<td>0.3</td>
</tr>
<tr>
<td>MTU</td>
<td>13.9 (2.8)</td>
<td>11.6 (3.4)</td>
<td>0.1</td>
</tr>
<tr>
<td>Modeled</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fascicle</td>
<td>9.5 (1.4)</td>
<td>7.4 (1.9)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>SEE</td>
<td>1.0 (0.2)</td>
<td>1.1 (0.1)</td>
<td>0.7</td>
</tr>
<tr>
<td>MTU</td>
<td>11.4 (1.8)</td>
<td>9.0 (2.3)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>
**Fig 1.** Measured (solid lines) and simulated (dashed lines) data.

**Discussion:** While optimization of MG lopt and anterior ligament stiffness resulted in good simulation of the moment-angle curves, fascicle and in particular, SEE lengthening were not accurately simulated. This indicates that the generic model SEE is overly stiff and should be adjusted for both TDC and CP. Furthermore, altered MG properties such as increased fascicle stiffness and increased tendon compliance in CP are not fully explained by morphological alterations (i.e. shorter lopt). To accurately model fascicle and SEE properties in individual patients, US data could serve as input to the model rather than validation data. Furthermore, separating out aponeurosis and free tendon might give better insight in altered properties in CP.

Direct kinematics and kinematic fitting provide very similar outputs when using the conventional gait model

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¹College of Health and Social Care, Salford, UK, ²The Royal Children’s hospital, Melbourne, Australia, ³The Murdoch Childrens research Institute, Melbourne, Australia

Introduction:
Musculoskeletal simulations use Kinematics Fitting (KF) to track the skeleton. Despite its extensive use in the clinical setting, the Conventional Gait Model (CGM) [1] implements Direct Kinematics (DK) and thus does not provide adequate inputs for musculoskeletal simulations. The effects of the tracking method (DK or KF) on kinematics are still unclear. Groen [2] compared the CGM with OLGA, a model which mixed KF and functional estimate of the joint centres and axes. Recently, Kainz [3] compared the CGM and Opensim models involving skin clusters.

Research question: Does KF significantly affect the outputs of the Convention Gait Model?

Methods:
Gait analysis was performed on 16 healthy adults with a state of the art VICON system (VICON, Oxford UK). Calibration of the CGM used the Knee Alignment Device and ankle medial markers. The position of the hip joint centres were derived from Hara et al. [4]. The CGM was replicated as an Opensim model, which included 3DoF joints for the hip, knee and ankle joints. DK computations were carried with pyCGM2 [5] and KF with Opensim API [6]. Markers’ weights were equal and accuracy was set to 1.e-8 for FF. We calculated the root mean square difference (RMSD) between DK and KF to estimate the effect of the tracking method on the CGM outputs.

Results:
Overall, the RMSD were small. For kinematics, the maximal RMSD was 1.9° for ankle dorsiflexion. For kinetics, RMSD for the hip flexor moment was 0.045N.m.kg⁻¹. KF reduced the range of movement of knee varus/valgus over the gait cycle. Some larger differences were found locally around foot off for hip rotation and knee abduction kinematics.

### Angle (°)

<table>
<thead>
<tr>
<th>Angle</th>
<th>Pel Tilt</th>
<th>Pelv Obl</th>
<th>Pelv Rot</th>
<th>Hip Fle</th>
<th>Hip Abd</th>
<th>Hip Rot</th>
<th>Knee Fle</th>
<th>Ankle Fle</th>
<th>Foot Pro</th>
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<tbody>
<tr>
<td>Mean(sd)</td>
<td>0.4(0.1)</td>
<td>1.1(0.2)</td>
<td>0.5(0.3)</td>
<td>0.7(0.2)</td>
<td>1.1(0.3)</td>
<td>1.9(0.6)</td>
<td>1.0(0.4)</td>
<td>1.9(1.5)</td>
<td>0.9(0.5)</td>
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<tr>
<td>Range</td>
<td>0.6</td>
<td>1.0</td>
<td>1.1</td>
<td>1.4</td>
<td>1.4</td>
<td>2.7</td>
<td>1.9</td>
<td>7.2</td>
<td>3.2</td>
</tr>
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</table>

Discussion:
Our results tend to show that the tracking method (DK and KF) may only be a minor source of differences in the outputs of the CGM. However, our results need to be replicated in larger and broader cohorts, for example in paediatric or overweight populations. If these results were to be confirmed, the CGM may use IK, instead of DK, as the default tracking method. Such a change would allow to perform musculoskeletal simulations of gait from routine clinical gait analysis protocols.

References:
References:

[3] Hara et al, Scientific Reports, 2016(6);1-9
[4] pycgm2.github.io
Subject-specific muscle forces derived from simulations of clinical muscle strength assessments alter estimated gait functionality in children with cerebral palsy

Hans Kainz 1, Tessa Hoekstra 1, Antoine Falisse 1, Lorenzo Pitto 1, Mariska Wesseling 1, Marije Goudriaan 1, Catherine Huenaerts 2, Guy Molenaers 2, Kaat Desloovere 2, Friedl De Groote 1, Ilse Jonkers 0

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Introduction:

Current musculoskeletal simulations of gait typically do not include patient-specific muscle forces but rely on a scaled generic musculoskeletal model, with muscle forces left unscaled or scaled to the person’s body weight. However, to use these simulations to inform clinical decision-making in children with cerebral palsy (CP), inclusion of subject-specific muscle forces is of utmost importance in order to represent each child’s compensation mechanisms introduced through muscle weakness.

Research Question:

Does inclusion of subject-specific maximal muscle forces derived from simulations of clinical muscle strength assessments alter estimated gait functionality in children with CP?

Methods:

Three-dimensional motion capture data and clinical assessment of muscle strength (five-point MRC scale [1]) was obtained from five children with CP (age: 7.8±1.5years, weight: 28±4kg, height: 1.3±1m, 3female, GMFCS 2). Additional motion capture data of one age matched typically developing (TD) child was collected. A modified version of the ‘gait2392’ OpenSim [2] model was scaled to each child’s anthropometry. Hip and knee muscle strength measurements were simulated in OpenSim. Maximal muscle forces of the scaled OpenSim model were modified so that the strength assessments based on the child’s MRC grade could be performed. These muscle forces, which allowed just to generate the strength assessment (Fclin) [3], were compared to the original muscle forces in the OpenSim model (Forig) and to muscle forces scaled based on the child’s body weight (Fbw). Then, the model’s motor capability (i.e. moments generated by muscle [4]) to reproduce the person’s own kinetics but also the kinetics based on the TD child’s kinematics was used to evaluate if the simulations could be generated with each force set (Fclin, Fbw and Forig). We assumed that representative muscle force estimates would allow to reproduce the patient-specific, but not the TD gait pattern.

Results:

All children with CP had muscle strength between grade 3 and 4 on the MRC scale. Musculoskeletal simulations of clinical muscle strength assessments decreased maximal hip flexor, hip extensor, hip abductor, and knee extensor muscle forces in average by 45±24%, 72±9%, 68±16% and 17±8% (Fclin). Scaling muscle forces based on the child’s body weight decreased all maximal muscle forces by 62±5% (Fbw). All CP models were able to reproduce the patient-specific gait pattern. Using the scaled model including Forig and Fbw, TD gait could be reproduced in all participants with CP, whereas including Fclin, TD gait could only be reproduced for one CP child. The TD model with Fbw was not able to generate the TD child’s own gait pattern.

Discussion:

Using models based on Forig in children with CP over-estimated strength on average by 50% and should not be used for dynamic simulations of CP gait. Fclin were, over all muscle group, on average 12% lower than Fbw. Consequently, using a model with Fbw, both the patient-specific and normal gait patterns could be reproduced, whereas using a model with Fclin only the patient-specific gait pattern could be reproduced. Scaling based on Fbw, therefore, potentially over-estimates hip extensor and abductor muscle forces in children with CP with a grade 3 or 4 on the
MRC scale. Fbw may be inappropriate for pediatric participants with a low body weight given the inability of the TD model to reproduce TD gait. It can therefore be concluded that muscle force estimates derived from clinical muscle strength assessments present a more patient-specific representation of the gait functionality in children with CP.

Muscle Strength: The Missing Link between Lesion Height and Gait Pathologies in Patients with Lumbar and Sacral Spinal Cord Injuries – a Theoretical Approach

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Introduction: Patients with lumbar and sacral spinal cord injuries (SCI) develop gait pathologies depending on their muscular impairments [1]. For determining lower limb motor function, the ASIA Impairment Scale (AIS) is clinical standard. The AIS evaluates motor function of specific key muscles by using a manual muscle test. Each key muscle corresponds to a certain spinal segment and provides information about lesion height and whether the SCI is complete or incomplete [2]. However, all muscle groups are innervated not only by one but a range of spinal segments. Within that range, total innervation of a muscle group depends on innervation of its single muscles. Nevertheless, the classification of muscle strength within a muscle group’s innervation range has not been determined yet.

Research Question: How can muscle strength within the range of innervation be calculated for each muscle group in order to roughly determine gait pathologies and orthotic treatment options in early phases of SCI?

Methods: For eight muscle groups the muscle strength in each analysed spinal segment within innervation range is calculated. To this end, (1) the number of active muscles, (2) the level of segmental innervation and (3) the relevance of each muscle for the target movement are taken into account. By evaluating the influence of these parameters, innervation range of each muscle group is classified into six different levels of muscle strength (0–5).

Discussion: With the clear assignment of muscles to their innervating spinal segments [3], the level of injury can provide information on whether a muscle group is unaffected (muscle strength = 5) or completely impaired (muscle strength = 0) by a SCI. For the area of partial innervation (muscle strength >0 and <5) a classification was created using the most relevant muscular parameters. With the exception of knee extensors, dorsiflexors and pronators, that classification is assumed to be non-linear depending on different innervation ranges of its single muscles. The resulting model is significant for patients with complete SCI, but limited for those with incomplete SCI. These findings help roughly determine gait pathologies and orthotic treatment options in early phases of SCI. Nevertheless, the ability to walk should always be determined with a manual muscle test. This theoretical approach needs to be clinically validated.
How well do stroke survivors adhere to an 18-month physical activity and exercise programme? Secondary results from a randomised controlled trial

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Introduction: Adherence to physical activity is important to maintain motor function across all stages after stroke.

Research Question: The aim of this study was to investigate to what extent patients were adherent to an 18-months physical activity and exercise programme.

Methods: The intervention-arm of a multicentre, randomised controlled trial followed patients for 18 consecutive months [1]. The intervention consisted of individualised monthly coaching by a physiotherapist who motivated patients to adhere to 30 minutes of daily physical activity and 45 minutes of weekly exercise. Patients' self-reports in training diaries and adherence reported by the physiotherapist reviewing these, were combined and assessed as the primary outcome. A multilevel mixed-effects logistic regression model was used to analyse change over time. Borg scale and Goal Attainment scaling were secondary outcomes.

Results: A total of 186 informed consenting patients, with mild to moderate stroke (mean age 71.7 years (SD 11.9)), were included three months after onset. Thirty-four (18.3%) patients withdrew and nine (4.8%) died during follow-up. Adherence to the amount of physical activity and exercise per protocol ranged from 41.9% to 57.0% and from 42.5% to 64.0% each month, respectively (Figure 1). Adherence to the combination of physical activity and exercise proved to increase significantly over time (OR =1.04, 95%CI 1.01-1.08, P=0.022). Further, most of the exercise was performed at moderate to high intensity levels, ranging from 12 to 16 on Borg scale. Overall, there were low levels of goal achievements over time.

Discussion: To our knowledge, no studies have investigated self-reported adherence to physical activity and exercise after stroke in such a long-term perspective and with such strict demands of adherence as in the present study. Findings indicate that patients with mild to moderate stroke who received individualised regular coaching manged to establish and maintain good adherence to daily physical activity and weekly exercise over time.
Gait patterns and walking ability after training with a hybrid robotic exoskeleton compared to conventional gait training in early stroke rehabilitation

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Introduction: Impaired gait after hemiparetic stroke remains a challenge. Although walking speed often improves due to structured rehabilitation approaches and with time, asymmetric and compensatory gait patterns tend to develop and remain [1]. Robotic gait assistive devices may enable early gait training after stroke and may allow more reproducible gait movements than manual movement support by a therapist. The Hybrid Assistive Limb (HAL) is a hybrid exoskeleton that provides motion support based on the wearer's voluntary intention as captured by surface electromyography (sEMG) recordings from lower limb muscles. The operator can adjust the degree of support for the knee and hip joint separately to obtain a symmetrical gait pattern as close to normal gait as possible. The HAL system enables gait training in patients with severe lower limb paresis to start early after stroke [2].

Research Questions: Does 4 weeks of gait training with HAL training during inpatient rehabilitation after stroke improve gait pattern functions (assessed with laboratory gait analysis), and are there any associations between gait pattern functions and clinical assessments of body function and activities, as compared to conventional gait training?

Methods: This study is a subsample from a randomized controlled trial including patients with severely impaired gait function < 8 weeks after stroke. Patients were randomized to either evidence-based conventional gait training only or to HAL training in addition to the conventional program. Conventional gait training was performed according to current best practice (approximately 30-60 min per day, 5 days per week). Patients in the HAL group received HAL training, by use of the single-leg version of HAL, 4 days a week for 4 weeks (i.e. 16 sessions). Training was performed on a treadmill with body weight support. Blinded assessments were performed before and after intervention covering aspects of motor function, balance and walking including the Functional Ambulation Categories (FAC), which evaluates walking ability on a six-grade-ordinal-scale, ranging from non-functional walking to independent walking outdoors [3], the 2 Minute Walk Test (2MWT), the Berg Balance Scale, the Fugl-Meyer scale for sensorimotor function and the NIH Stroke Scale (NIHSS) for stroke severity. 3D gait analyses were performed after the intervention period with a motion capture system (Vicon MX40). Patients walked barefoot and with their walking aid if needed.

Results: Seventeen patients completed a full assessment directly after the four-week intervention, 10 in the HAL group and 7 in the Conventional group. Patient characteristics are presented in Table 1. Kinematics, kinetics, GPS/MAP, GDI, and temporo-spatial parameters will be presented, as well as their correlations to clinical assessments.

Discussion: To our knowledge this is the first study including gait analyses as an outcome after training with HAL in the sub-acute stage after stroke. This subsample is also part of the first blinded randomized controlled trial comparing gait training with HAL with conventional gait training according to current best practice. As group sizes are small and variances generally high, the statistical power is most likely too low to compute reliable statistical differences. For this reason, we analyse the data qualitatively, and present correlations and differences in terms of trends. As this study was exploratory, we believe the findings will be most valuable to guide both clinical praxis and further studies of robotic gait training.

Table 1

<table>
<thead>
<tr>
<th>N</th>
<th>Men/Women</th>
<th>Age Mean (SD)</th>
<th>Days to inclusion Mean (SD)</th>
<th>Paretic side Left/Right Mean (SD)</th>
<th>NIHSS at inclusion Median (IQR)</th>
<th>FAC score at inclusion Median (IQR)</th>
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<td>52.4 (11.1)</td>
<td>32 (14)</td>
<td>8/2</td>
<td>11 (8.75-13)</td>
</tr>
<tr>
<td>--------</td>
<td>------</td>
<td>-----</td>
<td>------------</td>
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<td>-----</td>
<td>-------------</td>
</tr>
<tr>
<td>CONVENTIONAL</td>
<td>7</td>
<td>6/1</td>
<td>50.3 (12.7)</td>
<td>42 (16)</td>
<td>5/2</td>
<td>12 (11-13)</td>
</tr>
</tbody>
</table>

References:
Grip strength during the first year after stroke and its relation to upper extremity motor performance and dexterity

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Introduction: Hemiparesis is common after stroke and often leads to reduced grip strength in the affected hand. Hand dynamometers reliably measure grip strength [1] as well as the strength ratio between the affected and non-affected hand [2]. Grip strength is influenced by muscle length, and people with stroke are relatively weaker when their muscles are in a shortened range [3]. The five-rung grip test on a Jamar hand dynamometer can be used to measure grip strength at different muscle lengths by changing the 5 handle positions from narrow (position 1) to wide (position 5). Little is known about the time course of the recovery of grip strength in different hand positions and how the recovery of grip strength is related to upper extremity motor performance and dexterity.

Research Question: How does grip strength, assessed in 5 different positions, develop during the first year after stroke, and how is it related to upper extremity motor performance and dexterity?

Methods: Eleven participants with mild to moderate stroke participated in this study. The participants, a subsample of the Norwegian Constraint-Induced Therapy Multisite Trial (NORCIMT), were recruited 7-28 days' post stroke and were assessed 5 times during a 1-year period. Grip strength in both hands was assessed by Jamar design dynamometer (G100, Biometrics Ltd., UK) using the testing positions recommended by the American Society of Hand Therapists. The dynamometer allows adjustment of the handle, and maximum voluntary contraction (MVC) was measured in 5 positions, ranging from a close to a wide grip. Upper extremity motor performance was assessed by the Wolf Motor Function Test (WMFT), dexterity by the Nine Hole Peg Test (NHPT).

Results: Three women and 8 men participated in the study, mean age was 79.1 years. Preliminary results show that the MVC in all 5 handle positions in the paretic hand increased during the one year follow-up period, with most improvement occurring during the first 6-months after the stroke. The ratio of the grip strength between paretic and non-paretic arm at all 5 time points, the influence of hand dominance, and the association between grip strength and upper extremity motor performance (WMFT) as well as dexterity (NHPT) will be presented at the conference in September.

Discussion: The influence of grip aperture, assessed by five-rung test, as well as handedness on the recovery of grip strength of the paretic hand will be discussed. Further, we will discuss the association between grip strength and upper extremity motor performance as well as dexterity and possible clinical implications of these findings.

Analysis of the immediate effect of gait training with virtual reality on the parkinsonian walking.

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Introduction: Subjects with Parkinson’s Disease (PD) presents alterations in gait and balance. The use of walking training with Virtual Reality (WTVR) in the elderly and people with neurological diseases has shown positive effects. However, little is known about the immediate effect of WTVR on the PD gait.

Research Question: Does the WTVR produces immediate effect in gait parameters of individuals with PD?

Methods: 12 subjects with PD (age: 60.25±9.28 years old; gender: 11 males and 1 female; weight: 77.33±14.16kg; height: 169.08±9.68cm; H&Y 1.41±0.51; UPDRSIII 13.39±8.11) performed 1 session of 20 minutes of WTVR. For the virtual reality training the Xbox 360 Kinect’s game ‘Your Shape - Run the World’ was used. Immediately after the therapy the gait of these patients was evaluated by an inertial sensor G-WALK (BTS Bioengineering S.p.A, Italy). The following variables were analyzed: gait speed [m/s], stride length [m], step length [m], cadency [steps/minutes], stride duration [s]; the percentage of the support phase [%], swing phase [%], double support phase [%] and simple support [%]; propulsion [m/s²], pelvis flexion/extension [°], internal/external rotation [°] and adduction/abduction [°] angles. T-test for repeated measures was applied to compare the differences between these variables pre and post-intervention (α=0.05).

Results: No gait differences after WTVR were found for any of the variables studied: gait speed (t12 = -0.594; p=0.558), stride length (t12 = -0.485; p=0.633), step length (t12 = 0.355; p=0.726), cadency (t12 = -0.411; p=0.685), stride duration (t12 = 0.038; p=0.970); the percentage of the support phase (t12 = -1.297; p=0.208), swing phase (t12 = -1.297; p=0.208), double support phase (t12 = -1.578; p=0.129) and simple support (t12 = 0.615; p=0.545); propulsion (t12 = -1.000; p=0.328), pelvis flexion/extension (t12 = -0.208; p=0.837), internal/external rotation (t12 = -0.645; p=0.525) and adduction/abduction (t12 = -0.208; p=0.837) angles.

Discussion: A single WTVR caused any immediate effect on the gait of people with PD. However, a previous study has shown that after 18 WTVR sessions patients with PD increased 8.9% of walking speed. In addition, the stride length and stride time were improved, as well as those results were maintained at follow-up. In this way, we believe that the WTVR can be efficient in the improvement of the parkinsonian gait after several training sessions. Anyway we expect that other aspects, not yet included in this paper, like a better postural control might benefit by this treatment and may be studied in further analysis.

References:
Postural mediolateral asymmetry and potential inter-related movements during gait post-stroke

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Introduction: In a hemiparetic condition, asymmetrical movement patterns usually arise during gait as the unaffected side of the body tends to be more engaged in body support and balance control. This asymmetry may result in reductions in ambulatory ability and development of compensatory strategies, potentially followed by higher risk of falls and increased energy costs. To further understand the characteristics of the gait pattern post-stroke it is important to investigate this asymmetry in relation to trunk, arm and leg movements. This study aims to use kinematic data to evaluate gait in persons post-stroke compared to the gait pattern of non-disabled controls, by particularly investigating the medial CoM-ankle inclination angle (CoM-a-IA) during the entire gait cycle. Further, the study explores associations between CoM-a-IA and the kinematics of the upper and lower extremities.

Research Question: How does the medial CoM-a-IA during gait discriminate between persons post-stroke and non-disabled controls and is there any relation to kinematics of the upper and lower extremities?

Methods: Kinematic gait analysis was performed in 25 persons post-stroke and 25 age- and gender-matched non-disabled controls. Data were collected using an eight camera motion capture system (240 Hz; Qualisys AB; Gothenburg; Sweden), and processed in the software Visual 3D (C-motion Inc., Germantown, MD, USA). CoM-a-IA was defined as the medial angle between CoM and the centre point between two markers placed on the medial and lateral malleolus, respectively. Kinematics of upper and lower extremities were quantified using the Arm Posture Score (APS, cf. 1) and Gait Profile Score (GPS, 2). Associations were explored using Spearman’s correlation, while group comparisons for CoM-a-IA during the entire gait cycle were analysed using functional data analysis methods (3).

Results: Preliminary results, in line with earlier studies (4), suggest a larger medial CoM-a-IA in persons post-stroke compared to controls. These differences were significant within the early stance phase and in late swing phase. This was true for the gait cycle of both affected and non-affected leg. For the post-stroke group, the medial CoM-a-IA angle was positively correlated to both the APS (rho=0.72, p<0.000, affected arm) and the GPS (rho=0.54, p=0.005; rho=0.58, p<0.002, affected and non-affected leg) scores. No such correlations existed for the controls.

Discussion: The larger medial CoM-a-IA, most notable in the early stance phase and in late swing phase, seems to reflect the compensatory movement pattern observed in post-stroke gait. The deviations in the limb movement patterns captured with the APS and GPS measures in the stroke group, and the positive correlations of these values to the medial CoM-a-IA, further confirm the asymmetrical postural behaviour involving the whole body post-stroke. The associations need to be further investigated, eg. in relation to injury location and extent, extremity weakness and spasticity. The medial CoM-a-IA, earlier used in studies of postural control in elderly (4), may be useful to deepen our understanding of implicit factors influencing compensation post-stroke.

References:


Optimal Classifier of Parkinson’s Disease based on features selected by Information Gain in 3D Gait Analysis for Differential Diagnosis.

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Introduction: Parkinson’s Disease (PD) is clinically evaluated by different rating scales, which give an overall picture of the PD patients, but are highly affected from subjective observations [1]. Since walking has been signalled as a sensitive indicator for the progression of PD [2] and platforms of 3D gait analysis generate kinematic measurements of a wide range of variables across the gait cycle, in our work we used the information gain concept [3] to measure feature relevance in differential diagnosis among spatio-temporal and kinematic parameters obtained from Human Motion Analysis.

Research Question: What are the most relevant kinematic features in characterising gait and movement of Parkinson’s Disease patients?

Methods: 12 informed patients (7 females, 5 males) were enrolled at the Neurological Department of Local Hospital of Brindisi (Age = 75.83 (8.32) years, BMI = 28.77 (5.84) kg/m², UPDRS - III Section, Gait Score = 1.83 (0.94)). According to the previous neurological diagnosis, patients were in 2 groups: 1) G1, patients with no diagnosis of PD (n=8); 2) G2, patients with PD (n=4). All measurements were been performed in the KISS-Health Human Motion Analysis Laboratory, located in Mesagne (Brindisi, Italy). Spatio-temporal information (cadence [step/min], velocity [m/sec], stride length [m]) and kinematic parameters of gait were acquired using an optoelectronic system (BTS Bioengineering, Italy) [4], following a standard Davis Protocol. Kinematic data were subsequently summarized using concise measures of gait quality, Gait Variable Score (GVS) and Gait Profile Score (GPS) [5]. We then used an Artificial Neural Network (ANN) [5] to classify the degree of neurological disorders between the 2 groups. A method based on the Information Gain (IG) algorithm was used to measure the amount of information for the class prediction according to the ranking of the relative importance of the features for the corresponding class distribution [3].

Results: All the participants completed both clinical and instrumental evaluations. Optimal feed-forward ANN topologies were designed by Genetic Algorithm based procedure (GA) [6,7]. 3 different groups of features were used: i) all the 25 features; ii) 19 features and iii) only spatio-temporal features, that resulted from the IG as the most selective features. In all the cases the dataset consisted of 64 positive sample and 40 negative samples. We finally discussed our average results evaluated on 200 iterations in terms of Accuracy, Specificity, and Sensitivity [7]. For the IG, the results are reported in Table 1 as the amount of information stored in the feature.

<table>
<thead>
<tr>
<th>Left Cadence</th>
<th>Right Stride Length</th>
<th>Right Velocity</th>
<th>Right Cadence</th>
<th>Left Velocity</th>
<th>Left Stride Length</th>
<th>GVS</th>
<th>GPS</th>
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<td>0.501</td>
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<td>0.388</td>
<td>0.374</td>
<td>0.3 - 0.106</td>
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</table>

Discussion: Nowadays, PD influences a large part of worldwide population (about 1% of the population over 55 years old). Most of the current methods used for evaluating PD rely heavily on human expertise. In this work, we tested an innovative set of features derived from 3D gait analysis platforms in order to discriminate PD with respect to normal and other neurological diseases. Before designing the optimal supervised classifier, we performed the IG in order to measure the relevance of selected features. Best performance was reached by an ANN classifier based on all 25 the features yielding an Accuracy of 95.05%.
Validity of the Functional Data Analysis in the assessment of the post-stroke gait in relation to clinical scales

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Introduction: Kinetic analysis with force plates is a useful methodology to interpret the characteristics of hemiplegic gait post-stroke. The main characteristic is variability in force patterns, which differs significantly from the norm. Functional Data Analysis (FDA) is an alternative to parametric analysis for analysing the complete curve (1). FDA has been applied to the analysis of ground reaction forces of patients post-stroke in order to explain their variability (2).

Research Question: The aim of this work is to describe the relationship between validated clinical scales for gait assessment and FDA in the analysis of ground reaction forces of patients during 6 months post-stroke.

Methods: Thirty people were assessed seven times during six months after stroke: after achieving the stand-up position, at the beginning of outpatient rehabilitation, a month after beginning rehabilitation and three, four, five, and six months post-stroke. The assessment instruments have been: Muscular Manual Test at tibial anterior (MMT), Functional Ambulation Classification of Massachusetts General Hospital (FAC), Functional Ambulation Classification of Sagunto Hospital (FACHS) and kinetic gait analysis using a force plate. FPCA (Functional Principal Components Analysis) is the FDA methodology used for the analysis of the ground reaction forces. Statistical analysis consisted of an ANOVA of FPCA factors with scales and side as factors.

Results: The results show that the first component of anteroposterior (Fx1) and mediolateral forces (Fy1) are the factors that best fit the clinical scales of gait assessment (FAC and FACHS). Fx1 and the first component of vertical forces (Fz1) do the same with MMT (figure 1). The differences between the highest levels are significant (p<0.05).

![Figure 1: Graphical representation of the marginal means of the ANOVA test of Fx1 and Fy1 with FAC and side as factors (side left) and Fx1 and Fz1 with MMT and side as factors (right).](image)

Discussion: FPCA of ground reaction forces after stroke are strongly related to validated clinical scales. Therefore, FPCA is a valid, objective methodology to analyse gait recovery after a stroke. The variables that best fit the scales come from the three components of the force. FPCA of ground reaction forms can be applied as alternative of parametric analysis in gait assessment.

References:
(1) Ramsay JO. Functional data analysis. Wiley Online Library; 2006.

Reproducibility of a simplified methodology of biomechanical assessment of the knee during walking up and down stairs.

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Introduction:

One of the major sources of error in the biomechanical assessment is the low reproducibility associated to the experimental procedures. The purpose of this study was to examine the intrasubject reproducibility of a simplified methodology for the biomechanical assessment of the knee joint during walking up and down stairs.

Research Question:

Is the simplified biomechanical model reproducible for the biomechanical assessment of the knee during stair walking?

Methods:

Kinematic and kinetic data were collected from 58 subjects without pathology and for two trials per subject during ascending and descending stairs with the purposed methodology. One observer performed 2 measurement sessions for each subject, in the same day. Two force platforms and an 8-camera photogrammetry system were used. The biomechanical model was composed by 16 reflective markers. A calibration measurement was performed to calculate the position of 4 anatomical markers in the external malleoli and condyles. The stair walking test was executed with 12 technical markers placed as triads on the thigh and leg segments, both in the right and left limb. Subjects performed a two-step climbing at comfortable speed. The test was performed barefoot and with arms crossed over their chest. Temporal parameters, 3D reaction forces, sagittal knee angles and knee sagittal and frontal moments were calculated. The intraclass correlation coefficient (ICC 2,1) (1), the standard error of the measurement (SEM) and the relative standard error (RSE) were used to determine the intrasubject reproducibility (2).

Results:

<table>
<thead>
<tr>
<th></th>
<th>Stepping up</th>
<th>Stepping down</th>
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</thead>
<tbody>
<tr>
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<td>ICC</td>
<td>SEM</td>
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<td><strong>Fx 2</strong></td>
<td>0.40</td>
<td>0.03</td>
</tr>
<tr>
<td><strong>Fy 2</strong></td>
<td>0.88</td>
<td>0.02</td>
</tr>
<tr>
<td><strong>Fz 2</strong></td>
<td>0.71</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Fy 3</strong></td>
<td>0.41</td>
<td>0.03</td>
</tr>
<tr>
<td><strong>Fx 3</strong></td>
<td>0.83</td>
<td>0.03</td>
</tr>
<tr>
<td><strong>Fy 3</strong></td>
<td>0.72</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Fz 3</strong></td>
<td>0.41</td>
<td>0.02</td>
</tr>
<tr>
<td><strong>Mf 1</strong></td>
<td>0.10</td>
<td>0.01</td>
</tr>
<tr>
<td><strong>Mf 2</strong></td>
<td>0.84</td>
<td>0.01</td>
</tr>
<tr>
<td><strong>Ms 1</strong></td>
<td>0.77</td>
<td>0.02</td>
</tr>
<tr>
<td><strong>Ms 2</strong></td>
<td>0.74</td>
<td>0.02</td>
</tr>
</tbody>
</table>

The variables of anteroposterior and lateral reaction forces (axes x and y, respectively), which obtained lower values in both tests were suppressed from the subsequent statistical analysis. Once these variables have been suppressed, it is seen through the ICC, that 92% of the variables have a high reliability (0.70–1) in the stair climbing test, while 61% do so in the stairs down test. With RSE, 84% of the variables show a high or acceptable concordance (>10%) in the stair climbing and 69% walking down stairs (Figure 1).

**Discussion:**
The experimental procedure is reproducible, especially for the vertical forces, the sagittal angles and frontal and sagittal moments. These results are compatible to those obtained in another study with respect to the repeatability of kinetic and kinematic variables in the up and down stairs activities (3). These results support the hypothesis that it is feasible to design a simple and reproducible measurement procedure for the biomechanical assessment of the knee during walking up and down stairs.

**References:**
Postural characterization in subjects with Parkinson’s disease using a synthetic index based on the Gait Profile Score

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Introduction: Parkinson’s Disease (PD) is a progressive neurological disorder, characterized by four cardinal features: tremor rest, rigidity, akinesia (or bradykinesia), and postural instability [1]. The 3D Gait Analysis (GA) is able to characterize many features of the postural abnormalities; however, it provides data of no simple and fast understanding. Synthetic indexes, e.g. the Gait Profile Score (GPS, obtained as the sum of several Gait Variable Scores, GVSs) [2], can summarize the GA kinematic variables and facilitate the interpretation of the GA results [3]. We developed a synthetic index, based on the GPS, able to characterize the postural biomechanical profile in PD compared to a healthy control group, and correlated it with the clinical scale “Unified Parkinson’s Disease Rate Scale” (UPDRS).

Research Question: Is the GPS effective in the quantification of the postural abnormalities in subjects with PD?

Methods: The 5seconds-standing trial of 40 patients with PD (age [y] = 68.43 (6.36); UPDRS = 32 (9.17)) and 21 healthy control subjects (age [y] = 62.3 (9.5)) were acquired at the Motion Analysis Laboratory of the IRCCS San Raffaele Pisana (Rome, Italy) using an optoelectronic system (Elite 2002, BTS, Milan, Italy) [4]. From the 3D GA data, a synthetic index, based on the GPS and including a variable related to the 3D posture of the trunk, was developed [3]. The standing kinematic variables were used for the computation of 12 GVSs, from which the GPS was obtained. The GPS and the GVSs in PD and CG were compared using a T-test, and the Pearson correlation between the GPS, GVSs and the UPDRS was computed.

Results: The GPS differed between PD and CG both including the trunk variable (GPS_PD[°] = 8.61 (2.73); GPS_CG[°] = 6.11 (1.79); p=0.0001) and not including it (GPS_PD[°] = 8.83 (2.95); GPS_CG[°] = 6.54 (2.02); p=0.002). Five of the GVSs, computed for the calculation of the GPS, were different in PD compared to the CG (Table 1). Finally, a positive, low Pearson’s correlation coefficient was found between the trunk GVS and UPDRS (r = 0.354, p= 0.028).

<table>
<thead>
<tr>
<th>GVSs</th>
<th>Mean (SD) PD</th>
<th>Mean (SD) CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trunk flex/ext [°] *</td>
<td>7.77 (6.53)</td>
<td>2.63 (1.95)</td>
</tr>
<tr>
<td>Trunk int/ext rot [°] *</td>
<td>3.60 (3.37)</td>
<td>1.89 (1.51)</td>
</tr>
<tr>
<td>Hip flex/ext [°] *</td>
<td>9.20 (6.23)</td>
<td>5.10 (4.17)</td>
</tr>
<tr>
<td>Hip abd/add [°] *</td>
<td>4.92 (2.24)</td>
<td>2.96 (1.77)</td>
</tr>
<tr>
<td>Knee flex/ext [°] *</td>
<td>9.25 (5.73)</td>
<td>5.37 (3.45)</td>
</tr>
</tbody>
</table>

Table 1. Mean and SD of the GVSs in PD and CG. * All the variables were statistically different in the two groups (p <0.05)

Discussion: The GPS and the GVSs are effective in the postural characterization of PD. The GPS provides quantitative information about the overall quality of posture; while, through GVSs, we have a detailed insight about the individual kinematic variables that may impact more on the postural abnormality. For example, the inclusion of the trunk GVS highlighted the influence of this variable on GPS, also considering it was the only GVS to correlate with the UPDRS. This finding
allows applying the GPS to the characterization of the posture in PD, to the evaluation of its follow up and to the assessment of the rehabilitation effects.

References:

Gait performance in assessing donor-site morbidity following osteocutaneous free fibula transfer: a preliminary study

Ilaria Pacifici1, Ludovica Pallotta1, Alessandro Bolzoni2, Giada Beltramini2, Matteo Zago3,1, Chiarella Sforza1

1Department of Biomedical Sciences for Health, University of Milan, Milan, Italy, 2Maxillo-Facial and Dental Unit, Fondazione IRCCS Ca’ Granda Ospedale Maggiore Policlinico, Milan, Italy, 3Department of Electronics, Information and Bioengineering, Politecnico di Milano, Milan, Italy

Introduction: Autologous free fibula flap (FFF) is one of the most popular technique used for reconstructing mandibular, maxillary, and segmental long bone defects [1, 2]. Previous studies have investigated motor alterations on the lower limbs due the intervention, reporting several changes relative to spatio-temporal parameters [3] and kinematics [4]. However, the functional deficits following FFF are generally ignored by the patient and the perception of morbidity is low [3; 5]. The purpose of this study was the evaluation of donor-site significant alterations after the intervention and, on the base of the findings, the planning of a focused rehabilitation treatment.

Research Question: Are there biomechanical lower limb alterations during the gait after free fibula transfer for facial reconstruction?

Methods: The gait performance of eight patients (age [y] = 60 (16); height [cm] = 171 (6); weight [kg] = 65 (9)), who underwent facial reconstruction with FFF removal, was assessed at the Motion Analysis Lab of the Department of Biomedical Science for Health (University of Milan), before and 6 months after the intervention, using a SMART optoelectronic computerized system (BTS spa, Milan). Spatio-temporal parameters and the Range of Motion (ROM) of hip, knee and ankle angles in the sagittal plane were computed before and after the intervention, for both sides, and compared using the non-parametric Wilcoxon Rank-Sum Test (p <0.01).

Results: Step length, step width, cadence, velocity, percentage of stance, swing, and support phases did not differ between pre and post operation, for both sides (healthy and operated). Also, no significant differences were found in the ROM of hip, knee and ankle flexion/extension angles (Table 1).

<table>
<thead>
<tr>
<th>Gait variables</th>
<th>PRE</th>
<th>POST_ healthy side</th>
<th>POST_ operated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stance [%]</td>
<td>70.07 (1.57)</td>
<td>70.57 (1.19)</td>
<td>70.39 (1.29)</td>
</tr>
<tr>
<td>Swing [%]</td>
<td>29.93 (1.58)</td>
<td>29.43 (1.19)</td>
<td>29.60 (1.29)</td>
</tr>
<tr>
<td>Cadence [step/s]</td>
<td>1.34 (0.15)</td>
<td>1.19 (0.21)</td>
<td>1.20 (0.21)</td>
</tr>
<tr>
<td>Step length [m]</td>
<td>0.71 (0.06)</td>
<td>0.69 (0.09)</td>
<td>0.69 (0.09)</td>
</tr>
<tr>
<td>RoMhip [°]</td>
<td>39.98 (4.37)</td>
<td>41.34 (4.21)</td>
<td>41.14 (3.34)</td>
</tr>
<tr>
<td>RoMknee [°]</td>
<td>66.38 (5.03)</td>
<td>68.47 (4.38)</td>
<td>69.22 (4.65)</td>
</tr>
<tr>
<td>RoMankle [°]</td>
<td>27.81 (4.19)</td>
<td>28.90 (3.94)</td>
<td>28.59 (3.88)</td>
</tr>
</tbody>
</table>

Table 1. Mean and SD of some of the study GA variables. No significant differences were found (p <0.01)

Discussion: No functional limitations during gait performance were found. These findings are only partially in agreement with previous studies that reported some differences relative to the lower limb functionality [3-5]. Together with small sample sizes, differences relative to the pre-condition of the patient and to the period of follow up may influence the results. However, the anatomical alteration following the FFF removal is significant and permanent and, in addition, there is no data relative to assessments performed many years after the intervention. Therefore,
despite the absence of alterations, it would be appropriate to promote a multidisciplinary follow-up that considers the physiotherapy and rehabilitation features.

Analysing the activation of the plantar flexor muscles during treadmill walking

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¹University of Applied Sciences Brandenburg, Brandenburg, Germany, ²Helios Klinik Brandenburg, Brandenburg, Germany, ³Städtisches Klinikum Brandenburg, Brandenburg, Germany

Introduction: In clinical settings, a treadmill is often used during physiotherapeutic interventions for repetitive exercise of walking. To improve the gait of patients with cerebral palsy (CP), physiotherapeutic interventions include among other repetitive walking on a treadmill to strengthen the plantar flexor muscles. Oliveira et al. [1] investigated the muscle activation during overground (OG) and treadmill (TM) walking. Their results show that there are differences in the muscle activation in both scenarios. Van der Krogt et al. [2] found differences in kinetics of children with CP in OG and TM walking. An examination was performed to prove the assumption that the plantar flexor muscles are less activated during TM walking.

Research Question: Are the plantar flexors muscles less activated during treadmill walking?

Methods: The gait of 23 young and healthy subjects (8 m, 15 f, age: 25.6 (± 5.4) years, height: 170 (± 10) cm, weight: 69.0 (± 13.0) kg) was examined. The muscle activation of the primary plantar flexors (M. soleus (SO), M. gastrocnemius medialis (GM) and lateralis (GL)) was registered using EMG-sensors with 8-channel measuring device of bioplux (Plux Wireless Biosignals S.A., Lisbon, Portugal). For stride-based analysis of the muscle activation, the initial contact was captured using 3D-accelerometers, which were fixed on each heel. The subjects were asked to choose their comfortable walking speed during OG walking which was registered for each of the six trials for the 40 m straightforward distance (OG). Each subject passed two walking trials on the TM, one without inclination (TM1) and another with an inclination of 1.5 % (TM2) following recommendations [3,4,5] with a 1 km/h reduced speed based on literature [6,7] and own examinations. The mean activation of each muscle was determined based on the stride detection. The peak height was calculated for each setting and each muscle. The parameter was analysed descriptively and regarding significant differences. For the descriptive analysis, the difference between the settings were considered. A negative value indicates a lower activation of the plantar flexor muscles during TM walking.

Results: The parameters show significant differences between the OG and TM walking (see table below). The parameter peak height has a negative difference for all considered scenarios and muscles.

<table>
<thead>
<tr>
<th>GM</th>
<th>Parameter</th>
<th>Mean OG</th>
<th>Mean TM</th>
<th>Diff (* p &lt; 0.01)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GM</td>
<td>Peak height (mV)</td>
<td>4722.93</td>
<td>3963.36</td>
<td>-759.57*</td>
</tr>
<tr>
<td>GM</td>
<td>Peak height (mV)</td>
<td>4722.93</td>
<td>4312.86</td>
<td>-410.07*</td>
</tr>
<tr>
<td>GM</td>
<td>Peak height (mV)</td>
<td>3470.75</td>
<td>2621.18</td>
<td>-849.57*</td>
</tr>
<tr>
<td>GM</td>
<td>Peak height (mV)</td>
<td>3470.75</td>
<td>2763.14</td>
<td>-707.61*</td>
</tr>
</tbody>
</table>

Note: * indicates significant difference at p < 0.01.
<table>
<thead>
<tr>
<th>OG vs. TM1</th>
<th>Peak height (mV)</th>
<th>2575,85</th>
<th>1773,51</th>
<th>-802,34*</th>
</tr>
</thead>
<tbody>
<tr>
<td>OG vs. TM2</td>
<td>Peak height (mV)</td>
<td>2575,85</td>
<td>1720,35</td>
<td>-855,50*</td>
</tr>
</tbody>
</table>

**Discussion:** Based on the results, with the main focus on the parameter peak height and the difference between the settings, the hypothesis can be confirmed. Using the given setting the plantar flexor muscles are less activated during treadmill walking. Thereby, the results achieved for SO are in accordance to Oliveira et al. [1]. However, the results achieved for GM and GL are inconsistent to [1]. A trend is recognisable that based on the TM inclination the activation of the muscles is comparable to the activation during OG walking. To confirm the found trend, further examinations are planned to find the conditions, which are necessary to achieve the same or higher activation of plantar flexor muscles during TM walking. To know these conditions are essential for physiotherapeutic intervention.

**P13**

**Are preterm-born survivors at risk of long-term consequences?**

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*University of Physical Education, Faculty of Rehabilitation, Warsaw, Poland*

**Introduction:** Advancements in perinatal care have led to improved survival rates among prematurely born infants, but developmental disorders of morphology and organ function often result. The respiratory system is particularly at risk, which in turn has a negative impact on physical fitness. Although the immediate effects of this type of birth and treatment methods are quite well researched, not many studies have looked at the long-term impact stretching into adulthood (Saigal & Doyle, 2008).

**Research Question:** What are the long-term effects of preterm birth on the respiratory system and exercise tolerance?

**Methods** Prematurely born female subjects were stress-tested twice, once during puberty (n=70), and part of the same group again in adulthood (n=13), each time compared against a reference group of their peers. Each time, a W_{150} test was performed while striving to maintain HR=150 bpm; the observed level of total physical work performed (W) therefore depended only on physical fitness / exercise tolerance. Lung function was also evaluated with a MES LungTest Handy spirometer.

**Results:**

<table>
<thead>
<tr>
<th>Group</th>
<th>Puberty</th>
<th>Adulthood</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FEV1%</td>
<td>Total work (kJ)</td>
</tr>
<tr>
<td>Preterm-born</td>
<td>100.7±23.6</td>
<td>26.94±9.40</td>
</tr>
<tr>
<td>Reference</td>
<td>98.3±18.7</td>
<td>25.79±8.74</td>
</tr>
</tbody>
</table>

*p<0.001*

**Discussion:**

Long-term consequences of preterm birth are complex and notoriously problematic to study (particularly in maintaining the same group of subjects over a prolonged period of time), and so a major strength of our study is its longitudinal design. Most previous studies of continuous lung functions in preterm-born subjects have been limited to childhood/adolescence or have been cross-sectional (Vrijlandt et al., 2006, Narang et al., 2009). In our study, we found an increase both in dynamic lung ventilation and exercise tolerance during adolescence, which seems to indicate that preterm-born individuals manage to compensate for the earlier negative effect of premature birth. However, the occurrence of respiratory impairment in premature infants and the incidence of chronic and recurrent respiratory infections in such children could, over time, lead to a change in the functional condition of the respiratory system, and therefore to changes in breathing conditions (Vrijlandt et al., 2006). Such a negative longer-term impact was indeed confirmed by the results of our follow-up examination of part of the same group in adulthood. The preterm-born adults showed poorer lung function (lower forced expiratory volume in one second – FEV1%) as compared to a reference group of adults (not statistically significant), as well as a statistically significant, lower value of total work performed on the stress test (p<0.001). Obstructive lung impairment (lower FEV1%) in conjunction with lower physical fitness (total work) together entail the possibility of experiencing exercise-related shortness of breath, which is the second-most important (after pain) factor restricting exercise tolerance. Therefore, we conclude, the lung function and exercise tolerance in preterm-born individuals needs to be monitored at different stages of life, not only during puberty.

**References:**


Clinical gait analysis and physical examination do not correlate with the physical activity intensity of children with cerebral palsy

Anne-Laure Guinet, Eric Desailly

Fondation Ellen Poidatz, Saint Fargeau Ponthierry, France

Introduction:
The benefits of regular physical activity on health are widely recognized (WHO, 2010). Children with cerebral palsy practice less daily physical activity than typically developing (TD) children [1] [2]. This may affect their quality of life and may increase their impairments. In our experience clinical gait analysis is usually performed when physical activity is less assessed. Moreover the effect on physical activity of treatments such as Single Event Multi Level Surgery (SEMLS) is unknown. The effect of SEMLS is mainly assessed by Clinical Gait Analysis (CGA) when one of its main purpose may not be solely to improve gait quality but also to improve activity quantity and intensity.

Research Question:
Do CGA and physical examination correlate with the physical activity of children with cerebral palsy?

Methods:
Children with CP, aged 11 – 18, with (GMFCS) I – II are included. Physical activity is recorded with an Actigraph GT3X [3] during 7 days. CGA and physical examination are realized during the same month. The level of association between variables is tested with a Spearman’s rank correlation coefficient performed with R 3.0.2. after a multiple regression model has been performed to avoid the bias of underestimating the dependence between both limbs.

Results:
28 patients has been included. They have a median GDI of 74.22 (range, 46.24-96.46), a median time spent in MVPA of 13.0 (range, 4.4-30.8) and median steps per day of 5114 (range, 1874-10503).

The percentage of time in moderate to vigorous physical activity (MVPA) shows no correlation with GDI. MVPA is only correlated with some clinical measurements of hip range of motion (0.4<r<0.6, p<0.05). The average daily step count is correlated with GDI (r=0.48, p<0.001), knee and ankle flexion at loading response (r=-0.5, p<0.0001), hip extension at toe off (r=0.42, p=0.003, spatio-temporals parameters (0.35<r<0.45, p<0.05) and with clinical hip range of motion, knee and hip strength or selectivity (0.33<r<0.52, p<0.05). There is no correlation between gait analysis data and moderate to vigorous physical activity (MVPA).

Discussion:
Children included have less physical activity than typically developing ones. They are also less active than children included in Wilson’s study, maybe because of the slightly higher ratio of patients in GMFCS II.

Those results indicate that gait analysis could very partially reflect the overall level of daily physical activity [4]. It is not a good predictor of MVPA. If CGA and some clinical data may help
to estimate the activity patients do, they can't inform about the intensity they have. Physical activity may be more dependent of personal, socio-familial an environmental parameters. Regarding the strength of the observed correlations we recommend to associate CGA and actimetry in the longitudinal follow-up of patients with CP.

References:

The interpretation of conventional gait indices is related to the normative data’s walking speed

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Introduction: Walking speed influences most of the gait parameters: spatiotemporal, kinematics, kinetics and muscle activity [1]. Since the spontaneous walking speed of patients is often slower than for asymptomatic subjects, conventional gait indices (i.e. Gillette Gait Index (GGI) or Normalcy Index [2], Gait Deviation Index (GDI) [3], and Gait Profile Score (GPS) [4]), may also be influenced by walking speed. Clinically, it is of primary importance to distinguish between the contribution of the impairments associated with the pathology and the influence of walking speed on gait deviations. The fact not to level the walking speed of the two compared populations (i.e. patients and asymptomatic subjects) may influence the analysis of gait deviations, and thus lead to misinterpretations regarding the impact of the pathology on gait.

Research Question: Using a data repository of asymptomatic subjects walking at different speeds [5], the objective was to evaluate the impact of the normative data’s walking speed on the interpretation of GGI, GDI and GPS in asymptomatic adults.

Methods: Fifty-four adults (24 women – 30 men, 37.9 ± 13.7 years, 1.74 ± 0.10 m, 72.8 ± 13.3 kg) with no neuro-orthopaedic trouble were included in this study. They all gave informed written consent prior to their inclusion and the protocol was approved by the Institutional Review Board. The participants were asked to walk on a 10-m straight level walkway and four conditions of walking speed (C1, C2, C3 and C4) were recorded using a 10-camera optoelectronic system (OQUS, Qualisys AB, Sweden). Conditions C1, C2 and C3 were respectively ranged between 0 and 0.4 m.s⁻¹, 0.4 and 0.8 m.s⁻¹, and 0.8 and 1.2 m.s⁻¹. Condition C4 corresponded to the participants’ spontaneous walking speed. A minimum of 5 gait trials were recorded for each subject and for each condition. Four normative data repositories (N1, N2, N3 and N4) were established corresponding respectively to the four conditions of walking speed. For each subject, GGI, GDI and GPS were computed for each gait trial of the four conditions using alternately the four normative data repositories. Paired t-tests (confidence level of 95%) were then performed for each index, to compare two-by-two averaged index values computed for a same condition with the four different normative data repositories, or computed for the four different conditions with the same normative data repositories.

Results: The averaged walking speed for all subjects was 0.29 ± 0.05 m.s⁻¹ in C1, 0.61 ± 0.08 m.s⁻¹ in C2, 0.97 ± 0.11 m.s⁻¹ in C3 and 1.14 ± 0.15 m.s⁻¹ in C4. Indices for Ci computed with matching Ni were closed to the values reported in the literature. Meanwhile, when the averaged walking speed of the investigated condition moves away from the averaged walking speed of the respective normative data repository (i.e. Ci and Nj with i ≠ j), index values move away from these reference values in a statistically significant manner in most cases. Particularly, for computation with N4, the three investigated indices were significantly different from their reference values for the conditions C1 and C2 while no significant effect was found if the walking speed of the subject remains above 0.8 m.s⁻¹ (C3).

Discussion: In clinical practice, normative data repositories obtained at spontaneous walking speed (i.e. N4) are often used as the reference for patients walking at a lower speed. In this configuration, a difference with reference values was found for the GGI, GDI and GPS indices for the conditions C1 and C2. Gait indices should thus be interpreted cautiously. If the aim is to consider the global distance to normality, a normative database at spontaneous walking speed should be used to include the walking speed as a potential impairment. If the aim is to measure the deviation from normal gait due to clinical impairments, walking speed-matched normative database should be preferred.

References:


Independent domains of gait in adults: a comparison of different populations

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¹University of Antwerp, Antwerp, Belgium, ²Antwerp University Hospital, Antwerp, Belgium, ³Revarte, Antwerp, Belgium

Introduction: Covariance among spatio-temporal parameters of gait (STP) is high, suggesting redundancy (1). Principal Component Analysis (PCA) can be used to extract relevant gait domains from the high-dimensional dataset of STP (1-3). It has been suggested that these domains reflect motor, cognitive or behavioural constraints (1). To evaluate this hypothesis, the number and the nature of gait domains should be compared between different populations faced with different constraints.

Research Question: Are the number and nature of gait domains population-dependent?

Methods: Gait analysis was performed in 102 healthy adults and elderly (age 20-89, 50 males) during barefoot walking. A set of 10 STP (Fig. 1) was entered into the PCA (varimax rotation, eigenvalues > 1). PCA results were compared to data from 8 relevant studies (1 – 8) obtained through a systematic literature search in PubMed and Web of Science (keywords: ‘Principal Component Analysis’, ‘Factor Analysis’, ‘Gait’ and ‘Variability’). Studies were included if they exclusively applied PCA on STP during overground walking.

Results: Four key domains were identified: pace, rhythm, base of support (BOS) and variability (Fig.1). Pace, rhythm and BOS show consistency in healthy adults and elderly, community dwelling elderly, mild cognitive impairment and Parkinson’s disease. However, in an asymmetrical condition (elderly with a fracture) consistency of STP loading on these domains is lost. Variability is consistent in pathological conditions but in healthy adults and elderly and community dwelling elderly, certain STP reflecting variability load on the domains of pace or rhythm.

Discussion: The results from this study confirm the hypothesis that the number and nature of gait domains are population dependent. This suggests that a model of gait domains provides rationale for selection of gait characteristics to pursue hypothesis-driven research to identify underlying gait mechanisms in aging and pathology and to identify key STP contributing to gait disturbances.
Validity and repeatability of the two-minute walk test on a self-paced treadmill in healthy adults

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Introduction:

In recent years instrumented treadmill training in a virtual reality environment has been used for balance and gait training in rehabilitation centres. It provides intensive, repetitive and task specific training in a motivational and safe environment, including the possibility to give real time feedback. In addition, its measurements properties allow for collection of objective gait data. However, to monitor training progression and evaluate training effects in clinical practice, short and task specific tests to be performed on the treadmill are needed. Previous studies indicate a preference for self-paced treadmill walking to allow for more natural stride variability [1] and a virtual reality environment to more quickly reach the preferred walking speed [2]. The purpose of the study was to evaluate external validity and repeatability of the two-minute walk test (2MWT) on a treadmill in the self-paced mode in a virtual reality environment.

Research Question:

What are the external validity and repeatability of the 2MWT on a self-paced treadmill in self-paced mode in a virtual reality environment in healthy adults?

Methods:

Twenty-two healthy adults performed a conventional 2MWT overground (OG) and two 2MWTs on an instrumented treadmill in a virtual environment (Gait Realtime Analysis Interactive Lab, GRAIL) in self-paced mode (GRAIL1 and GRAIL2). Motion sensors (Shimmers3) were attached to the ankles to assess spatiotemporal parameters (mean stride length, mean and standard deviation (SD) stride time) during all tests. For the 2MWTs on the GRAIL, markers were placed to control the walking speed in the self-paced mode. ICCs and Bland-Altman analyses (upper and lower limits of agreement, LoA) were performed to analyse the external validity (OG versus GRAIL1) and repeatability (GRAIL1 versus GRAIL2).

Results:

Participants covered a significantly larger distance during the 2MWT OG(199.1(SD 27.1)m) compared to GRAIL1 (179.6(SD 30.6)m, p< .001). The ICC for covered distance was 0.67 and the upper and LoA’s were -14.62m and 53.7m, respectively. Stride length was significantly longer and stride time and SD stride time significantly shorter during OG.

During GRAIL2 (186.3(SD 34.6)m), a significantly larger distance was covered compared to GRAIL1 (p=.014). The ICC was 0.92 and the upper and lower LoAs were -29.6m and 16.2m, respectively. For the GRAIL2, mean stride length was significantly larger and no differences were found in mean stride times and mean SD stride times.

Discussion:
The external validity of the 2MWT on a treadmill in the self-paced mode in a virtual reality environment was moderate indicating that the results of the 2MWT OG and GRAIL are not interchangeable. Based on the ICC, the repeatability was very good for the 2MWT on a treadmill in self-paced mode in a virtual reality environment. The small differences between GRAIL1 and GRAIL2 in covered distance (both mean and LoA) were similar with those reported for the 2MWT overground in the literature [3,4]. Larger stride length during GRAIL2 indicate an increased familiarization to treadmill walking in the self-paced mode. In conclusion, the 2MWT on a treadmill in self-paced mode in a virtual environment is useful to evaluate and monitor gait training on such treadmills but cannot be interchanged with a 2MWT overground. The generalizability of these results to various patient groups should be further investigated.

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The utilisation of full length orthotics to improve gait in children with idiopathic toe walking

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Introduction: Children with no neurological, orthopaedic or psychological condition who prefer to walk on their toes but can perform heel-to-toe gait are commonly diagnosed with idiopathic toe walking (ITW) [1]. Continued ITW has been associated with gastroc-soleus equinus [2]. Several studies have investigated treatments of ITW yet there is no definitive long term treatment solution. Orthotic treatment is considered a conservative treatment that can either mechanically or sensor-perceptually treat the equinus. Ankle foot orthoses may improve gait during use, but these changes are not sustained when the AFO is removed. Rigid foot orthoses (RFO) however appear to have a positive impact on gait after a six week period [3]. Current clinical practice of the authors JM & CW is to combine full length RFOs with Nike AIR FORCE 1 (NAF1) shoes for the treatment of ITW. The aim of this study was to determine the impact of this combined treatment approach on heel contact, spatio-temporal parameters of gait and sagittal plane ankle range of motion in children with ITW.

Research Question: Do custom made carbon RFO combined with NAF1 shoes increase the number of heel contacts in children with ITW?

Methods: This within subject design randomised controlled trial recruited 15 children (10 males, 5.93±1.83 years, height 120.03±13.76cm, weight 24.84±8.20kg), with a minimum of 15° of ankle range of motion. All children were diagnosed with ITW during a multidisciplinary assessment [4]. Standard anthropometric measures were recorded in addition to the weight bearing lunge test (WBL) to determine available ankle dorsiflexion range. These measures were taken with the TiltMeter app on an Apple iPhone, using a method with high intra-rater reliability [5]. Gait measures were recorded on an 8.3m long GaitRite® (CIR Systems Inc.), an electronic walkway with excellent reliability in recording heel strike and spatial-temporal gait measures in children [6]. Two trials of three walking conditions at preferred speed were randomised; walking barefoot, with socks and usual play footwear, and with custom made carbon RFO and NAF1 shoes. Data were analysed using Stata v.13.7 to express each variable in means (SD) or frequency (%) and all full and partial foot strikes were manually counted.

Results: There were more heel strikes observed during the RFO and NAF1 condition (26.4±3.8) than the barefoot condition (22.5±12.6) and partial heel strikes were significantly reduced in the RFO and NAF1 condition (p= 0.021). Footwear only had little impact on altering heel contact. Gait speed was less in the RFO and NAF1 condition compared to usual footwear. This was associated with a significant reduction in cadence (p=0.005). Stride time was substantially increased in the RFO and NAF1 (p<0.006) compared to barefoot walking. This was associated with a decrease in the percentage of swing phase in the gait cycle (p<0.010), an increase in stance phase (p<0.010) and an increase in double support time (p<0.001) at both loading and unloading of the weight bearing limb. These changes were not apparent in the barefoot versus footwear only condition.

Discussion: Children with ITW changed their gait when fit with RFO and NAF1 shoes. Heel contact occurred in 89% of all foot contacts versus 64% barefoot and 67% in usual footwear. This increase in heel contacts is likely to encourage tibialis anterior activity and assist in maintaining calf length in gait. With more of the foot in contact with the ground, stride time naturally increases, resulting in longer double support phases and shorter percentage of the gait cycle spent in swing phase. This suggests the combined treatment of the RFO and NAF1 shoes promotes a more stable base of support during stance phase. Further studies to evaluate muscle activity and the impact of the NAF1 shoe alone are necessary. Long term outcomes of this conservative standard practice treatment are unknown and required to determine if this treatment sufficiently controls ITW and possibly limits its progression as the child grows.

Increased femoral anteversion related biomechanical abnormalities: Gait and hypermobility

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Introduction: Increased femoral anteversion (IFA) is the forwardly rotated femoral head relative to transcondilar axis of the knee. Femoral anteversion (FA), which is high in newborn, decreases by ages and reaches normal values by bone growth completes. Although, for some healthy individuals, FA angle does not decrease as it is seen in healthy peers or conversely increase (1). IFA related gait alterations have not clearly defined. Additionally, a common believe is, there is a high correlation between IFA and hypermobility syndrome (2), and gait alterations may related with hypermobility, which are also questionable.

Research Question: To clearly determine the IFA related kinematic and temporal-spatial gait abnormalities and to investigate the correlation between hypermobility, IFA and IFA related gait parameters for neurologically intact individuals.

Methods: Biomechanical alterations of eigthy-six participants (age: 8.3±3.1) with IFA who have hip internal rotation angle 65°≤ (72.1±9.8°) and external hip rotation ≤20°, (trochanteric prominence angle test (TPAT): 45.54±8.5°, and fifty pairs (age: 9.97±3.1, hip internal rotation: 43.26±12.13°, TPAT: 23.68±12.27°) were participated in this study (Totally 118 participants). In which, 36 participants with IFA (age: 8.79±3.67) and 16 healthy peers (age: 10.12±2.24°) were analyzed by 3D Motion Analysis System to define the sagittal plane pelvis, hip, knee, ankle kinematics, and the temporal-spatial parameters. Hypermobility score was determined for all participants according to Beighton test (3). For comparison gait parameters, Mann-Whitney-U test was utilized and spearman correlation coefficient test was used for correlation between IFA (goniometric mean hip internal rotation and TPAT angles) and hypermobility scores (p<0.05, weak correlation: r<0.3)(4).

Results: During gait, peak plantar flexion angle (p=0.01), knee range (ROM) (p<0.001) reduced, and peak dorsiflexion angle (p<0.001), ankle ROM (P=0.04), peak knee extension (p<0.001), knee ROM (<0.001), hip internal rotation (p<0.001), pelvic-rotation (p<0.001), stance duration (%gait cycle) increased (Figure 1a-c). Relative to their pairs, in participates with IFA, hypermobility score (p=0.03) was found as increased. Although, against the common believes, correlation of IFA with hypermobility was weak (for TPAT r: 0.26, for hip rotation r: 0.23, p<0.05). Only, pelvic obliquity was moderately correlated with hypermobility (r: 0.3, p=0.04), although knee-ROM, peak flexion, extension, mean internal rotation of the hip, mean pelvic tilt, pelvic rotation and obliquity and hip rotation were strongly correlated with increased femoral anteversion (r<0.7, p<0.01).

Discussion: This study clearly defined the kinematic and temporal-spatial gait alterations of IFA by including the highest number of participants in literature. IFA alters the gait biomechanics as not only causing increased internal hip rotation, in-toing and pelvic ROM in transverse plane, but...
also by flexing the knee and enhancing ankle dorsiflexion in stance, reducing the knee ROM, and stance phase duration. Different than it is thought, although hypermobility increased in IFA group, hypermobility and increased hip internal rotation angle are weakly correlated (2, 3). Disagreed with the literature, mean anterior pelvic tilt was not seen as increased (1), which may be because of increased knee flexion in stance phase. Additionally, hypermobility was found as weakly correlated with IFA related gait parameters. **Acknowledge:** This project supported by TUBITAK No: 214S049.

Describing the influences of hip abductor muscle weakness on gait parameters in healthy individuals.

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Introduction: Introduction: Hip abductor muscle weakness is a common problem in clinic causes trandelenburg gait pattern (1) Although, selective hip abductor weakness in healthy individuals have not clearly defined for healthy individuals in literature.

Research Question: What are the influences of the hip abductor muscle weakness on walking?

Methods: Nine healthy participants (9 dominant limbs, Av. Age: 22±0.6, Weight: 168.44±7.35 kg, Height: 57.66±9.93 cm) were included in the study. As it was described in Fowles et al.’s work (2), abductor muscles were self-stretched by a strict protocol (135 sec x 13 repetition and 5 sec resting). Stretching intensity was set as 6/10 in severity according to visual analogue scale (VAS, on set of discomfort accepted 10). Placing the participant in the standing position while taking the dominant side string in flexion; The targeted dominant side’s gluteus medius muscle was self-stretched while maintaining the pelvis and trunk symmetry (figure 1a). In order to stretching under the discomfort threshold, the same researcher verbally acknowledged in every 30 seconds. The dominant side of the participant's hip abductor muscle strength before and after stretching was dominant in the supine position, hip and knee extension in the dominant side, the non-dominant side was in hip and knee flexion, while the participant's pelvis was fixed with external support, hip abductor muscle strength was measured with a handheld dynamometer with the help of a belt attached to a fixed mechanism (figure 1b) (3). The gait parameters in sagittal, frontal and transverse planes (pelvic obliquity, pelvic and rotation, hip abd-adduction, hip flex-extension, hip rotation, knee flex-extension, ankle dorsi-plantar flexion, foot progression) were compared before and after the stretching by computerized 3D gait analysis at self-selected speed. Paired t-test was used for the statistical comparison (p<0.05).

Results: Hip abductor strength was successfully dropped %33.34±6.86 stretching (from 250.8±77.8N to 166.3±45.9N, p<0.01). Mean pelvic tilt (from 6.61±5.15 to 8.21±4.93)(p:0.006), pelvic obliquity range (from 9.48±3.63 to10.33±3.84)(p:0.05), peak hip flexion (from 25.70±5.20 to 74.56±1.33)(p:0.003), and hip adduction at initial contact (from -1.45±2.44 to -3.22±2.97)(p:0.07) increased at the stretched side and mean gait velocities were similar (1.18±0.08, 1.17±0.14). Peak pelvic obliquity (pelvic-up) increased (from 4.17±1.52 to 5.01±1.46) near significantly (p=0.07).

Discussion: The present stretching procedure was able to reduce the hip abductor muscle force approximately 35% in healthy individuals. As agreed with the literature, reduced hip abduction strength caused pelvic drop at the opposite side and enhanced hip adduction ipsilateral side in early stance, when gluteus-medius muscle is normally active (1). On the other hand, increased anterior pelvic tilt and hip flexion in terminal swing may due to the reduced contour-abductor-force, which should act against the adding influence of the hip flexors (1). Therefore hip flexors may become dominant in terminal stance. Additional EMG and trunk kinematics would help us to understand the abductor-muscle-weakness related gait alterations better. Acknowledge: We thank the chief of the department for permitting to do this work.
Figure 1a,1b: Illustration of self-stretching (a) and measuring (b) protocol.

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Gait function on inclined surfaces of children with spastic bilateral cerebral palsy - a focus on tempo-spatial parameters and foot positioning at initial contact

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Introduction: Children with cerebral palsy (CP) experience difficulties when climbing stairs or walking on uneven [1] or inclined surfaces. Yet, studies about functions and mechanisms of walking on inclined grounds are scarce. Children with CP use similar, but pronounced postural adaptations to sloped surfaces compared to children with typical development (TD) [2].

Research Question: How do the gait function with its tempo-spatial parameters and the strategies of foot positioning at initial contact (IC) of children with CP differ from those of children with TD when walking on inclined surfaces?

Methods: The gait function with its tempo-spatial parameters (see Table) of six children with bilateral CP (GMFCS I-II) and five with TD, aged 6-10 years, was assessed with instrumented 3D gait analysis on even ground and on ramps with 5° and 10° incline. Children with TD and CP and the different walking condition were compared against each other. Further, foot positioning at IC was qualitatively examined by measuring the amount of different foot position types at IC.

Results: This preliminary study showed that affected children had a shorter step length and a lower velocity in all conditions and predominantly later foot-offs compared to those with TD. Exceptions were that children with CP had higher cadences than those with TD only during downhill walking. Additional differences especially on the 10° incline were found: Unimpaired children increased their step length, those with CP shortened it during uphill walking compared to walking on even ground. Children with TD decreased their velocity when walking downhill, children with CP showed an increase of velocity and an earlier foot-off (see Table 1). Focussing on foot positions at IC, children with TD had 100% heel contacts in all conditions. However, in children with CP different methods of foot positioning were seen. On level ground 94% of strides were heel contacts. Depending on the degree of disability and incline more flat foot contacts (FFC) and forefoot contacts (FC) with and without secondary heel touch were observed. Foot strikes on the 5° incline were mainly heel contacts (62-65% uphill and downhill), but also FFC (25% up- and downhill), FC with secondary heel touch (5% uphill, 10% downhill) and FC without secondary heel touch (2% uphill, 0% downhill). During uphill walking of 10° incline heel contacts (47%), but also more FFC (28%), FC with (9%) and without (18%) secondary heel touch occurred. During downhill walking of 10° incline heel contacts (57%), FFC (28%), FC with (38%) and without (2%) secondary heel contact were seen.

<table>
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<tr>
<th>condition</th>
<th>step length [m]</th>
<th>velocity [m/sec]</th>
<th>cadence [steps/min]</th>
<th>foot-off [% GC]</th>
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<tr>
<td>TD</td>
<td>CP</td>
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<td>64.06±1.32</td>
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<td>64.07±0.77</td>
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<td>even</td>
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<td>62.03±1.28</td>
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Table 1: Temporo-spatial parameters of children with CP and TD on all conditions (mean value±standard deviation)

**Discussion**: The focus of this study was on strategies for walking control and conspicuousities on inclined surfaces. A higher velocity and cadence during downhill walking in children with CP may improve balance maintenance or may occur due to the lack of control mechanisms as the slowing down of walking speed. Restricting factors such as muscular weakness may result in smaller step length during uphill walking. Flat foot contacts, providing a large base of support, may sustain the balance during uphill walking. FC and FFC at IC may help to control the velocity during downhill walking as an additional braking strategy to increased knee flexion [3] [4]. Understanding the neuromechanical mechanisms of walking on inclined surfaces of children with CP may help to develop therapeutic interventions improving their everyday mobility in the future.

A topological approach for human movement classification and anticipation

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Introduction: The motion capture systems are increasingly used for biomedical purposes. In order to recognize and classify the movements, however whole-body movements using passive markers, generate a huge amount of data. Several works have been realized, with the main idea of using kinematic data as input for independent component analysis (ICA), or machine learning algorithms [1]. These approaches return high accuracy, but remain very sensitive to the noise and to the impact of the morphological difference between subjects. In contrast, we propose to apply a topological data analysis method, based on persistent homology [2], which captures essential features of data in a robust manner [3] that avoids these limitations, before to perform classification using machine-learning methods.

Research Question: Can topological data analysis methods improve the recognition of movements? Can we use the results of this analysis combined with particular types of neural networks to anticipate the continuation of a movement?

Methods: With motion capture systems, the movement is defined as a sequence of postures. Thus, we record a sequence of N postures. The main idea of our work is to apply a topological analysis method on the 3D coordinates of the markers at each posture, in order to define a topological signature called persistent diagram [2]. Thus for a movement with N postures, we obtain N topological signatures, one for each posture. Once the topological analysis is carried out, distances between topological signatures can be obtained using a metric like Wasserstein or Bottleneck distance as described in [4]. We obtain an N×N distance matrix, which contains pairwise distances between each posture and the others for a same movement. We then reduce the dimension of matrix, using dimensional reduction method like MDS or Isomap, which generates point cloud, representing the distribution of topological signatures that we use as input for neural networks. In second time, we use recurrent neural network to anticipate the movements.

Results: For the inter-motion classification, with either kinematic data or topological signatures, we obtain a high accuracy ≈99% (Fig1). But the use of kinematic data directly for intra-motion classification is impacted by the morphological difference between subjects, contrary to the topological approach (Fig2). For the robustness test, with the addition of a white noise spanning the range [10mm; 100mm], we lose more quickly the accuracy of the classical method using kinematic data, with a decreasing accuracy from 99% to 40%. With the topological approach, we lose less quickly precision which stays around 60% even at 100mm of noise (Fig1). Finally, we use a sample of the topological signatures, which represents ≈15% of the whole recording as an input for an Elman neural network (Fig3). We obtain ≈90% of anticipation accuracy.

Discussion: The results show that the addition of a topological analysis step in a movement data analysis process, based on the persistent homology before the classification, improve dealing...
with noise issue and morphological difference between subjects, for the intra-movement comparison. An advantage of the topological analysis method of movement is its ability to be combined with a recurrent neural network to anticipate movements. More than physical rehabilitation applications, the topological analysis method of kinematic data in order to classify and anticipate the movement can be applied in different fields, like providing a safety environment, by supervising physical activities of older persons, or in virtual reality applications.

Correlation between MAP and GPS and muscles co-contraction during gait in children with Cerebral Palsy

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Introduction: Children with Cerebral Palsy (CP) have abnormal gait pattern. One of the reasons for this abnormality is impaired control of the muscles (spasticity, lack of selectivity). The level of gait pathology could be summarized by Movement Analysis Profile (MAP) and Gait Profile Score (GPS) [1], while abnormal muscular activity by cross correlation coefficients, expressing their co-contraction [2,3]. The dependence of the pathological kinematics on abnormal muscular activity is not a direct one in CP patients, and is still a subject of investigation.

Research Question: Are correlations between muscle co-contraction, MAP and GPS in CP children statistically significant? Which MAP elements are correlated with muscle co-contraction?

Methods: Fifty one patients with CP, aged from 2 to 11.5 years old participated in the study. They underwent the instrumented gait analysis at their first admittance to the rehabilitation program. The gait analysis was performed using 6 camera VICON MX system. Plug-In-Gait marker set and model were used. At the same time surface EMG was recorded using Motion Lab System. Data were synchronized. Electrodes were placed on selected legs muscles according to SENIAM recommendations. The data taken during 6 trials were later processed, and averaged. From EMG signals the envelopes were calculated, and later averaged. Cross correlation coefficients [2] for the following pairs of the muscles were calculated: rectus femoris – biceps femoris; rectus femoris – medial hamstring; lateral gastrocnemius – tibialis anterior, and biceps femoris – medial hamstring. MAP and GPS were calculated using own MATLAB procedures. Data from right and left legs were pooled together. Correlations between MAP, GPS and muscle cross correlation coefficients were later calculated using Spearman rank correlation test in STATISTICA (StatSoft).

Results: The following correlations were found statistically significant: co-contraction rectus femoris – biceps femoris and pelvic rotation (R=0.2), co-contraction rectus femoris – biceps femoris and hip rotation (R=0.308), co-contraction gastrocnemius – tibialis anterior and ankle flexion (R=0.295), co-contraction biceps femoris – medial hamstring and pelvic tilt (R=0.241), co-contraction biceps femoris – medial hamstring and hip rotation (R=0.223).

Discussion: The study of van der Houven [4] proved, that the use of botulinum injections together with intensive rehabilitation treatment lead to improvement of gait kinematics, but they do not modify the EMG patterns. This finding confirms that the dependence between abnormal EMG patterns and gait dysfunction is not a direct one. The results of this study show, that there are some weak correlations between the muscular dysfunction (expressed by the cross correlation coefficients of some pairs of muscles), and gait dysfunction, represented by Movement Analysis Profile.

Increased co-contraction of gastrocnemius and tibialis anterior muscles influences the ankle movement of CP patients: gastrocnemius is responsible for plantarflexion, tibialis anterior for dorsiflexion. The correlation shows that stronger co-contraction results in higher ankle movement abnormality. Other co-contractions are responsible for abnormal pelvic movements (rotation and tilt), and hip rotation: co-contractions rectus femoris – biceps femoris, and biceps femoris – medial hamstrings. Although all investigated muscles apart from tibialis anterior are spanning the knee joint no dependence between abnormal knee flexion and any co-contraction were found.

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A protocol to measure everyday use of lower limb orthotics and quality of life in subjects with neuromuscular gait disorders

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Introduction:
Patients with neuromuscular impairments are often affected in their everyday mobility. As a conservative treatment to improve gait function patients are provided with different types of orthotics reaching from single DAFOs to modular orthotic concepts. Biomechanical effects of orthotics are already addressed as research questions. However, little is known about more general effects like every day usage, patient satisfaction, and quality of live to help. A better understanding could help the caregiver team optimizing individual treatment.

Research Question:
How often are orthotics used and which patterns of usage can be identified? How satisfied are patients and parents and how do they rate quality of life? Does usage correlate to gait impairment, type of orthotics, or tempo-spatial parameters (TSP)?

Methods:
In this on-going study 31 user (28 ICP, 3 MMC age 4-36 years) meeting the inclusion criteria (neuromuscular disease, GMFCS I-III, age > 4 y, lower limb orthotics) are enclosed over the last three month (targeting to n=50). At T1 the exact type of orthotics is documented and 5-cent-sized temperature sensors [1] are implemented. To measure time of usage sensors log temperature every 15 minutes. Values in the range of 29-38.5°C are tracked as ‘used-time’. After 90 days (T2) TSP are measured via optical marker tracking plus video. Depending on orthotics, different conditions are measured (eg. DAFO plus shank adaptation) in addition to barefoot and shoed walking. Users undergo a physical examination looking at range of motion, strength, deformities and spasticity and 4 questionnaires are completed: CPchild, Quest, EQ5-D-Y, and Disab. kids/parents [2-5].

Results:
One subject (m, 7y, 23kg, 1.19m, ICP, GMFCS I) already completed T2. He uses a unilateral (right) DAFO and a modular shank-adaptation with an external rotation strap (DAFO+). The use for all components is 4 h/day on average. The DAFO is used more often than DAFO+. The daily time of use is longer on working days compared to weekends. In comparison weekends have more days without orthotics in percentage. TSP show slight differences especially in speed. Total scores in all questionnaires result in almost similar outcomes compared to high scores (HS). The Disab. kids/parents illustrates that parents rate the impairment higher than the subject.

Discussion:
Monitoring orthotic usage over longer time periods is feasible and enables insights in individual usage, which is even more interesting when looking at modular orthotic concepts. The average use per day is a rough number since usage differs between work days (more hours) and weekends. Usage measured via temperature can’t be rated as activity but as ‘worn’. TSP with orthotics should also be compared to barefoot and shoed walking even if these are conditions not all patients perform every day. A detailed quantification on different areas of daily living is provided
by the questionnaires. These parameters are helpful to correlated self-reported experiences and perceptions with physical impairment, TSP, orthotic concept and usage.

References:
[1] Rollerwerk medical engineering, Balingen, Germany
Can Virtual Reality games improve scores on clinical balance scales in children with cerebral palsy: preliminary results of a randomized controlled clinical trial.

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Introduction: Due to their sensorimotor disorders, children with cerebral palsy (CP) typically experience poor balance control during standing and walking [1]. Virtual Reality (VR) is increasingly used in balance rehabilitation since literature has indicated some promising effects on for instance motivation [2] and functional outcomes [3] in several patient populations. Some preliminary studies have investigated the effect of VR training on balance in children with CP, however, they describe mixed results [4,5]. The contradictory findings could be the result of insufficient power due to small sample size and use of different measures of balance.

Research Question: Can 6 weeks VR home-training promote balance control on a range of clinical scales in children with CP?

Methods: In this registered RCT (NTR6034), 41 children with spastic CP will be recruited (7-14 years old) and randomly distributed in the intervention or control group (ratio of 31/10 in intervention/control group). Children with CP are included if they (1) are diagnosed with bilateral spastic CP, (2) have GMFCS level II, (3) had no surgical interventions (e.g. orthopaedic, selective dorsal rhizotomy) in the past twelve months, and (4) had no Botulinum Toxin A injections in the past six months. VR home-training comprises X-box One & Kinect (Microsoft) training for 6 weeks. Children exercise using Kinect sports games with a focus on balance (tennis, football, bowling) 5x/week for 30min/session. Patients in the control group do not receive VR training. Balance is assessed with several clinical scales; i.e. Pediatric Balance Scale (PBS) – 14-item measure which examines functional balance in the context of everyday tasks (on 56 points), balance subscale of the Bruininks-Oseretsky test for Motor Proficiency 2nd edition (BOT-2) – 9-item subscale which examines static and dynamic balance for use by practitioners and researchers to diagnose motor impairments and evaluate interventions (on 37 points), and the Trunk Control Measurement Scale (TCMS) – 15-item scale for postural control which assesses static and dynamic aspects of trunk control (on 58 points). As the RCT has just started (i.e. five children have been recruited), we present preliminary data of three children that performed the baseline measurement and measurement after 6 weeks (post-training).

Results: All three boys were allocated to the intervention group. Table 1 provides their baseline and post-training scores on the clinical balance scales. All participants improved on two out of the three scales.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Participant 1 (10y 7 mo)</th>
<th>Participant 2 (9y 9mo)</th>
<th>Participant 3 (8y 0mo)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PBS</td>
<td>Baseline</td>
<td>41</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td>Post-training</td>
<td>46</td>
<td>49</td>
</tr>
<tr>
<td>BOT-2 (balance)</td>
<td>Baseline</td>
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<td>2</td>
</tr>
<tr>
<td></td>
<td>Post-training</td>
<td>11</td>
<td>7</td>
</tr>
<tr>
<td>TCMS</td>
<td>Baseline</td>
<td>39</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>Post-training</td>
<td>36</td>
<td>43</td>
</tr>
</tbody>
</table>

Discussion: We present the protocol of our RCT and the results of our first included participants. We assessed balance using multiple clinical balance scales to be able to compare our results to
previous studies. From our preliminary results, it seems that balance might be improved using VR home-training for 6 weeks in some children with CP. However, it appears from these three patients that VR training might result in improvements of different aspects of balance (lower limb versus trunk control); e.g. participant 1 increased most on PBS (i.e. more than the minimal clinically important difference [MCID] of 3.66 points on the PBS [6]) but showed a decrease on the TCMS, while participant 2 and 3 increased most on the TCMS (i.e. 9 and 17 points out of the possible 58; MCID not available) but showed a (negligible) decrease on the PBS. Assuming that a single mechanism of keeping balance would be sensitive to training, the use of multiple measures of balance might thus provide some insight in the contrasting results of previous studies.

An open source implementation of the Conventional Gait Model in Python

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Introduction:

The Conventional Gait Model CGM [1,2] has been a standard in clinical gait analysis since the 1990s. Well-known by its commercialisation as Plug-in Gait (PiG, Vicon, Oxford, UK), it is simple and widely understood facilitating discussion between biomechanists and clinicians. Most commercial manufacturers now provide some version of the model. Despite its common use there has been little development of the model since the 1990s perhaps because open source versions have not been available. None of these replicates fully the range of options that are used by different users. The first aim of this paper is thus to present an open source version of the CGM which fully replicates those options.

One of the well-known limitations of the model is the difficulty in defining the coronal plane of the femur and tibia. The original publications [1,2] relied on accurate placement of thigh wands. Later the use of a Knee Alignment Device (KAD) during a static calibration trial was proposed. Other models (such as CAST [3]) have used medial epicondyle and malleolar markers which appear to give less variable data. The second aim of this paper is thus to modify the model to allow the coronal plane of the femur and tibia to be defined by medial epicondyle and malleolar markers placed during the static trial.

Research question: Can Open-source software reproduce the output of the conventional gait model?

Methods:

PyCGM2 is an open-source python package which itself uses two motion-capture dedicated packages: openMA [4] and Biomechanical ToolKit [5]. PyCGM2 applications can be called from Vicon Nexus 2.i through its python shell. The first application was to replicate PiG, renamed as CGM 1.0. This was tested by comparing outputs from CGM 1.0 with those from PiG across a range of patients and processing options.

CGM 1.1 is then a version with modification of the pelvic angle sequence according to Baker [6] and definition of the femur plane by using a medial knee markers during calibration but applying the same logic used when a KAD is applied to generate thigh and shank rotation offsets. A practical illustration of the CGM1.1 was carried out with one patient, whose doctors requested assessment of a femoral nerve block test due to a limited knee flexion during swing. This requires two sets of gait trials during the session. Wands must be removed for injections complicating the analysis. With CGM1.1, influence of wand markers is reduced since knee medial markers were marked then placed during the pre-block calibration and re-positioned after injection. In consequence, CGM1.1 should highlight relevant clinical outcomes.

Results:

Replication of the PiG presented root mean square difference below 0.01 deg and 0.08 Nm.Kg⁻¹ for angles and moments respectively. Through involvement of medial knee markers, CGM1.1 procedure revealed an increase of the knee flexion after foot-off not exhibited by PiG which also showed clear signs of kinematic crosstalk from repositioning wands.

Discussion:

This communication introduces an open-source python package “PyCGM2” (http://pyCGM2.github.io) callable from Vicon Nexus 2.i (Vicon, Oxford, UK). All variants of the PiG were replicated in CGM 1.0 to within very close tolerances. A new variant named CGM1.1 uses medial knee makers to replace the KAD calibration leading to easier clinical implementation.
Overall, pyCGM2 is also a framework for developing, testing and spreading clinically-relevant methods related to the CGM.

References:

Assessment of the spatiotemporal gait parameters of children with cerebral palsy in daily-life settings: comparison between wearable systems using different sensor location

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Introduction: The spatiotemporal parameters (STP) of gait are commonly used to describe the global gait quality of patients with motor disorders including those with cerebral palsy (CP) which is the most frequent motor disorder in childhood [1]. However, these measurements can change between a laboratory environment and everyday-life situations, especially in a paediatric population [2]. The use of wearable devices is of great interest to objectively quantify the motor performance of children with CP in their daily life. Their validity has mainly been studied in healthy or elderly population but scarcely in childhood populations. Bregou-Bourgeois et al. [3] used foot-worn inertial sensors to compute STP in children with CP and showed a good accordance with an optical system (0.03±0.05 m for stride length and 0.04±0.04 m/s for speed). Nevertheless, given the heterogeneity of ankle and foot movement patterns in children with CP, the reliability of other sensor set-ups requires exploration in order to determine the optimal set-up weighing reliability versus usability.

Research Question: In this study, we aimed at comparing the errors of STP computation using three wearable systems defined by different sensor positioning on lower limbs for children with CP and typically developing controls (TD).

Methods: We included 11 children and adolescents with CP (age: 14.0± 3.1 years; GMFCS I (n=7)-II (n=1)-III (n=3)) and 11 age- and sex-matched TD controls. The participants were asked to walk on a 10-meter walkway at their self-selected speed while wearing 6 synchronized inertial sensors (Physilog4, Gait Up) on both thighs, shanks and feet. The sensors recorded 3D acceleration and 3D angular velocity at 100Hz. Three different STP estimation methods were tested according to the sensor location: the feet (‘Feet’) [4], the shanks (‘Sh’) [5] and the shanks and thighs (‘ShTh’) [6] methods. The gait events (foot strike and foot off) as well as the stride time, stride length and walking speed were computed for each gait cycle. Accuracy ± precision (i.e. mean±standard deviation) of the three methods were determined in comparison with a reference system using forceplates (Kistler) and manual detection of events as in [7]. The number of non-detected gait cycles was also reported for each method.

Results: ‘Sh’ and ‘ShTh’ methods showed better foot strike detection (0.03±0.07s for both methods) compared to ‘Feet’ method (0.06±0.12s) for all participants. Similar results were observed for subgroup analyses of TD, CP-GMFCS I, CP-GMFCS II and CP-GMFCS III and for foot-off detection. ‘Sh’ and ‘ShTh’ methods showed 1.49% of non-detected cycles and ‘Feet’ method 4.38%. For stride time estimation, ‘Sh’ and ‘ShTh’ methods showed better performances (0.00±0.02s) than ‘Feet’ method (0.01±0.09s) for the whole population as well as for the different subgroups. ‘Feet’ method was more accurate at estimating the stride length for both TD (0.05±0.08m) and CP children (0.02±0.28m) (against >0.08±0.06m and >0.03±0.16m for ‘ShTh’ and ‘Sh’ methods). However, ‘ShTh’ method showed better results within the CP-GMFCS II and III subgroups (0.03±0.10m) than ‘Sh’ (0.16±0.15m) and ‘Feet’ (0.14±0.38m). Similar observations were made for the estimation of velocity.

Discussion: The results showed that for the whole study population (TD+CP) the three methods were comparable for STP estimation; with ‘ShTh’ and ‘Sh’ being slightly more robust for the temporal parameter estimation and ‘Feet’ slightly better for the spatial parameter computation. However, ‘Sh’ and ‘ShTh’ were more robust to detect gait events in challenging gait patterns (less non-detected cycle compared to ‘Feet’) and ‘ShTh’ was found more accurate for the patients with a higher level of disability (GMFCS II-III). These findings suggest that methods using sensors on
the shanks and thighs might be preferable for reliable STP estimation in children with CP; and one possible explanation could be that the movement of the proximal parts of the lower limbs are less affected by the pathology. However, when choosing the best set-up for STP computation, other factors such as acceptance by the patients, feasibility and computation of complementary parameters (foot clearance and foot/floor angle for ‘Feet’ method versus the knee angle for ‘ShTh’ method) have to be considered carefully. Finally, our results were not as good as in [3] possibly due to the higher level of disability in our CP population and also the use of a different reference system.

Effect of rounded bottom profile shoes on foot clearance in children with stiff knee gait.

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Introduction: Stiff knee gait (SKG) presents in up to 80% of children with cerebral palsy (CP), it is characterized by limited knee flexion in the swing phase which consequently affects clearance of the swing limb’s foot [1]. Many studies found that rocker shoes enhance toe clearance in young and older adults. However, its effects on toe clearance during the swing phase in children with SKG are unknown.

Research Question: Hence, the aim of the study was to investigate the effects of rocker profile shoes on foot clearance, gait kinematics, and kinetics in cerebral palsied children with SKG.

Methods: Eight ambulant spastic CP children (mean age (SD) 11(2.5) years) with SKG pattern according to the literature [2], participated in a gait assessment using a Vicon system. Two nearly identical pairs of shoes were used for each child. The standard pair was a commercially available shoe with a flat sole and was used for baseline measurements. The intervention shoe was the same model but its sole was modified to have a rocker profile. The two pairs were similar in general fit, but different material was used for the creation of the rocker. The two pairs were differ in their sole geometry, mass, stiffness and corresponding toe height at the tip of the shoe (2 cm for the standard shoe versus 4 cm for the rocker shoe), due to rocker angles of 10° and 20° for standard and rocker shoe respectively. Minimum toe clearance (MTC), knee and ankle kinematic and kinetic data were measured for each child during walking in standard baseline shoes and modified rocker profile shoes. Subsequently a paired t-test was used to determine the effect of shoe type on gait parameters. Hence, subjects each served as their own control.

Results: The rocker shoes showed higher MTC about 18% compared to the standard shoes, however, the result was not significant at the 0.05 level. No significant differences were found between rocker shoes and standard shoes in other kinematic and kinetic data.

Discussion: These findings did not support the hypothesis that rocker shoes may increase toe clearance among children with SKG, many reasons attributed to these results: Children with SKG have limited hip, knee and ankle motion due to their impairments (e.g. spasticity, weakness, abnormal muscle co-contraction) resulting in difficulty in controlling forward progression and minimize mechanical advantage of the rocker apex to propel the foot. The selected shoes were dressy slippers, with no dorsal fixation. Wearing shoes without securing the heels allows the heel to move easily out of the shoe during pre-swing time. Moreover, The 30% increase in weight for the rocker shoe design could hence have been another limiting factor, given the weak muscles of those children, which may have had a negative effect on their foot clearance. Another limitation of this study is related to using new footwear without considerable training period for motor re-learning to develop new motor control strategies. Finally, this study reports on data obtained from a group of eight children, and the small sample size may be contributing to non-significant findings. Future work needs to address the above outlined limitations in the study design to further substantiate these findings.
An open database of synchronized, high precision 3D motion capture data for human gait analysis research and development

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Norwegian University of Science and Technology, Trondheim, Norway

Introduction: The number of recordings of human gait done by 3D motion capture (MOCAP) systems is increasing every day. Despite this, few open databases of time series of multi-view video images are available [1]. The number of motion and gait capturing systems is also increasing, both with respect to passive video-based systems and active body-worn sensors. In addition, systems are becoming more portable and easy to use, and the sampling of data is done not only in a lab, but also in daily life. Typically, each institution has its own system for capturing, storing and analysing data, often restricting possibilities to compare and exchange these data. To help organizing and enhancing data assimilation and testing out new systems and algorithms, a framework for a simple, expandable web-based database has been developed and filled with a first set of example data.

Research Question: How can a database containing motion capture data be constructed and organized to support research and development of gait analysis?

Methods: In the development of a user-friendly database system with easy data input and searching, a relational database with a web-interface has been implemented (see Figure below). The web interface makes the data accessible from all desktop platforms, requiring only a web browser. To help organize the data, time series of raw data can also be stored directly in the database during capture. Data quality control is implemented to ensure the data meets required standards. A first example data set has been collected at the NTNU Visualization Lab, measuring 14 x 7.5 m, with blue walls and floor to support foreground extraction and segmentation of human motion. The video cameras used are visual light cameras, allowing using the images both for testing marker-based and non-marker-based gait analysis algorithms. Cameras are calibrated, with an accuracy of 3D marker positions of +- 1 mm. All intrinsic and extrinsic calibration parameters for all cameras are available.

Results: A first version of the database system is available for testing with example data (multi-view synchronized images) from the proprietary camera system at the NTNU Lab. The functionalities of the web-interface can be adjusted and expanded to meet different user requirements. Currently, the database consists of gait data from 20 healthy adults (aged 16-70 yrs), captured by 16 synchronized, digital video cameras. Subjects are wearing passive reflective markers, positioned according to the CMU guide [2]. Corresponding time series of marker 3D coordinates are given for most of the video sequences. The system is free to use, and can be installed anywhere. The data is openly available for research purposes.

Discussion: Future work includes the possibility of input data from other MOCAP systems and new sensor data, e.g. force/pressure sensor mats for gait analysis and wearable sensors, e.g. inertial measurement units (IMU). Furthermore, possible collaborations with other movement capture laboratories will be explored, as well as expanding the database functionality.

Comparison of Selected Biomechanical Parameters in Forward and Backward Gait in Healthy Young Subjects

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Medical University of Warsaw, Warsaw, Poland

**Introduction**: Backward gait is a component of rehabilitation programmes serving to re-educate gait, activate and strengthen muscles and improve balance. It is still not clear what are the differences between forward and backward gait in gait parameters such as limb loading, muscle activation or duration of each gait phase.

**Research Question**: Are there relevant differences in parameters between forward and backward gait in healthy young subjects?

**Methods**: 41 healthy people aged 19-34 years (average age: 24 years) were enrolled. Before a walking test, each subject was fitted with accelerometers and EMG electrodes placed at locations for muscles and in-shoe sensors in his shoe as recommended by SENIAM. After calibration, the subject was instructed to walk a 10 m walkway forward (FW) and backward (BW). The third attempt was measured. The F-Scan® in-shoe plantar pressure analysis system was used to evaluate the centre of gravity and foot pressure. The activity of the gluteus maximus (GMax), semitendinosus (St), gastrocnemius medialis (GM), gluteus medius (GMed), rectus femoris (RF) and tibialis anterior (TA) muscles was recorded using surface electromyography (Delsys Trigno). The magnitude of muscle activation was analysed using an RMS filter and recorded as mean values. The resulting data were analysed in Statistica 13.0 PL with descriptive statistics (median, quartiles, range) and Wilcoxon’s matched pairs test. The level of statistical significance was set at \( p < 0.05 \).

**Results**: The average duration of the backward gait cycle was longer than in forward gait and the difference was statistically significant. There were lower pressure forces during the stance phase in BW than in FW. Significant differences in average pressure in the foot were also noted (Fig.1). There was a significantly lower activity of GMax, St, GM and TA in the swing phase in BW compared with FW. In the stance phase, GMed was significantly more active in BW and GM was less active in BW than in FW.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Median</th>
<th>Min</th>
<th>Max</th>
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<th>Upper Quartile</th>
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<tbody>
<tr>
<td>BW_Gait_Cycle_Time</td>
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<td>0.87</td>
<td>1.46</td>
<td>1.07</td>
<td>1.22</td>
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<tr>
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<td>0.71</td>
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<tr>
<td>FW_PTI (Mpa*s)</td>
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<td>0.02</td>
<td>0.21</td>
<td>0.05</td>
<td>0.10</td>
</tr>
<tr>
<td>BW_PTI (Mpa*s)</td>
<td>0.07</td>
<td>0.03</td>
<td>0.18</td>
<td>0.06</td>
<td>0.09</td>
</tr>
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</table>

**Discussion**: Our analysis showed statistically significant differences in gait cycle duration as in the study by Lee et al [1]. Analysis of pressure showed significantly lower foot pressure and peak pressure in BW. Similar results were obtained by Lee et al. and Soda et al. [1], [2]. This is also consistent with other authors reporting the usefulness of backward gait [3]. Reduced load can be crucial in patients after knee injuries. The use of backward gait in rehabilitation programmes may accelerate treatment of these patients. Further research is necessary involving a larger study group of individuals at different ages and also recordings of treadmill walking.
Coordination Variability in walking in different high of high-heel shoes in youth female

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Introduction:
Coordination in human movement is necessary to organize the complex and redundant degrees of freedom of the musculoskeletal system [1]. In recent times, young women have preferred to wear high-heeled rather than low-heeled shoes to make them look longer or slimmer and more fashionable. Surveys on shoe use show that between 39% and 69% of women wear high-heeled shoes on a daily basis [2–4]. High-heeled shoes are associated with instability, leading to injuries such as fracture and ankle sprain. High-heeled shoes increase the difficulty of maintaining balance and thus the risk of falling [5–7].

Measures of coordination variability give insight into stability, risk of falls, injury status, pathology, or aging [8].

Research Question:
What is the relationship between coordination and high of high heel shoes?

Methods:
Kinematic data were captured at 200 Hz using an 5-camera motion capture system (S Infrared, Vicon camera, Oxford metrics, Oxford, UK) as participants walked at preferred speeds on the ground. Five successful trials, for each condition were obtained. The order of the test conditions was randomized.

Results:
There was a significant main effect of activity on coordination variability for the thigh sagittal vs. shank sagittal and thigh sagittal vs. shank transverse couples. Differences in coordination variability across all phases of the gait cycle in thigh sagittal vs. shank sagittal and during mid stance in thigh sagittal vs. shank transverse couples were significant by certain test.

Discussion:
The finding of differences in coordination variability between different high of heel is somewhat unsurprising. Walking require different joint kinematics and kinetics. The coordination variability values from the current study add data to the literature to which injured, pathologic, or other special populations can be compared.

References:


Dynamic plantar pressure among intellectual disability and normal children during gait

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Introduction: Plantar pressure distribution in children with variety of neuromuscular disorders has been studied [1]. But less attention has been paid to the gait of intellectual disability children related to plantar pressure patterns. The aim of this study was to compare the peak plantar pressure between intellectual disability and normal student during the stance phase of walking.

Research Question: How does intellectual disability affect plantar pressure characteristics?

Methods: Peak plantar pressure of ten anatomical zones in 14 children with intellectual disability (10.9 ± 1.3 years) and 14 matched normal (10.3 ± 0.74 years) were recorded during stance phase of gait using a Foot scan Device [2]. Data were analysed using independent t-test (p<0.05).

Results: The mean peak pressure in intellectual disability group was higher in all 10 plantar zones compared to normal group. The most increases of peak pressure were observed under the heel medial and 3rd metatarsal head for intellectual disability group. While there was increased plantar pressure under M2-4 and heel medial zones for normal group (Fig. 1).

Discussion: Children with intellectual disability had higher peak plantar pressure than normal group. It seems focusing on plantar pressure variables during gait are required in designing an activity program for intellectual disability individuals.

Effect Of Side Running On The Foot Posture Of The Regional Assistant Football Referees

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Marmara University, Health Science Faculty, Physiotherapy and Rehabilitation Department, Istanbul, Turkey

Introduction: It is advised that especially the assistant football referees should follow the positions with the side running and run on the forefoot during the side running. When the literature was searched, it is seen that referees are examined by frequency or type of injury or complaints of musculoskeletal system by questionnaire studies, but there wasn’t any study which examine the effect of the side running made by the assistant football referees on the foot posture (1, 2, 3).

Research Question: Does the running on the forefoot during the side running made by football assistant referees selected for regional competitions effect on the distribution of pedobarographic parameters?

Methods: 30 participants were recruited to the study. Referee group consisted of 15 football assistant referee (18-24 years old, mean age: 21±1.9). In the control group, 15 healthy male volunteers with same age group (19-24 years old, mean age: 21.53±0.8) who did not perform professional sports were included. Pedobarographic analysis of each patient was performed by EMED pedobarography device (Novel, Munich, Germany). The subjects were asked to walk barefoot 5 times over the pedobarography device. Each foot were subdivided into 3 zone; hindfoot, midfoot and forefoot. Maximum force (normalized to BW) and peak pressure were evaluated. Tests of statistical significance was performed using a Mann Withney U test to determine whether differences were present between the 2 groups.

Results: Mean refereeing duration of the football assistant referees recruited the study was 20.9±8.6 months (13 months – 3.3 years). Although there was difference between the referee group and the control group on maximum force and peak pressure, any significant differences weren’t found (p>0.05) (Table 1).

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Z</th>
<th>Asymp. Sig.</th>
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<tbody>
<tr>
<td><strong>Maximum Force (% BW)</strong> – Right Foot</td>
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</tr>
<tr>
<td>Forefoot</td>
<td>84.41</td>
<td>7.55</td>
<td>65.5</td>
<td>97.8</td>
<td>-0.14</td>
<td>0.88</td>
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<tr>
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<td>21.33</td>
<td>9.46</td>
<td>6.8</td>
<td>56.2</td>
<td>-1.38</td>
<td>0.16</td>
</tr>
<tr>
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<td>68.22</td>
<td>8.20</td>
<td>43.2</td>
<td>82.1</td>
<td>-0.31</td>
<td>0.72</td>
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<td><strong>Maximum Force (% BW)</strong> – Left Foot</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Forefoot</td>
<td>86.71</td>
<td>8.01</td>
<td>67.3</td>
<td>100.1</td>
<td>-0.80</td>
<td>0.41</td>
</tr>
<tr>
<td>Midfoot</td>
<td>20.87</td>
<td>8.73</td>
<td>9</td>
<td>55.2</td>
<td>-1.03</td>
<td>0.29</td>
</tr>
<tr>
<td>Hindfoot</td>
<td>67.96</td>
<td>8.46</td>
<td>48.5</td>
<td>81.1</td>
<td>-0.78</td>
<td>0.43</td>
</tr>
<tr>
<td><strong>Peak Pressure (kPa)</strong> – Right Foot</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forefoot</td>
<td>381.8</td>
<td>115.79</td>
<td>235</td>
<td>700</td>
<td>-0.60</td>
<td>0.54</td>
</tr>
<tr>
<td>Midfoot</td>
<td>144.5</td>
<td>34.47</td>
<td>100</td>
<td>230</td>
<td>-0.08</td>
<td>0.93</td>
</tr>
<tr>
<td>Hindfoot</td>
<td>320.6</td>
<td>81.85</td>
<td>155</td>
<td>605</td>
<td>-1.88</td>
<td>0.05</td>
</tr>
<tr>
<td><strong>Peak Pressure (kPa)</strong> – Left Foot</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forefoot</td>
<td>380.3</td>
<td>126.75</td>
<td>190</td>
<td>760</td>
<td>-0.41</td>
<td>0.67</td>
</tr>
<tr>
<td>Midfoot</td>
<td>143.8</td>
<td>36.59</td>
<td>100</td>
<td>240</td>
<td>-0.68</td>
<td>0.49</td>
</tr>
<tr>
<td>Hindfoot</td>
<td>329.6</td>
<td>92.63</td>
<td>185</td>
<td>630</td>
<td>-0.78</td>
<td>0.43</td>
</tr>
</tbody>
</table>

Discussion: It was thought that the football assistant referees recruited the study may not have affected their foot pedobarographic parameters because of the short refereeing duration. Also, it
was thought that the study should be repeated with subjects who have refereed for a longer period of time.

Repeatability of a 3D multi-segment foot model during climbing and descending stairs.

Letícia Borges1, Fabiano Politti1, Silvio Garbelotti2, André Bley1, Cintia Ferreira1, Nayra Rabelo1, João Correa1, Paulo Lucareli1

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Introduction: Given the importance of the feet a multisegment model is needed that represents the maximum its complexity and its kinematic behavior in functional activities. The aim of this study is to evaluate the repeatability of the OFM model, during intra and inter-session and intra and inter-examiner, during climbing and descending stairs.

Research question: The OFM (Oxford Foot Model) kinematic model is reproducible during climbing and descending stairs?

Methods: Ten healthy adults, aged between 18 and 30 years, participated in this study. The markers were bilaterally attached to the lower limbs according to the OFM model for identification by the processing software. The volunteers were instructed to climbing and descending stairs with the same limb to be collected bilaterally, repeatedly, three times. Vicon® system (Vicon Motion System Ltd.) and Vicon Nexus 2.5 were used for data collecting and processing the data using OFM 2.0 model.

Results: No significant variations were identified intra-trials, inter-session and inter-days between the examiners, and between trials and sessions. The range of motion (ROM) and standard error of measurement (SEM) of all data are represented in the figure 1.
Discussion: The present study confirmed the repeatability of the OFM model during functional activities, climbing and descending stairs, in terms of the intra and inter-session and intra and inter-examiner comparisons. Although repeatability of the OFM was not found during climbing and descending stairs, it is possible to make an analogy with recent study by Lucareli et al.[1] and others in walking, where the repeatability of the OFM was evaluated with excelente repeatability. Therefore, the present study reinforce the use of the OFM, favoring in its clinical applications, mainly in the functional tasks.

Relation between navicular mobility and multi-segment foot kinematics during walking

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Introduction: Having its roots in the domain of clinical evaluation of the foot, navicular mobility in terms of cranial-caudal (NCC) and medio-lateral (NML) displacement of the navicular tuberosity is thought to be a representative measure of foot pronation [1, 2]. These parameters can relatively easy be assessed in practice compared to multi-segment foot kinematics, whose measurement is more complex and time-consuming and which require dedicated motion capture infrastructure. Up to date, the evidence if and how NCC and NML are systematically associated to multi-segment foot kinematics is poor.

Research Question: How is navicular mobility, in terms of NCC and NML, related to multi-segment foot kinematics during walking?

Methods: Navicular mobility and multi-segment foot kinematics were simultaneously assessed during walking with a recently developed 4-marker foot model [3] and the Oxford Foot Model [4], respectively. The cross-sectional study included 21 healthy individuals (14 males, 7 females) with asymptomatic feet. The participants walked barefoot at self-selected pace and between 6 and 15 trials of the right foot were averaged to retrieve representative stance phase kinematics. Relationships between navicular displacement and forefoot to hindfoot (FFtoHF) and hindfoot to tibia (HFtoTBA) angles were explored graphically by displacement-angle plots and analytically by median, maximum and minimum of cross-correlations at zero phase shift (Xc).

Results:

Discussion: In most of the participants, a caudal navicular drop was related to medial navicular drift but the dispersion towards a positive Xc does not allow to classify this relation as systematic. NCC was systematically related to FFtoHF and HFtoTBA dorsi-/plantarflexion and FFtoHF add-/abduction while it showed only poor relation to FFtoHF pro-/supination, HFtoTBA int./ext. rotation and HFtoTBA in-/eversion. NML showed systematic relation to FFtoHF add-/abduction, FFtoHF supination/pronation and HFtoTBA in-/eversion while poor relation was found to FFtoHF and HFtoTBA dorsi-/plantarflexion and HFtoTBA int./ext. rotation. NCC and NML showed in general a systematic relation to FFtoHF add-/abduction but a poor relation to HFtoTBA int./ext. rotation. Primary sagittal plane angles seem to be reflected in NCC while primarily frontal plane angles seem to be reflected in NML. NCC can be considered to characterize medial longitudinal arch function while the functionality of the pronation-supination mechanism can be evaluated by NML. Requiring only four markers per foot NCC and NML can be efficiently measured during dynamic
tasks. NCC and NML seem to represent different characteristics of foot function and should therefore be evaluated separately.

How does walking with looking down influence foot pressure distribution?

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Introduction: Different impairments like neurological diseases or balance disorders culminate in abnormal body posture and walking pattern (1). These patients may exhibit a posture with the head and shoulders bent forward during walking. There is no study, as we aware of, examining the effects of looking down gait that may change gait parameters and foot pressure in literature. Additionally, during computerized or video based gait analysis, it is ignored whether the patients are looking ahead or forward. This study provides a reference for future studies, which will consider different head position during gait.

Research Question: Therefore, the aim of the study was to investigate the effects of looking down gait on foot pressure behaviour in different speeds.

Methods: Seventeen healthy participants (Av. age: 21.6±1.18, Weight: 66.2±11.1 kg, Height: 168±10.9cm) were included in the study. The foot pressure was analyzed in 2 different conditions: 1- Looking forward (LF) 2- Looking down (LD) while participants were walking in three different cadences (self-selected, 70 bpm (slow walking), 110 bpm (fast walking)) by using metronome (Figure 1). To determinate the effects, 6 foot pressure parameters (first and second peak pressures (P1, P2) (N/cm²), time difference between of these pressures (T2-T1) (sec) maximum peak pressure (Pmax) (N/cm²), impulse of pressure applied to the corresponding foot (area under the pressure-time curve) (A) and total stance time (Ts) (sec)) were compared. The Mat Scan system (Tekscan Inc. Mass. USA) was used to analyze foot pressure. Paired t-test was used for the statistical comparison (p<0.05).

Results: In self-selected speed, P1 (from 72.25±16.78 to 69.62±15.36), P2 (from 69.82±14.56 to 67.76±14.09), Pmax (from 74.22±16.44 to 71.10±15.24) and A (from 38.31±8.87 to 37.53±8.74) decreased, while T2-T1 (from 0.32±0.07 to 0.35±0.05) parameter increased (p<0.05). In fast walking, only A (from 35.47±8.08 to 37.53±8.74) significantly increased. During slow walking T2-T1 (from 0.36±0.13 to 0.41±0.10) and Ts (from 1.00±0.06 to 1.01±0.06) increased, also P2 (from 66.19±16.63 to 64.88±14.18) and Pmax (from 67.67±16.32 to 66.93±14.63) decreased (p<0.05).

Discussion: This study demonstrated that, the foot pressure behaviour altered during self-selected walking by decreasing the foot pressure in stance and increasing stance duration, during fast walking by decreasing only the area, and during slow waking by decreasing peak pressure in late stance. The peak pressure in terminal stance corresponding with push off and, looking down may reduce plantar flexion moment during push-off because of shifted centre of mass by forwarded head. The looking down may slow the gait and reduce the peak pressures and increases the stance duration. Predictably, impulse of pressure applied during stance increased.

Figure 1: Illustration of look forward (a) and look down (b) gait
during fast walking, although, during slow walking, decreasing peak pressures in stance and increases stance duration stabilities the area (impulse) in pressure-time curve (2). 3D gait analysis should be utilized in order to see the relationships between foot pressure alterations and gait parameters

References:

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Increased Femoral anteversion related biomechanical abnormalities: Hypermobility, foot posture and pressure

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Introduction: Recent studies stated that foot pronation posture causes tibial and femoral internal rotation in static erect condition and is related with common musculoskeletal pain problems as well as anterior knee pain and low back pain [1,2]. There is no consensus about Increased Femoral Anteversion (IFA) and foot posture alterations.

Research Question: Defining the IFA related foot posture alterations during standing and walking conditions and investigating the correlation between hypermobility, IFA and IFA related foot posture parameters for neurologically intact individuals.

Methods: Biomechanic alterations of seventy six subjects (age:8.3±3.1 y) with IFA who have more than 65° (72.1±6.0°) hip internal rotation and less than 20° external rotation, trochanteric prominence angle test (TPAT): 45.54±8.5°, and 50 subjects (age: 9.97±3.1°, hip internal rotation 43.26±12.13°, TPAT: 23.68±12.27°) for control group were participated in this study. In which, 49 participants with IFA (age: 8.88±3.01) and 28 healthy peers (age: 10.19±2.9) were analysed by Matscan (Tekscan Inc. Mass. USA) to analyse peak plantar pressure of foot during standing (static) and walking (dynamic). The foot pressure index analysis was evaluated by calculation of five divided areas (MMF [Medial Midfoot] + MFF [Medial Forefoot]) – (LMF [Lateral Midfoot] + LFF [Lateral Forefoot])/ (MMF + MFF + LFF + LMF) as described in literature (Fig.1a)[3]. Foot posture was evaluation by FPI-6 index (Fig. 1b,c,d)[4]. Hypermobility score was determined according to Beighton test [5]. Student t-test and spearman correlation was used for statistics. The moderate relationship was interpreted as r=0.30-0.50, and strong relationship was interpreted as r≥0.50 by using Cohen guidelines [6].

Results: Hip internal rotation (p<0.001), TPAT (p<0.001), Beighton test (p=0.03), FPI-6 score (p<0.01), and MMF (0.02) values were significantly small in control group than IFA group. Although FPI-6 score has no relationship between hip internal rotation and TPAT, there is a moderate-level correlation with Beighton test (r=0.34). It was also found that Beighton test has a weak correlation with static foot pressure of MFF (r=-0.26) and LFF (r=-0.26) regions. TPAT moderately correlated with dynamic foot pressure of LMF (r=0.35) and MFF (r=-0.25).

Discussion: It was stated in recent studies that foot pronation posture causes increased hip rotation (2). In our study, IFA group is hypermobile and has more pronated foot posture than control group. Nevertheless, it was found that there is no correlation between femoral anteversion and foot pronation posture. Consequently, IFA has no direct effect on foot pronation posture but
hypermobility has a potential to cause foot pronation posture. Although, there is no correlation found between medial region of foot pressure, there is a significant increase in MMF peak pressure in IFA compared to control. Further studies needed to investigate the relationships between gait parameters and dynamic foot pressure and foot posture alterations. **Acknowledge:** This study supported by The scientific and Technological Research Council of Turkey (TÜBİTAK), No:214S049

How Fat Distribution in the Body Affects Foot Plantar Pressure?

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Introduction: Foot health is affected by many factors (age, disorders, obesity, etc.). There are many studies that highlighted the effects of obesity on foot health. Especially, it was emphasized that obesity caused structural and functional foot problems. The increase in percentage of body fat associated with obesity was found to be related to foot functions such as foot peak pressure, total plantar force and total contact area (1,2). However, there is no study examining the effect of body fat distribution on foot plantar pressure.

Research question: How fat distribution in the body affects foot plantar pressure?

Methods: This study included 33 participants (age: 20.0±1.35 years; 19 girls and 14 boys). Average body mass index of participants 21.8±3.81 kg/m² and 70.4% of participants have normal body weight. Participant’s segmental body fat were calculated by bioelectric impedance method using TANITA TBF 300 body composition analyzer (3). Foot plantar pressure were calculated per foot by using Emed-a 50/D pedobarographic system. This device controls the operation of all foot movements from toes to finger. At the same time, the results of maximum force (N) peak pressure (kPa), contact time (p), and contact area (cm²) are detected by this device (4). Relationship between percentage of body fat and foot plantar pressure were analyzed using Spearman correlation.

Results: The parameters that determine a correlation are shown in table 1. There is no correlation between peak pressure, contact time and BMR, segmental fat analyzes.

Table 1

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Significance</th>
<th>Basal Metabolic Rate</th>
<th>Right leg Fat (%)</th>
<th>Left leg Fat (%)</th>
<th>Right Arm Fat (%)</th>
<th>Left Arm Fat (%)</th>
<th>Trunk Fat (%)</th>
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<tbody>
<tr>
<td>LMF total</td>
<td>r</td>
<td>.952*</td>
<td>-.236</td>
<td>-.209</td>
<td>.028</td>
<td>.016</td>
<td>.473*</td>
</tr>
<tr>
<td></td>
<td>p-value</td>
<td>.000</td>
<td>.235</td>
<td>.297</td>
<td>.888</td>
<td>.937</td>
<td>.013</td>
</tr>
<tr>
<td>LCA total</td>
<td>r</td>
<td>.602*</td>
<td>-.434*</td>
<td>-.452*</td>
<td>-.124</td>
<td>-.142</td>
<td>.187</td>
</tr>
<tr>
<td></td>
<td>p-value</td>
<td>.001</td>
<td>.024</td>
<td>.018</td>
<td>.538</td>
<td>.481</td>
<td>.349</td>
</tr>
<tr>
<td>RMF total</td>
<td>r</td>
<td>.954*</td>
<td>-.242</td>
<td>-.216</td>
<td>.014</td>
<td>.002</td>
<td>.446*</td>
</tr>
<tr>
<td></td>
<td>p-value</td>
<td>.000</td>
<td>.223</td>
<td>.278</td>
<td>.943</td>
<td>.993</td>
<td>.020</td>
</tr>
<tr>
<td>RCA total</td>
<td>r</td>
<td>.669*</td>
<td>-.523*</td>
<td>-.511*</td>
<td>-.255</td>
<td>-.271</td>
<td>.097</td>
</tr>
<tr>
<td></td>
<td>p-value</td>
<td>.000</td>
<td>.005</td>
<td>.006</td>
<td>.200</td>
<td>.172</td>
<td>.631</td>
</tr>
</tbody>
</table>

LMF: Left Maximum Force, LCA: Left Contact Area, RMF: Right Maximum Force, RCA: Right Contact Area

*p-value<0.05
Discussion: Previous studies emphasized that the increase of the BMI affects the foot functions (1,2). In this study, there is a positive correlation between basal metabolik rate and LMF, LCA, RMF, RCA. It was determined that the maximum force and contact areas of individuals with high basal metabolic rate were high. Additionally, there was relationship between percentage of trunk fat and maximum force of both foot. Although the fat ratio in the legs affected the contact area, there was no effect of percentage of arm’s fat. This is the first study that investigates the relationship between segmental body fat distribution and foot plantar pressure. Because the increased body fat affects foot function and structure, avoidance of trunk fat can be a preventive treatment method for improving balance, posture and many other factors. Further studies should be carried out to interpret that link more accurately by increasing the number of cases.

References


Gait alteration in patients with Idiopathic Normal Pressure Hydrocephalus after cerebral spinal fluid removal

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Introduction: Gait disturbance is one of three cardinal signs of Idiopathic Normal Pressure Hydrocephalus (iNPH) and is considered as the important factor impeding the function in daily living [1]. Due to varied walking disturbances in this patient population, the aim of this study was to determine gait alteration after cerebrospinal fluid removal by spinal tap test in patients with iNPH.

Research question: Which gait parameters are sensitive for determining the alteration of gait after spinal tap test in patients with iNPH?

Materials and methods: Ten patients with iNPH who presented the symptoms according to clinical criteria [2] and ventriculomegaly detecting by magnetic resonance imaging were participated in the study. They were classified into the responders (n = 5) and non-responders (n = 5) to the spinal tap test. Averaged age of the responders and non-responders were 80.8 (7.05) and 79.8 (9.5) years, respectively. The participants were assessed gait at before and after spinal tap test within 24 hours apart. Gait was measured during their self-selected comfortable speed on the force distribution measurement (FDM) platform and processed with the Win FDM software. Response to the intervention obtaining from the patients and their care givers about gait ability after spinal tap test. Gait parameters including the left and right step length (cm), step time (s), foot angle (degree), stance phase (%), swing phase (%), load response (%), pre-swing (%), and single support (%). In addition, total double support (%), stride length (cm), stride time (s), step width (cm), velocity (m/s) were also included to determine performance of overall gait ability.

Results: Step length, stride length, step time, stride time, and gait velocity were consistently improved or deteriorated after spinal tap test in the responders and non-responders, respectively. Other gait parameters, the percentage of stance phase, swing phase, load response, pre-swing, single support, and total double support were inconsistent or did not change. Mean and standard deviation of the different values between pre- and post-tap tests of the responders and non-responders are illustrated below.
Discussion: Similar to previous studies, step length [3] and gait velocity [4, 5] were the sensitive parameters that usually used for identifying the alteration after spinal tap test. In addition, step time and stride time were also found to be the additional sensitive parameters in this study. All patients with iNPH spent longer duration in stance phase (~80% gait cycle) and shorter duration in swing phase (~20% gait cycle) but did not change after tap test. Changing in gait parameters relating with the proportion of time spent during gait cycle may require time for recovery or adjust the gait pattern. However, a greater number of participants is required to obtain more information and generalization.

Conclusion: We suggest that parameters including length and time of step and stride and gait velocity are useful and somewhat sensitive for detecting alteration of gait in patients with iNPH.

Comparison of functional outcome of calcaneal fractures after plate or screw osteosynthesis

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Introduction: In many cases intraarticular calcaneal fractures lead to a substantial functional loss¹. Common surgical treatments are open reduction internal fixation (ORIF) by plate osteosynthesis, or minimally invasive screw fixation. It remains unclear whether the kind of surgical treatment influences dynamic stability of patients’ foot. The aim of this study was to compare the outcome of the foot’s function after osteosynthesis by screw or plate in patients after intraarticular calcaneal fracture.

Research Question: Is there a difference in ankle moments, and scoring in SF-36 and AOFAS, between the two surgical treatment strategies of plate vs. screw fixation in patients after calcaneal fracture?

Methods: As a subgroup of a larger prospective study on rehabilitation of calcaneal fractures, a total of 38 subjects with intraarticular fractures were identified. N=18 of these patients (50±9 yrs; 13♂, 5♀; 8 Sanders III, 10 Sanders II classification) underwent ORIF with plate osteosynthesis, and n=20 (49±13 yrs; 16♂, 4♀; 5 Sanders III, 15 Sanders II classification) underwent minimally invasive fixation by screws. For evaluation of the foot function, a three-dimensional gait analysis (Vicon, Oxford, UK; AMTI, Watertown, USA) was conducted at three and six months post-surgery, in order to identify the maximum values of normalized ankle moment in stance phase. Subjective rating was done by SF-36, clinical-functional rating by AOFAS score. Statistical analysis of differences was done by SPSS (Vers. 19), using Kolmogorov-Smirnov, t- and Mann-Whitney-test (p=0.05).

Results: At three months post-surgery normalized ankle moments were larger in patients with screw fixation compared to patients with plate fixation (screw: 1,05±0,29 Nm/kg, plate: 0,83±0,36 Nm/kg, p=0,037, see fig.). Also AOFAS score demonstrated a better functional outcome after screw fixation (screw: 80±10 credits) compared to plate fixation (plate: 72 ±10 credits, p=0,023). The results of SF-36 did not show any differences, neither for the physical component summary (PCS) nor the mental component summary (MCS). At six months post-surgery only AOFAS showed a small difference between surgical treatments (screw: 82±12 credits, plate: 76±11 credits p=0,048).

Discussion: Our findings imply that the way of surgical treatment after calcaneal fracture influences the functional outcome of the foot, particularly with regard to higher ankle moments after osteosynthesis by screws. Higher ankle moments in stance phase are indicators for better foot stability and weight-bearing ability, as a large dorsiflexor moment in terminal stance requires a strong contraction of mm. gastrocnemius and soleus to stabilize tibia and ankle. As minimally invasive strategies reduce the risk of wound healing disorders and decrease recovery and rehabilitation times by smaller deep tissue dissections², they could be a suitable treatment strategy in osteosynthesis after intraarticular calcaneal fractures. In conclusion, our findings suggest that a minimal invasive approach by screw fixation creates sufficient mechanical stability for successful fracture healing and good functional outcome and thus may be a viable alternative to plate osteosynthesis for the treatment of intraarticular calcaneal fractures.

References:
Biomechanical model of the lower limb for dynamic control of knee rehabilitation parallel robot

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Introduction:

Parallel robots are increasingly being used for rehabilitation of the lower limb due to their simplicity, versatility, robustness, load capacity and low cost. In the last decade, a few rehabilitation parallel robots (RPRs) have been developed, mainly for the ankle [1] and, more recently, for knee rehabilitation [2]. Unlike exoskeletons, RPRs do not exert mechanical actions on the joints, but over the distal end of the limb. For this reason, the control actions monitored from the robot may not coincide with those transmitted to the muscles and ligaments. This, in turns, limits the effectiveness of the exercises as well as the possibility of developing dynamic safety systems [3]. In this paper, we present a hybrid model that estimates joint forces that will be incorporated as dynamic control signals of an RPR for knee rehabilitation.

Research Questions:

How close is the relationship between the actions performed by the end effector of a RPR and those transmitted to joints, muscles, joints and ligaments? Could an integrated model of the RPR-lower limb provide accurate estimates of such forces as the signal for dynamic control of an RPR?

Methods:

In this study, a model that integrates both the dynamic control of a 3 degrees of freedom RPR [2] and the dynamic model of lower limb described in [4] has been used. The dynamic model includes the inertial parameters of the lower limb, the cruciate and collateral ligaments position and the most important muscles controlling lower limb motion. Joint forces are computed from inverse dynamics. Muscle forces are estimated by using an optimisation technique [4]. To evaluate the model, a pilot test was performed by using the robot described in [2]. A seated subject should perform a cyclic knee flexion-extension movement, opposing the movement of the end effector with a force within a predetermined threshold.

Results: Figure 1 shows the relationship between the sum of muscular forces (MEF) estimated as a function of the control force (blue) and of the moment at the knee axis (red). The correlations were R = 0.6161 and 0.996 respectively. Figure 2 shows the anterior-posterior force in the knee as a function of the external moment. This force is directly related to the forces in the cruciate ligaments. Note that the model can detect active muscles and estimate individual muscle activation level according to the total applied moment at the knee joint.
Discussion:

The correlation between the actions measured by the robot control sensors and those transmitted to the joint and muscles is low \((R=0.616)\) which suggests that it could be difficult to perform effective exercises from a control of RPR based directly on sensor forces. The information transformed by a dynamic model is much closer to the forces applied to muscles and ligaments \((R=0.996)\). The model can, therefore, evaluate ligament stress and thus to define safety thresholds. This information could be incorporated as a control signal to improve the safety of RPRs and the effectiveness of rehabilitation exercises at a very low cost.

References:

Introduction: In the past, many positive effects have been reported in the treatment of children and adults with cerebral palsy (CP) with ankle foot orthoses [1]: Energy-efficient gait, increased foot clearance in swing-phase, improved balance and a higher walking speed [2-4]. In clinical practice, orthoses are also used postoperatively after single-event multilevel surgery (SEMLS). Typically, the focus of research is on the outcome after operation. Therefore, the aim of this study is to evaluate how far orthotics contributes to the surgical effects with respect to walking ability and gait pattern.

Research Question: How do orthoses effect spatiotemporal parameters and kinematics after single-event multilevel surgery?

Methods: In 31 patients aged 5-16 years (8 girls and 23 boys) with GMFCS level 1-3, an instrumented 3D gait analysis with and without AFO was carried out one year after SEMLS (U2). 19 children had hinged AFOs with ventral shell, 8 had a Nancy Hilton orthosis (DAFO) with shank adaptation (toe-off) and 4 were supplied with pure DAFOs. The orthoses were adjusted on average to 6 ° dorsal extension and 13 ° plantar flexion. A preoperative standardized 3D gait analysis (U1) and walking ability at least with walking aids were provided. At both times the children were clinically examined and the Gillette Gait Index (GGI) as well as the Gait Profile Score (GPS) [5, 6] were determined. A cohort of 31 healthy children, matched by age and BMI, served as a standard collective. Linear mixed models were used for statistical evaluation.

Results:

<table>
<thead>
<tr>
<th></th>
<th>barefoot</th>
<th>orthoses</th>
<th>barefoot vs. orthoses (significance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>stride length [m]</td>
<td>0,37 ± 0,11</td>
<td>0,48 ± 0,11</td>
<td>&lt; 0,001</td>
</tr>
<tr>
<td>velocity [m/s]</td>
<td>0,67 ± 0,30</td>
<td>0,82 ± 0,28</td>
<td>0,003</td>
</tr>
<tr>
<td>steps width [cm]</td>
<td>10,50 ± 8,28</td>
<td>10,00 ± 7,89</td>
<td>0,804</td>
</tr>
<tr>
<td>cadence [steps/minute]</td>
<td>104,56 ± 26,88</td>
<td>100,49 ± 26,88</td>
<td>0,350</td>
</tr>
<tr>
<td>relation stand-phase to double step length [%]</td>
<td>71,01 ± 0,89</td>
<td>67,64 ± 0,64</td>
<td>0,059</td>
</tr>
<tr>
<td>stride time [s]</td>
<td>0,55 ± 0,17</td>
<td>0,60 ± 0,17</td>
<td>0,334</td>
</tr>
<tr>
<td>GGI</td>
<td>350,81 ± 197,42</td>
<td>283,62 ± 185,22</td>
<td>0,127</td>
</tr>
<tr>
<td>GPS</td>
<td>12,27 ± 3,33</td>
<td>11,69 ± 3,33</td>
<td>0,466</td>
</tr>
</tbody>
</table>

The use of orthoses lead to initial heel contact in stance-phase and lower values in GGI and GPS. Data show improved i.e. reduced pelvic rotation as well as improved hip extension and timing of knee extension during stance. With respect to the kinetic data, a momentum increase could be observed in the ankle joint.

Discussion: In summary, the results of the study show a significant improvement in the stride length and walking speed as well as further kinematic and kinetic parameters. These results are concordant with the literature, even if there is no study of orthoses in the postoperative course [7, 8]. In addition, the tendency of the relation between stand-phase and double step length shows normalization without reaching a level of significance. The interpretation of the gait indices
suggests that an improvement in walking ability occurs, but the gait quality is not affected. This could be due to the heterogeneity of therapeutic targets and orthoses. The aim would then be to carry out a subgroup analysis depending on the surgical method and the type of orthoses.

Learning from experience to improve multilevel surgery planning and to predict post-operative outcome in cerebral palsy

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¹Fondation Ellen Poidatz, Saint Fargeau Ponthierry, France, ²Hopital Universitaire Necker Enfants Malades, Paris, France

Introduction:

Patients with cerebral palsy have as many similarities as differences. If the clinician’s experience is decisive in planning a “tailor-made” single event multilevel surgery, the objectivity of this empiricism is not absolute, and may be affected by multiple non-specific factors.

Research Question:

Is it possible to develop an objective tool for comparing the patient to be operated with those that have already been operated?

Methods:

141 children with PC, operated with at least one clinical gait analysis before and after surgery are included. Spatio-temporal parameters, kinematic angles of both lower limbs (dimensionally reduced in 186 variables by Fourier series) as well as clinical examination data were considered. For each patient, his closest neighbors are searched by a k-nearest neighbor algorithm [1]. Two options are possible: the analytical study of surgeries and postoperative results of the nearest neighbors and the prediction of the probable kinematic outcome of the patient under consideration. The latter is, if possible, calculated by the mean of the postoperative results of the k closest neighbors with a preoperative distance less than X points of “Gait Profile Score” (GPS) [2] and having had surgery equivalent to that planned. The performance of this second option is evaluated by leave-one-out by the calculation of GVS and GPS between predicted and true outcome. The effects of k and X are tested on the matching and prediction performance.

Results:

The combination of k = 20 and X = 10 ° allows postoperative prediction for 25 patients with an average “GPS” prediction error (standard deviation) of 8.3 ° (1.6 °). Concerning anteversion, inclination and pelvic rotation, flexion, abduction and hip rotation, knee flexion, ankle flexion and foot progression the “GVS error” were 5 (3), 4 (1), 8 (3), 7 (3, 4 (2), 10 (4), 10 (5), 8 (4) and 9 (5) degrees.

Discussion:

The system is capable of presenting the surgeries performed and their associated results for all the patients closest to the patient being tested. In cases where the intended surgical strategy has already been performed on similar patients, an estimate of the possible outcome of surgery is generated. This relatively rudimentary system has the advantage of being very robust and places the clinician at the heart of his clinical experience.

References:


Assessment of the effect of rectus femoris transfer by propensity score matching in cerebral palsy.

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Introduction:

The rectus femoris transfer (RFT) as any musculotendinous transfer procedure has the specificity of having only a functional objective. In the context of single event multilevel surgery, it is associated to the surgical program with the aim to improve knee kinematics during swing phase. While many indicators have been introduced to describe knee stiffness and thus help to clarify RFT indication, most of the clinical studies are case series. Only one study with a randomized control group (RCT) [1] was conducted and although it highlights the positive effect of TRF, the relevance of this procedure remains controversial. Our objective in order to evaluate the effect of this gesture is to carry out an observational study with the creation of a control group by Propensity Score Matching (PSM).

Research Question:

Is the RFT efficient at improving stiff knee gait and does it have a prophylactic benefits when the knee is not stiff?

Methods:

151 children with cerebral palsy, operated with at least a clinical gait analysis before and after surgery are studied. The lower limbs (LL) with a Goldberg index [2] quoted “Stiff” or “Borderline” are included. A RFT subgroup is matched to a non-RFT subgroup by PSM [3]. The PSM is based on multiple knee kinematics parameters. The homogeneity of the samples is checked after pairing. The difference of the postoperative results between the two groups is studied on a set of kinematic variables by Student test. A further analysis is carried out on “Non-Stiff” patients to assess the possible prophylactic interest of RFT.

Results:

The two subgroups are each composed of 57 LL. No significant difference between the preoperative variables studied is present after pairing. The non-RFT group exhibited significant postoperative worsening of peak knee flexion in swing phase (non-RFT = 51 ° vs RFT = 57 °). The maximum knee flexion velocity is significantly greater after RFT (non-RFT = 130 °/s vs RFT = 161 °/s). The second evaluation focuses on two groups of 18 LL. No differences were found on postoperative variables between those two Non-Stiff groups.

Discussion:

The PSM approach is not a substitute for an RCT study but has the advantage of being able to be performed when ethical considerations make the randomization of surgical indications questionable. It then ensures a "comparability" of the two groups with regard to the variables used. This study confirms the interest of the RFT to improve some kinematic variables qualifying or even conditioning a good oscillation of the knee. The prophylactic indication of RFT does not seem to be relevant when the knee is Non-Stiff preoperatively. These results corroborate those of previous studies.

References:

Effects of Different Walking Aids on Three-Dimensional Trunk Kinematics of Patients Having Undergone First-Time, Elective Transforaminal Lumbar Interbody Fusion

Andreas Kranzl, Christoph Thalhammer, Lukas Panzenboeck, Eva Scheibenreif, Michael Ogon
Orthopädisches Spital Speising, Vienna, Austria

Introduction:

The objective after surgical lumbar interbody fusion is the rapid retrieval of the patient’s mobility. It generally holds that after surgical lumbar interbody fusion patients should not depend on walking aids. In everyday practice, however, walking aids prove to be useful at least during the first few days post-operatively.

Research Question:

These considerations raise the central question: What effects do different walking aids have on frontal, sagittal and transverse plane trunk kinematics of patients undergoing first-time, elective transforaminal lumbar interbody fusion (TLIF) across one to three motion segments? Crutches (four-point gait), anterior walker and posterior walker as well as using no aids at all were compared.

Methods:

Eligible patients were between 20 and 70 years of age and received first-time, elective TLIF across one to three motion segments. Patients with recent fractures or psychiatric diagnoses and when suffering from neurological disorders associated with impaired motor control were excluded. Recruitment was based on a power analysis for 80% power, with alpha set at 0.0125 and a two-tailed t-test. Patients were instructed on how to use each walking aid preoperatively. On the fifth day post-surgery a three-dimensional motion tracking system was used for gait analysis. The four conditions were randomized. Target parameters measured included time–distance features and trunk movement in the three anatomic planes. Data were subjected to simple analysis of variance with repeated measurements and Bonferroni corrections.

Results:

A consecutive sample of 13 female and 12 male patients (mean age: 59.3 years) was recruited for this study. Gait velocity and cadence were highest when patients used no walking aids and lowest when walking with crutches. The trunk was most upright when no aids were used and most tilted forward with the anterior walker. In the sagittal plane, the posterior walker showed the smallest range of motion (ROM) whereas crutches caused greatest ROM. In the frontal plane, the anterior walker showed the least excursion, followed by the posterior walker. Although these differences were not statistically significant, a significant difference in the ROM in the frontal plane could be found when the two walkers were compared to the other two conditions. In summary, anterior and posterior walkers induced the least trunk movements in all three planes. The four-point gait with two crutches showed the greatest ROM of the trunk in all three planes.

Discussion:

Posterior and anterior walkers can be recommended in the first days following TLIF surgery. Crutches should not be used whenever possible. Slight but non-significant advantages were
found for the posterior walker in comparison with the anterior walker with respect to the ROM of the trunk.
Biomechanical immediate and mid-term (6-week) effects of an ankle foot orthosis in knee osteoarthritis patients

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Universitätsklinikum Münster, Münster, Germany

**Introduction:** Knee osteoarthritis (KOA) is the most common form of arthritis with an estimated lifetime prevalence of 44.7% (1). KOA is the leading cause of pain and limitations in activities of daily living and the chance of developing KOA rises after the age of 45 years. The use of orthotic devices (knee braces, wedged shoes) is a generally accepted conservative therapy for KOA patients (2). One of the new conservative treatments is an ankle-foot-orthosis (AFO), however, studies on the biomechanical effects are limited. A pilot study on 14 healthy patients showed promising results with a reduced external knee adduction moment (KAM) when using an AFO (3). A biomechanical study of AFOs in KOA patients would be needed to further validate the effectiveness of this type of intervention.

**Research Question:** What are the knee unloading effects of an AFO in KOA patients after 6 weeks of use in comparison with the immediate unloading effects?

**Methods:** 28 medial KOA patients (mean±SD age 59±10.7 years, height 1,69±0,1 m, weight 79,3±19,1 kg and BMI 27,3±5,4 kg/m², 17 females), clinically diagnosed according to the ACR Guidelines, were recruited for the study. Patients were asked to wear the AFO as much as possible for a 6-week period. They completed a diary to record the daily wear time. Patients performed a 3D gait analysis pre- and post-intervention in two conditions in a randomized order: control (own shoes), AFO (Agilium Freestep®, Ottobock, Germany). KAM, KAM impulse and knee flexion moment (KFM) were retrieved from frontal and sagittal plane kinematics and kinetics and used as the primary outcomes.

**Results:** Immediate effect: The first peak of the KAM and the KAM impulse were significantly reduced by 40% and 19% (KAM: p < 0,001; KAM impulse: p < 0,001) while using the AFO. The KFM was significantly increased by 48% (p < 0,001).

Mid-term effect after 6 weeks: The first peak of the KAM, KFM and KAM impulse were significantly reduced by 29%, 27% and 17% while using the AFO (KAM: p < 0,001; KFM: p = 0,036; KAM impulse: p = 0,03). There were some changes in the KFM using the AFO (p < 0,001), showing a 30% increase in the extension moment.

<table>
<thead>
<tr>
<th></th>
<th>Immediate effect</th>
<th>Mid-term effect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>AFO</td>
</tr>
<tr>
<td>1peak KAM (Nm/kg)</td>
<td>0.59 (0,20)</td>
<td>0.35 (1,16)</td>
</tr>
<tr>
<td>2peak KAM (Nm/kg)</td>
<td>0.41 (0,14)</td>
<td>0.36 (0,15)</td>
</tr>
<tr>
<td>1peak KFM (Nm/kg)</td>
<td>0.31 (0,25)</td>
<td>0.46 (0,25)</td>
</tr>
<tr>
<td>Min KFM (Nm/kg)</td>
<td>-0,18 (0,19)</td>
<td>-0.12 (0,20)</td>
</tr>
<tr>
<td>KAM impulse (Nm*s/kg)</td>
<td>18,96 (6,52)</td>
<td>15,37 (7,16)</td>
</tr>
</tbody>
</table>

Table 1: Mean (±SD) KAM, KFM and KAM impulse from immediate and mid-term gait analysis.
Discussion: As previous studies showed that KAM, KFM and KAM impulse should be considered to get a complete description of knee loading in KOA patients (4), we focused on and examined those parameters. There were some differences between parameters when we focused on the KFM, showing a lower increase (18% less) in the extension moment after the 6-week period. The AFO significantly reduced the first KAM peak and the KAM impulse in both, immediate and mid-term gait analysis and, therefore, apparently reduced the load on the medial compartment of the knee. However, there was a less pronounced unloading on the knee after the 6-week period, which could be due to the patients getting used to wearing the AFO. Future studies should examine the long-term effect of the AFO (e.g. 6 months to 1 year).

References:


Effect of Botulinum toxin-A treatment on ankle and knee kinematics in spastic CP patients based on combination of treated muscles

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Introduction: Spasticity is a common problem that interferes with gait in cerebral palsy (CP). Botulinum toxin-A (BoNT-A) injection is widely used in the management of spasticity. Conclusions about the effect of BoNT-A treatment are complicated by the heterogeneity in impairments and level of severity in CP. Analysing subgroups of spastic CP (SCP) patients could be helpful to distinguish which patients will benefit most of BoNT-A treatment. In this study we evaluated SCP children walking with increased knee flexion and incomplete foot contact in Midstance (MSt). We investigated whether the gait pattern normalized in subgroups that received medial hamstrings (HM) and/or gastrocnemius (GM) injections, with the aim to improve knee extension and ankle dorsiflexion.

Research Question: Do ankle and knee kinematic features change towards a normal gait pattern after treatment with BoNT-A in GM and/or HM as expected by injected muscles?

Methods: Retrospective analysis was conducted of ambulatory SCP treated with BoNT-A combined with intensive physical therapy and if indicated serial casting, between 2010 and 2015, and with the aim to improve walking ability. All patients were characterised by a gait pattern with excessive knee flexion (≥10°) and incomplete foot contact in MSt (N=86; 54 boys; mean age 9.3 ±3.8y, bilateral involved =74, GMFCS I=15, II =38, III =28, IV=5). This resulted in 167 treated limbs, which were subcategorised by treated muscles into 4 groups; 1) Not treated in GM and HM (N=9); 2) Treated in GM only (N=50); 3) Treated in HM only (N=34); and 4) Treated in both GM and HM (N=74); ignoring other treated muscles for this analysis. Kinematic features were analysed from video recordings to evaluate the expected effect of BoNT-A of GM combined with HM (tibia inclination in loading response and knee angle in MSt, TSt and TSw) and treatment of GM only (ankle angle in MSt and TSt). Joint angles were measured with a digital goniometer [1] before and 6-12 weeks after BoNT-A treatment. Differences in treatment effect on kinematic features were determined with repeated measures ANOVA (p<0.05). When an interaction effect was present, a post hoc One Way ANOVA with Tukey correction (p<0.05) was performed on the pre-post differences.

Results: A significant main effect was found for tibia inclination in loading response, ankle in TSt and knee angle in MSt and TSt (see figure), but not for knee angle in TSw. A significant interaction effect was found for ankle angle in MST when treated in GM alone or GM combined with HM compared to HM only.
**Discussion:** Overall, kinematic features of ankle and knee improved after BoNT-A combined with intensive physiotherapy with or without serial casting. Ankle angle improved only if GM was treated, as expected, in this specific group of SCP patients. Treatment effect in knee angle was not significantly different between subgroups, i.e. treatment of GM, HM or combined showed a similar effect. We hypothesized that the lacking effect of BoNT-A on knee angle in TSw could indicate that besides spasticity, also decreased level of selective motor control and/or loss of push off power contribute to the decreased knee extension in TSw. Subdividing SCP patients in more homogeneous groups, based on gait pattern and injected muscles provides more in depth insight in whether BoNT-A treatment acts as expected in children with SCP.

**References:**


Equinus correction during multilevel surgery in adults with cerebral palsy

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¹Heidelberg University Hospital, Center for Orthopaedic and Trauma, Paediatric Orthopaedics and Foot Surgery, Heidelberg, Germany, ²Orthopaedic Hospital for Children, Behandlungszentrum Aschau GmbH, Aschau, Germany

Introduction: Equinus foot deformity constitutes a common gait disorder in ambulatory adults with bilateral spastic cerebral palsy (BSCP). Tightness of the calf muscles and limited range of motion lead to instability and unphysiological load of adjacent joints during stance phase (1-3). Multiple procedures for the correction of equinus deformity in children with cerebral palsy have been described primarily for fixed equinus (4-5). Surgical treatment for equinus gait in children is successful, if multilevel surgery is done in combination with orthoses and rehabilitation (4). The outcome after intramuscular aponeurotic lengthening in the context of single-event multilevel surgery (SEMLS) in adulthood has not been investigated.

Research Question: Does gastrocnemius-soleus intramuscular aponeurotic recession or Achilles tendon lengthening as part of multilevel surgery improve equinus deformity in adults with BSCP? How is the overall rate of overcorrection (calcaneal gait) or persistent equinus in adults?

Methods: We followed a group of 31 ambulatory adults with BSCP and equinus, who underwent SEMLS including gastrocnemius-soleus intramuscular aponeurotic recession or Achilles tendon lengthening. All patients were analyzed pre- and at least one year (mean follow up period: 1.6 years) postoperatively by clinical examination and three-dimensional instrumented gait analysis.

Results: Clinical examination showed no significant improvement of ankle dorsiflexion (p = 0.5), an unchanged plantar flexion (p = 0.7) with knee extended, but a significant postoperative reduction of spasticity in the calf muscle (p = 0.0001) as measured by clinical examination following the modified Ashworth scale. Significant improvements in kinematic and kinetic parameters of the ankle joint were found postoperatively including mean dorsiflexion in stance and swing (p = 0.0001). The GPS decreased (p = 0.0001) and improved significantly from 15.9 ± 4.6 to 11.4 ± 3.1. Persistence of equinus and calcaneal gait indicating under- and overcorrection at follow-up were found in one patient (3%) respectively.

Discussion: Intramuscular gastrocnemius-soleus intramuscular aponeurotic recession as part of multilevel surgery corrects equinus deformity in adults. In cases with additional midfoot break, foot stabilization surgery is needed to correct lever-arm dysfunction. The increase in muscle length leads to significant improvements of kinetic and kinematic parameters during walking without a loss of muscle strength and push off capacity. The risk of overcorrection after equinus correction in adults with BSCP is relatively low.

References:
Factors associated with long-term improvement after SDR surgery in children with spastic diplegia

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Introduction: Selective dorsal rhizotomy (SDR) is a neurosurgical treatment to reduce spasticity in children with cerebral palsy (CP). Where some children show large improvements on domains of motor function and mobility, others do not [1-3]. Since SDR is a highly invasive and irreversible treatment, it is important to select only those candidates that are most likely to benefit from the procedure.

Research Question: The goal of the present study was to identify factors associated with long-term improvement in overall gait quality, in children who undergo SDR-surgery. In addition to overall gait quality, changes in knee angle at initial contact and midstance were evaluated.

Methods: Data of 37 ambulant children with spastic diplegia (mean age: 7 (2.5-13); GMFCS: I (n=13), II (n=17), III (n=7)) were analyzed before and five years after SDR. Data included gait analysis, with video recordings in the sagittal and frontal plane and EMG. Custom made, open-source software (MoXie Viewer) was used to assess 2D kinematic parameters, including knee angles at initial contact and midstance. Overall gait performance was quantified using the Edinburgh Gait Assessment Scale (EGAS), summed for both legs. Surface EMG of 5 muscles of the most affected leg was analysed to assess muscle synergies, using nonnegative matrix factorization, expressed as variance accounted for by one synergy (VAF). Backward multiple linear regression analysis was performed to identify parameters associated with improvement in EGAS and changes in knee kinematics. Evaluated baseline predictors were: age at SDR, birth weight, etiology based on MRI scan, GMFCS, GMFM, VAF, kinematic parameters and EGAS score. Because of the small sample size, effects of p<0.1 were treated as trend effects.

Results: For most children, EGAS improved after SDR, but there was a large variation between patients (range 5 to -34; negative values indicate improvement). The explained variance for EGAS improvement by the final regression model was $R^2 = .657$ (p<.001). Overall, children with lower GMFCS levels (better functional mobility level) showed greater improvement (see figure). Factors related to improvement in EGAS, were: GMFCS (I: reference group; II(β=5.310; p<.056); III (β=14,454; p<.001), higher EGAS before SDR (β= 2.074; p<.01) and knee flexion at initial contact SDR (β=0.472; p<.001). VAF, age, birth weight and MRI scan did not significantly contribute to the explained variance of EGAS change (p>.1). Similar effects were found for knee kinematics, where lower GMFCS and lower VAF (better selective motor control) before SDR were related to greater improvement in knee extension at initial contact (GMFCS (II: β=-9.9; p<.013; III: β=-20.8; p<.000) and VAF (β=70.241; p=0.09)). The explained variance for improvement in knee angle at IC was $R^2 = 0.399$ (p<.001).
Discussion: Children with better functional mobility level at baseline seem to reach greater improvement in overall gait quality five years after SDR, which is in agreement to previous studies [2,3]. Some caution is needed, since expectations of gait development over time is different between GMFCS levels [4]. Therefore, the present findings do not implicate that SDR failed to achieve the intended treatment goal in children with GMFCS III, but it may guide clinicians to set expectations for long term outcomes after SDR surgery. Although previous studies showed that selective motor control (VAF) is a strong predictor for treatment outcome [5], in our study it was not related to EGAS improvement, but only to improvement in knee angle at initial contact.

Introduction:

Many elderly and patient groups experience varying degrees of mobility impairment. Assistive devices play a crucial role in their lives and impact on their ability to live independently and perform basic tasks of daily living. In Europe, it is estimated that over 51 million people experience a longstanding difficulty with walking [1]. XoSoft is an EU project, funded under the European Union’s Horizon 2020 framework programme, that proposes the development of a modular soft lower-limb exoskeleton to assist frail elderly and patients after stroke and incomplete spinal cord injury with mobility impairments. It aims to be user friendly and comfortable to wear, with a significant impact on the person’s mobility and health, on their independence and quality of life. Being a modular system, it comprises of ankle, knee and hip elements, which can be used individually or combined and used unilaterally or bilaterally.

Research Question:

What are the design requirement of the primary users (PU; frail elderly, patients with stroke or incomplete spinal cord injury) and secondary users (SU; healthcare professionals, (in)formal caregivers, family).

Methods:

The XoSoft concept is being developed via an iterative user centered design (UCD) process, with user requirements driving technical innovations [2]. UCD employs design ethnography and participatory stakeholder involvement as key drivers for the technology development to ensure user needs are at the forefront of XoSoft’s development. A semi-structured interview study was undertaken to assess PU and SU expectations and requirements.

Results:

Fifteen PU and 26 SU were recruited in the Netherlands, Germany, Switzerland and Ireland. Among others, PU expected the system to facilitate better quality walking during longer distances with less effort, provide adaptable support and offer a hands-free solution. Safety with respect to safe ambulation and usage of the device was also a priority. SU felt that user safety (including fall-prevention) was the most important function of a device to assist mobility. The flexibility and the adaptive nature were perceived as positive, allowing the system to be used by many different patients with varying conditions. Furthermore, the possible use outside the laboratory setting was valued. Based on the user requirements, the first prototype was developed and tested in a laboratory setting. This prototype consists of existing technologies and its main purpose is to use it as a test bed for the technologies and a mechanism to ensure the design process remains user centered.

Discussion:
Based on this information an iterative product design methodology was used which re-evaluates and improves the user appropriateness of the system at each stage. Three consecutive versions of XoSoft are identifiable based on the module and subsystem developed. The final version of the product is expected to be fully autonomous as a person would use it (i.e. run on batteries and have an on-board computer). The three concepts will be tested extensively in the lab, and subject to trials in clinical settings and home environments. Next versions compromise advanced textiles and smart materials to create sensing, variable stiffness joints and flexible tactile sensors. The last version will include the full sensing and actuation system.

References:


Comparison of dynamic gait parameters before and after an unloading knee brace intervention (pilot study)

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Introduction: Knee joint is the most common localization of osteoarthritis. Depending on the degree of disability a specific therapy is indicated. One of the conservative treatment possibility is a functional unloading knee brace. This type of knee brace transfers the load away from the affected part of the knee joint by every step [1].

Research Question: How does an unloading knee brace affect the dynamics of gait in patients with knee osteoarthritis?

Methods: The research involved twelve subjects with predominantly unilateral medial knee osteoarthritis grade 2 and 3. Six patients did not accomplished the study. We processed data of six persons (age 68.3 ± 4.4 years, weight 83 ± 15.9 kg, height 170.5 ± 11.7 cm). Two Kistler force plates (type 9286AA, Kistler Instrumente AG, Winterthur, Switzerland) were used to determine ground reaction forces. Subjects underwent three measurements. The first one at the beginning of the research, the second one after three months of bracing and the last one was three months after the brace removal. Six attempts were evaluated in total - three attempts with the knee brace and three attempts without it. Differences within the experimental group were compared by paired Wilcoxon test.

Results: After a single knee brace application the minimum (p = 0.020) and the second maximum (p = 0.035) of vertical reaction force significantly increased on the unaffected limb. After three months of bracing we found greater vertical force in braking phase (p = 0.006) and greater maximal vertical force in braking (p = 0.001) and propulsion phase (p = 0.035) on affected side. After three months of the brace removal we observed a significant elongation in the overall duration of the stance phase of gait (p = 0.001) on the affected limb.

Discussion: The results suggest that using unloading knee brace can influence the dynamics of gait. Short-term effects of unloading brace are reflected in the increasing load of unaffected limb. Schmalz et al. (2010) came into similar result after 4 week knee brace intervention by gonarthrosis. In long-term effect we found out a prolongation of the stance phase at both extremities. The positive effect of the knee brace tend to persist even after the brace removal.

THE EFFECT OF INTERVAL TRAINING ON FATIGUE OF LEG MUSCLES

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Introduction: Fatigue in a muscle takes place as a result of an intensive activity of this muscle and is reflected by certain changes in its electromyogram (EMG) signal in either the time (iEMG) or frequency domains (MPF) [1]. The study of bioelectrical activity of muscle may serve an overall assessment of the muscular system, muscle co-operation and their central control and regulation.

Research Question: The purpose of this study was to determine changes in bioelectrical muscle activity during interval training based on the same intensity of running and different length of distances.

Methods: Four professional male athletes that have an international master class in men's 800m took part in that research. The athletes aged 22±1 were 177±3 cm high and 64±3 kg weight. EMG measurements were recorded during the run on tartan athletic track in the indoor treadmill. The athlete had to run six various distances with a similar speed in the following order: 300 m, 400 m, 600 m, 400 m and 300 m. The speed of each distance was adjusted to 5.5 m/s and was controlled by stopwatch. The rest between each distances was 90 seconds. Bipolar surface EMG recordings were obtained from the rectus femoris (RF) and biceps femoris – long head (BF) of right and left thigh were obtained using self-adhesive pairs of disposable Ag/AgCl surface electrodes. The raw SEMG signal was recorded at the sampling rate of 1000Hz, amplified (differential amplifier, CMRR > 130dB, total gain 1000) with a bandwidth from 20 to 500Hz, analog-to-digital converted (14-bit) using a device ME3000P4 (Mega Electronics, Finland). Power spectral analysis of those signals were performed to calculate MPF on 1024-point (Hamming window processing) by fast Fourier transformation (FFT) technique.

Results: Muscle fatigue was evaluated by the slope of regression line. It characterizes the rate of changes in mean power of EMG signal spectrum (MPF) during the test exercise. The greater the magnitude of the slope, the steeper the line and the greater the rate of change. The data obtained in the study lead to the conclusion that the test exercises caused fatigue in all muscle groups analyzed in the study (see tab. 1).

Table 1: Average value (±SD) of the slope of regression line [Hz/s]

<table>
<thead>
<tr>
<th>Distance [m]</th>
<th>Muscle</th>
<th>Side</th>
<th>300</th>
<th>400</th>
<th>600</th>
<th>400</th>
<th>300</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rectus femoris</td>
<td>Right</td>
<td>0,021</td>
<td>0,029</td>
<td>0,032</td>
<td>0,021</td>
<td>0,051</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Left</td>
<td>±0,01</td>
<td>±0,01</td>
<td>±0,02</td>
<td>±0,01</td>
<td>±0,02</td>
</tr>
<tr>
<td></td>
<td>Biceps femoris</td>
<td>Right</td>
<td>0,015</td>
<td>0,028</td>
<td>0,041</td>
<td>0,071</td>
<td>0,082</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Left</td>
<td>±0,01</td>
<td>±0,01</td>
<td>±0,02</td>
<td>±0,03</td>
<td>±0,03</td>
</tr>
</tbody>
</table>

Discussion: It has been noted by Eldgerton et al. [2], that the RF was a muscle characterized by a typology strongly dominated by type II fibres, what according to Komi [3] among others, made it a fatigable muscle. However BF showed significantly greater intense use than RF during both
uphill and level running. Sloniger et al. in their study [4] proved that BF was one of the most activated muscles during horizontal (76+/-12%) and uphill running (79+/-7%) while RF shows less activation during uphill running (29%). It might make BF a more fatigable muscle (which on the basis of decreased MPF values is consistent with our study) than RF. This fact can be caused by greater composition of fast-twitch fibers, more eccentric work and smaller muscle cross-section in BF compared to RF. Another important aspect of our study is a greater fatigue of the left limb compared in RF and right limb in BF. In our opinion the greater forces and greater concentric work were caused by the curve of the track.

COMPARISON OF THE LOWER LIMB JOINT RANGES OF MOVEMENT AND JOINT MOMENTS BEFORE AND AFTER BOTULINUM TOXIN INJECTION FOR CEREBRAL PALSY PATIENTS

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Introduction:
Intra-muscular botulinum toxin injection is a general way to treat cerebral palsy patients, but the effect of the treatment on patient gait has not been fully investigated. This study aimed to compare the joint parameters, such as the ranges of joint angle, the joint moments at the hip, knee and ankle before and after the botulinum toxin injection.

Research Question:
Are the joint moment and range of motion in the patients with cerebral palsy changed after botulinum toxin injection?

Methods:
Nine males and six females with a mean age of 9 years old with ranged 5-16 years old, mean height of 1.25 m ranged 1.05-1.65 m, mean bodymass 27 kg ranged 17-40 kg, mean body mass index 16 ranged 14-20, were assessed after an average of seven weeks following the treatment. Gait data from fifteen cerebral palsy patients before and after the treatments was collected using Vicon® Motion Capture System and Kistler force platforms. The ranges of joint angle and the joint moments at the lower limb joints before and after the treatments were calculated. The ranges of joint angles were studied in three-dimensional planes and the joint moments were analysed in the sagittal plane [1].

Results:
The joint angles and moments were calculated using the Plug-in-model of Vicon and standard methods [2]. Statistical analysis of the data investigated showed that the magnitudes of the joint moment were significantly reduced by approximately 30% in most of the patients, and the timing of wave patterns of joint moments were significantly shifted by approximately 3% in most of the cases although the shifts were not large in terms of clinical meaning. No statistically significant change was found in the ranges of joint angles.

Discussion:
Botulinum toxin seems to have some role as an adjunct to other treatment modalities in spastic cerebral palsy. In the future, a prospective study with larger number of patients would conclusively demonstrate the efficacy of this treatment.

References:
1. Roy Abraham, the MCh Master thesis with University of Dundee, 2005.
Lower limb muscle fatigue during walking in children with spastic cerebral palsy

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Introduction: Children with cerebral palsy (CP) have reduced strength levels of the lower limb muscles compared to their typically developing (TD) peers [1]. This can cause muscles to fatigue more early during activities of daily life such as walking. In addition, alternative walking patterns are common in children with CP. This can increase required muscle force during gait, further contributing to early muscle fatigue during gait. Though, no research has been conducted to investigate whether muscle fatigue occurs during gait in children with CP, and whether this is different from TD peers.

Research Question: Does lower limb muscle fatigue during normal gait differ between children with CP and TD peers?

Methods: Thirteen children with CP (boys/girls: 4/9; age: mean (SD) = 11y (4y)) and fifteen TD children (boys/girls: 9/6; age: mean (SD) = 10y (2y)) walked 5 minutes over ground at self-paced comfortable walking speed (5MWT). Average walking speed was obtained from the total walking distance. Muscle activity of m. tibialis anterior (TA), m. rectus femoris (RF), m. gastrocnemius medialis (GA), m. soleus (SOL) and m. semitendinosus (ST) was recorded using surface electromyography (EMG) bilaterally. Accelerometers were placed on shoes to identify separate steps. Median frequency (MF) and root mean square (RMS) of the EMG recordings were identified per step, as indicators of muscle fatigue. Changes in MF and RMS as a function of time were obtained from individual linear regression lines. MF and RMS of each individual step were normalized to the intercept of the linear regression line. An independent t-test was used to investigate differences in the slope of the normalized regression lines of MF and RMS between children with CP and TD children.

Results:

Walking speed was slightly slower in children with CP (GMFCS I/II/III: 9/3/1) than in TD children (CP: 1.04m/s; TD:1.13m/s; t=1.979, p=0.059), but not significantly different between the groups. Boxplots of the normalized slopes of RMS and MF are shown in figure 1. The rate of increase in RMS of the GA and SOL muscles was significantly larger in children with CP compared to TD children (figure 1; GA: t=-2.996, p=0.008; SOL: t=-2.412, p=0.025). In addition, the rate of decrease in MF of the GA was significantly larger in children with CP compared to TD peers (figure 1; GA: t=3.061, p=0.008).
Discussion: This is the first study to show more prominent signs of muscle fatigue during gait in the calf muscles of children with mild to moderate severe CP (GMFCS I, II and III) compared to their TD peers, indicated by a larger decline in MF and larger increase in RMS of EMG recordings of the GA and SOL muscles. No differences were observed in thigh muscles. Hence, calf muscles of children with CP seem to fatigue more than those of TD children when they walk at their own comfortable walking speed for five minutes. Muscle fatigue seems to occur more prominently in calf muscles than in thigh muscles of children with CP. This can be explained by earlier findings showing that strength that is exerted during gait is higher (relative to maximal strength) in calf muscles compared to thigh muscles plantar [2,3]. In conclusion, muscle fatigue could cause limited walking capacity of children with CP.


Correlation between an inertial and camera based system for the assessment of temporal parameters of gait in the knee arthroplasty population

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Introduction: The recovery of normal walking plays a crucial role in the early rehabilitation after a knee replacement [1]. The detection of gait events such as Toe-off (TO) and Initial contact (IC) allows the identification of temporal variables, such as the stance and swing phases, in a gait cycle. The detection of TO and IC often requires a laboratory equipped with infra-red cameras and force plates. Besides their cost, the handling of these devices might present itself as a complex task, preventing their use in daily clinical practice. Therefore, new devices have been developed to answer the need for easier and outside-laboratory gait analysis. Inertial measurement units (IMUs) are one of these devices that recently gained popularity [2]. Their use in the assessment of temporal parameters of gait (TPOG) has been studied in many populations [3]. However, more evidence is necessary to support the use of IMUs for the evaluation of TPOG in patients with a knee replacement.

Research Question: To evaluate the correlation between the TPOG derived from IMUs and a camera-based motion capture system in patients with a knee replacement.

Methods: Fifteen knee arthroplasty (age: 64.1 years; height: 1.70m, weight: 91.3kg) subjects were recruited for this study. Exclusion criteria were any comorbidities that may affect gait. Subjects were instructed to walk barefoot at a self-selected speed along a 6-m walk way. Raw gyroscopic data were gathered from shank-mounted IMUs during gait trials. Gait events from gyroscopic data were detected using a custom written algorithm. Simultaneously, marker data were collected using six Optitrack cameras (flex 13, NaturalPoint). A total of 56 complete gait cycles were taken into account for data processing. TO and IC were computed using a coordinate- and marker-based algorithm, respectively [4,5]. The following TPOG were assessed for the operated and non-operated leg: cycle time (CyT), stance time (StT), swing time (SwT). The Intra-class Correlation Coefficients (ICC) between both methods were calculated using a two-way, random, single measure analysis for each TPOG. Additionally, mean difference and root mean square (RMS) difference were calculated between both systems.

Results: High levels of agreement between the IMU and camera-based method were demonstrated for all variables (table 1), both at the prosthesis and healthy side. For the CyT a small proportional bias of 0.006s and -0.0018s was demonstrated for the prosthesis and healthy side respectively. This indicates that the IMU system is able to detect IC events with a very high accuracy. A slightly higher bias was found when evaluating the SwT and StT, however, good to excellent correlations could still be demonstrated.

<table>
<thead>
<tr>
<th>Table 1.</th>
<th>ICC (95% CI)</th>
<th>Mean Camera(s)</th>
<th>Mean IMU(s)</th>
<th>Mean difference(s)</th>
<th>SD (s)</th>
<th>RMS (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CyT op</td>
<td>0.979 (0.952 – 0.991)</td>
<td>1.252</td>
<td>1.269</td>
<td>-0.018</td>
<td>±0.045</td>
<td>0.036</td>
</tr>
<tr>
<td>CyT non-op</td>
<td>0.972 (0.939 – 0.987)</td>
<td>1.252</td>
<td>1.246</td>
<td>0.006</td>
<td>±0.052</td>
<td>0.041</td>
</tr>
<tr>
<td>StT op</td>
<td>0.953 (0.862 – 0.981)</td>
<td>0.748</td>
<td>0.722</td>
<td>0.026</td>
<td>±0.044</td>
<td>0.041</td>
</tr>
<tr>
<td>StT non-op</td>
<td>0.913 (0.517 – 0.972)</td>
<td>0.754</td>
<td>0.713</td>
<td>0.041</td>
<td>±0.044</td>
<td>0.054</td>
</tr>
<tr>
<td>SwT op</td>
<td>0.826 (0.445 – 0.932)</td>
<td>0.504</td>
<td>0.593</td>
<td>-0.034</td>
<td>±0.047</td>
<td>0.049</td>
</tr>
<tr>
<td>SwT non-op</td>
<td>0.917 (0.821 – 0.962)</td>
<td>0.504</td>
<td>0.533</td>
<td>-0.029</td>
<td>±0.049</td>
<td>0.055</td>
</tr>
</tbody>
</table>
Discussion: The good to excellent agreement levels found in this study indicate that IMUs can be used with a high reliability for the assessment of TPOG in the knee arthroplasty population. These findings have a tremendous impact on the clinical evaluation of knee arthroplasty patients as IMUs have many advantages compared to a standard gait analysis system [2]. These small and user-friendly devices can be implemented in settings where the use of a camera based system might not be possible (e.g. in a hospital), which makes the evaluation of patients in more realistic daily situations such as during an outwalk protocol possible. The use of kinematic data as a reference for the detection of TO and IC might be argued upon, and seen as a limitation in this study. However, several studies demonstrated its validity and reliability under several conditions [6].

2D video Frontal Plane Projection Angle and 3D inertial sensor based assessment of Dynamic Knee Valgus. A Comparison

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¹University of Kaiserslautern, Kaiserslautern / Rheinland-Pfalz, Germany, ²Technische Hochschule Mittelhessen, Gießen / Hessen, Germany, ³Sporthochschule Köln, Cologne / Nordrhein Westfalen, Germany

Introduction:

Dynamic knee valgus (DKV) is one of the most discussed issues in recent applied biomechanical research [1]. It is the main parameter when predicting the risk of knee (re-)injuries concerning athletes who are about to return to sport. Recent research has focused on the evaluation of DKV using mobile sensor system suitable for field studies [2]. Therefore in this study two mobile systems, a 2D video analysis and 3D inertial sensor system were compared regarding their correlation in Lower Extremity (LE) kinematics during typical screening tasks of different dynamic.

Research Question:

How does frontal and transversal plane kinematic data delivered from an inertial sensor system correlate with the common Frontal Plane Projection Angle [2] (FPPA) gained from 2D Video analysis during quasi static and dynamic screening tasks?

Methods:

14 young and healthy soccer players (age 16.71 years) of a German Bundesliga club performed bilateral squat (FS) and vertical drop jump (DJ). 3D kinematic data was delivered from 7 inertial sensor measurement units (IMU) fixed to the segments of the LE and Pelvis. FPPA was calculated from 3 retroreflective markers placed on each leg according to Willson et al [2]. Coefficient of determination was calculated to quantify the association between 3D kinematic data and the FPPA.

Results:

Coefficient of determination showed very strong relationship between the inertial kinematic data and FPPA in the FS task. The correlation found for the DJ task was slightly weaker ranging from $r^2=0.367$ to 0.821. Results showed that a medial displacement of the Knee marker (negative FPPA) was strongly associated with Ankle Inversion in both tasks (see Fig.)

Bilateral Squat:  
Drop Jump:
Discussion:

The results indicate that there is a strong relationship between 3D kinematic data from an inertial sensor system and 2D FPPA in relatively static movements. With increasing speed of movement the association between 3D and 2D kinematic seems to decrease due to reasons not yet specified. Further the data suggests that there is an important correlation between Ankle Inversion and medial displacement of the Knee. More studies are needed to clarify the role of Ankle 3D kinematics in Dynamic Knee Valgus.

References:


Using Wearable Inertial Sensors to Track Body Kinematics During Gait

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¹APDM Inc., Portland, OR, USA, ²Portland State University, Portland, OR, USA

Introduction:

The need to characterize human movement has consistently driven researchers to develop improved motion analysis systems. The primary challenge is to design devices and algorithms that can accurately monitor movement regardless of the activity and testing location. Optical motion capture systems have been the gold standard for clinical research focused on tracking human movement [1-2]. However, these systems are costly, cumbersome, may suffer from optical occlusion, and because they require a dedicated motion laboratory with specialists to collect, process and interpret movement data, are not easily integrated into the outpatient clinic. Recently, wearable inertial sensors have been used to overcome these limitations [3-4]. We aim to develop an inertial system to provide joint kinematics similar to those provided by optical motion capture systems, the industry gold standard.

Research Question:

Evaluate the performance of the wearable sensors and the tracking algorithm in monitoring body kinematics.

Methods:

Our system uses 7 wearable inertial measurement units (IMUs) attached to sacrum, lateral surface of the thighs and lower legs, and superior surface of the feet. The IMUs use wireless synchronization, which is critical for measuring joint kinematics and coordination. We developed a tracking algorithm to estimate joint angles during gait. The algorithm tracks 3D orientation of pelvis and lower limbs to estimate joint angles of the hips, knees, and ankle joints. We used an industry standard motion capture system as a reference to evaluate the performance of our inertial tracking algorithm. The validation study was conducted at the Movement Disorders Laboratory at Oregon Health and Science University, which is equipped with a 12-camera motion capture system. We compared the inertial joint angles with those obtained from the reference system in 3 healthy adults.

Results:

With IMUs and reflective markers attached to the body, each subject walked at a comfortable pace for 60 seconds. The inertial and optical data was processed after data collection to calculate the lower limb joint angles. We used the mean absolute error (MAE) to compare the angles from both systems. The MAE for flexion/extension angles of the hip, knee, and ankle was 2.4±0.6, 2.1±0.9, and 1.4±0.2 degrees, respectively. Similarly, MAE for the abduction/adduction angles was 1.5±0.6, 2.7±1.0, and 3.3±1.5 degrees. And finally, MAE for the internal/extension angles was 1.9±0.6, 2.4±1.4, and 3.3±1.7 degrees.

Discussion:

The agreement between our inertial tracking system and the reference system was excellent. These results demonstrate the potential for using wearable sensors in assessment of human movement in the clinic. Unlike motion capture systems, the inertial system is more time efficient and easier to use in the clinic without the need for specialized equipment and personnel. We are currently continuing to collect more validation data from more subjects.

References:


Upper limb co-activation in typically developing children and in children with unilateral cerebral palsy: reliability and sensitivity to the EMG normalization technique.

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Introduction: Muscle co-activation (CA) is the simultaneous electrical activity of agonist and antagonist muscle groups. Excessive muscle CA is a common symptom in populations with cerebral palsy, restricting lower and upper limb movement. For diagnosis purposes, muscle CA is measured in clinical routine using surface electromyography (sEMG). However, there are many different ways of processing the sEMG signals, and of calculating muscle CA. Until today, studies measuring muscle CA cannot compare their results due to the various methodologies and the lack of knowledge about the effect of the sEMG processing and CA calculation method on the clinical results and interpretation. The most commonly used CA indices measure the common activation area (area under the sEMG processed signals) of the agonist and the antagonist muscles during a movement [1], [2]. The CA index following the Falconer method [2] has the added benefit of normalizing this common activation in relation to the total activation of the two antagonist muscles, thus giving a proportion of CA (%). In this study, we chose to address the problem of the reliability and sensitivity to the EMG normalization technique of the muscle CA calculated with the Falconer index. We focused our analysis on upper limb movements in children with unilateral cerebral palsy (UCP).

Research Question: Is muscle co-activation calculated with the Falconer index during upper limb movements reliable for typically developing (TD) children and children with UCP? Is it sensitive to the EMG normalization technique?

Methods: 10 children with UCP and 10 TD children came for two sessions in a motion analysis laboratory. The protocol involved performing 3 maximal voluntary contractions (MVC) for elbow flexion, extension, pronation, and supination. Then, participants had to perform at least 6 consecutive elbow flexion/extension and pronosupination cycles with an imposed frequency of 0.50Hz. Muscle activation was recorded from the sEMG signals of the biceps, brachioradialis, brachialis, triceps, pronator teres and quadratus. sEMG signals were bandpass filtered, rectified, and envelope filtered at 50Hz. Onset and offset of muscle activations were determined using [3]. sEMG signals were normalized using 3 different methods: 1. No normalization; 2. Normalization with the maximal value extracted during the MVC trials; 3. Normalization with the maximal value extracted during the dynamic trials. CA indices were calculated for 10 combinations: the Biceps/Triceps, Brachioradialis/Triceps and Brachialis/Triceps pairs during extension and during flexion, and for the Biceps/Pronator Teres, Biceps/Pronator Quadratus pairs during pronation and during supination. Intra-session and inter-session reliabilities of the CA indices were assessed with the Standard Error of Measurement (SEM). Mixed models were used for statistical analysis.

Results: Preliminary results are for 3 TD children and 1 child with UCP. All 10 CA indices combined, overall intra-session and inter-session SEM were low for TD children (resp. 4.63% and 5.93%) and slightly higher for the child with UCP (resp. 6.20% and 8.51%). Effect of the sEMG normalization on the value of the CA indices was significant for 5 CA indices for the TD children, while for only 1 CA index for the child with UCP. However, differences between groups were similar whatever the used normalization for all 10 CA indices (2 CA indices, biceps/triceps and brachioradialis/triceps CA during extension, were higher in the child with UCP than in the TD children). Intra-session and inter-session SEM were not sensitive to the normalization technique, for neither the TD children nor the child with UCP. Surprisingly, the lower inter-session SEM was obtained without normalization of the sEMG signals for both the TD children (5.45% without normalization; 5.71% with MVC normalization; 6.66% with dynamic normalization) and the child with UCP (resp. 7.60%; 9.59%; 8.35%).
**Discussion:** Muscle CA calculated with the Falconer index is reliable and has a low sensitivity to the sEMG normalization technique. It is therefore likely adequate to use for upper limb analysis in children with CP. In the context of CA analysis, these preliminary results also raise the question of the necessity to normalize sEMG signals?

**References:**


Increased gait variability during 5-minute walking in children with cerebral palsy detected with on the feet placed accelerometers

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NTNU, Trondheim, Norway

Introduction: Children with cerebral palsy (CP) have an early onset of fatigue which has profound negative effect on normal activities of daily living [1]. Whereas increased fatigue has frequently been shown by self-assessment questionnaires, an objective way to easily investigate its effect on an important motor task in daily living, like walking, does not exist for this group. The dynamics and continuous movement of multiple strides during walking could reflect fatigue. The aim of this study was to investigate if on the feet placed accelerometers can be used to detect changes in gait variability during walking at a comfortable walking speed.

Research Question: Will a 5-minute overground walking test reveal detectable changes in gait variability in children with CP when measured with on the feet placed accelerometers?

Methods: 11 children with CP (mean age 10.1 y, Gross Motor Function Classification System, GMFCS, level I-III (5 levels which describe gross motor function)) and 15 typically developing children (TD) (mean age 9.8 y) completed a 5-minute overground walking test in a comfortable speed wearing, on each foot, an accelerometer (Axivity, AX3) that registers acceleration in three dimensions. Differences of time series data were quantified by finding an underlying limit cycle attractor of the initial and final 30s intervals of the test for each foot (Fig. 1). Afterwards, three measures were calculated from the time series and four attractors; δM indicates the average distance between the attractors of the first and last intervals (i.e., differences of two movements), δD describes the deviation of the time series data points from the attractors (i.e., change in movement variation) [2]. Finally, δF is the product of the previous two indexes and an index for change. Outcomes for δF, δM and δD were measured as between group effects (CP and TD) and effect of time (first and last 30s).

Results: The preliminary results show that the attractors differed in children with CP compared with TD children (Fig. 1), and that the δF is significantly different between the two groups (p<0.05). The mean δF for the CP group is 0.130 (SD 0.001), and mean δF for the TD group is 0.005 (SD 0.004).

Discussion: Human walking may be looked upon as a stable system, and when not disturbed it is characterized by stable movement patterns and consistent motor control. The used method seems to be sensitive to reveal changes in gait variability when walking 5-minutes overground in

Fig. 1 Two-dimensional graph which shows acceleration data and the attractor of a subjects left foot at the beginning of a walk test.
a comfortable speed. More studies are required to explore the relationship between fatigue and gait variability.

A hypothesis on human intention for lower limb movement in stance phase and its application to control of exoskeleton

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Introduction: Despite great advances in exoskeleton technology for over five decades, there still remain many challenging issues to overcome Uncanny Valley. One of the critical issues is how to detect human intention for movement. Approaches based on sensory feedback (e.g. electromyogram (EMG) signal, electroencephalography (EEG) signal, interaction force signal, etc.) have been suggested; however these methods lead to high system complexity. Recently a novel approach is proposed [1]. The approach is based on a hypothesis on human intention for lower limb movement and therefore there is no need to feedback sensory information. The hypothesis is that in stance phase human tend to 1) stand upright, 2) maintain statically stable posture, and 3) minimize joint torques. The aim of this study was to verify the hypothesis.

Research Question: Is the hypothesis valid in most of the lower limb movements (e.g. level walking, stair climbing, etc.)?

Methods: As this is a preliminary study, one healthy male subject free from musculoskeletal and neurological disorders was participated in the experiments (age: 35 years; height: 1.76 m; weight: 75.1 kg). The participant underwent a 3D gait analysis (Vicon MX, AMTI force plates) at self-selected speed including level walking and stair climbing. Kinematic data and ground reaction force data was measured to determine human intention torques based on the hypothesis. We compared the human intention torques with joint torques predicted by the inverse dynamic model (IDM).

Results: Comparing human intention torques with joint torques determined by the IDM, we found that human intention torques follow a similar trend of joint torques by the IDM (Fig. 1).

Discussion: Based on our preliminary findings, we confirmed the hypothesis is valid during level walking and stair climbing. Further work is required to verify whether the hypothesis is still valid in a variety of lower limb movements.

This work was supported by Institute for Information & communications Technology Promotion (IITP) grant funded by the Korea government (MSIP) (No.R7520-16-0005, Development of creative technology based on complex 3D printing technology for labor, the elderly and the disabled).

References: [1] Lee et al., Auton Robot 2015;38:211-23
Development of the Dynamical Asymmetry Function for detection of regions of asymmetry

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¹University School of Physical Education in Wroclaw, Wroclaw, Poland, ²Wroclaw Medical University, Wroclaw, Poland

Introduction: Asymmetry index proved to be reliable tool for assessment side deviations in human gait [1]. Unfortunately, the formula proposed by Robinson et al. [2] has some limitations: is a single index, the differences are compared against their average value and is ineffective for small variable values. New formula, based on relative ratio index [3-5] is proposed for creation of so called dynamical asymmetry function (DAF) and tested on an example of able-bodied men and patients 6 weeks after unilateral total hip replacement (uTHR).

Research Question: Whether the developed DAF function is a good tool to localize the regions of asymmetry in the gait cycle.

Methods: 11 healthy able-bodied (normal) men and 12 male patients after uTHR took part in the experiment. Biomechanical assessment involved measurements of spatiotemporal gait variables and the range of motion in main lower extremity joints using BTS Smart-E MA system. We developed a variant of asymmetry index modified for the time dependence [1,5]. This dynamical asymmetry function (DAF) is a function of time and expresses the percentage difference between the right $X_{r}(t)$ & left $X_{l}(t)$ sides relative to its range of motion. The rate of change of DAF (DAF Rate) is the time derivative of the DAF:

$$\text{DAF}(t) = \frac{x_{r}(t) - x_{l}(t)}{\text{Range}(x_{r}(t)) + \text{Range}(x_{l}(t))} \times 100\%$$

$$\text{DAF Rate}(t) = \frac{d}{dt}\text{DAF}(t)$$

Time normalization of the right and left angles was performed numerically by means of decomposition of a time series (trend detection) using the Lagrange interpolation polynomial. The DAF's rate of change (DAF Rate) was calculated numerically adapting the 2nd formula.

Results: The figure below shows example results of DAF and DAF Rate calculations for the knee flex-ext angle in the three cases. Case 1: The highest asymmetry (~3%) found in the normal group corresponded with the maximum flexion at stance & swing. Case 2: The highest asymmetry found in the uTHR group was in the single stance region (~30%) and in the terminal swing (up to -50%). Case 3: The relative percentage difference between uTHR operated limb and healthy limb (normal group) was found to be up to 40% in the region of maximum flexion at stance and up to 80% for the maximum flexion at swing.

Fig. Knee flex-ext angle, DAF function and DAF Rate for: (A) normal, (B) uTHR & (C) normal vs uTHR cases. Note the scale!
**Discussion:** The developed DAF function proved to be a good tool to localize the regions of asymmetry and its positive or negative direction in the gait cycle in able bodied men and patients 6 weeks after uTHR. The DAF and the DAF Rate are functions of time and require right and left variables with equal duration. DAF is especially dedicated to time dependent variables and corresponds well with the index proposed by Nigg [6] for a stance phase. The DAF Rate accurately describes the speed of change of the DAF. For example, the DAF Rate close to 0 indicates regions of stability in the DAF, a positive/negative - points to the rate at which asymmetry increases or decreases. More work is required to evaluate the dynamical asymmetry function and to determine its possible interpretation and usefulness in the assessment of different human activities.

**References:**

Development of hydraulic nozzle system for walking-aid system

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Introduction: The human gait is divided into five to seven stages classified in the flexion and extension of knee joint and ground contact of foot. Each gait phase has a difference in the value of the knee flexion moment supporting weight bearing[1]. The desirable walking-aid system should be able to damp the knee flexion moment during stance phase as well as provide a supplementary extension moment[2]. In this study, we developed a hydraulic nozzle system as passive damping type that can support the bending moment of the knee during both stance and swing phase.

Research Question: 1) Optimal nozzle design to damp a variation of the knee flexion moment in each gait phase, 2) The magnitude of the damping force to be provided at each gait phase, 3) The timings of nozzle control

Methods: The nozzle was designed to correspond with the rapid damping force changes of both stance and swing phase. In order to verify a nozzle controllability, we developed nozzle tester device using flow control valve. The length of hydraulic cylinder (\( l_h \)) is function of \( \psi _k \) (relative knee angle). In order to define \( \psi _k \), we analysed gait data of the able person and amputee with Ottobock genium, and calculated piston displacement during stance and swing phase. Also, based on the gait data, we obtained knee flexion moment and required cylinder damping forces. The nozzle angle was sequentially controlled by DC motor during cyclic gait.

Results: The piston displacement was up to 2.5mm during stance phase. The damping forces were measured at each nozzle angle using instron tester (Table 1). The hydraulic cylinder generated a damping force with 2192N at 60°, which can support the flexion moment of the stance phase. We chose motor sequences considering required cylinder damping forces, and measured the cylinder forces during gait phase. (Table 2 and Fig 1).

Table 1. Stance flexion damping force map according to nozzle angle

<table>
<thead>
<tr>
<th>( F_N ) angle (degree)</th>
<th>0</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
<th>40</th>
<th>45</th>
<th>50</th>
<th>55</th>
<th>60</th>
</tr>
</thead>
</table>

Table 2. Motor sequences (command time)

<table>
<thead>
<tr>
<th>Phase</th>
<th>Test time (ms)</th>
<th>FLX (degree)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial setting</td>
<td>-</td>
<td>45</td>
</tr>
<tr>
<td>Stance</td>
<td>120</td>
<td>53</td>
</tr>
<tr>
<td>Swing</td>
<td>880</td>
<td>20( \rightarrow 35 )</td>
</tr>
<tr>
<td></td>
<td>1200</td>
<td>20</td>
</tr>
</tbody>
</table>

Fig 1. Damping force during cyclic gait
**Discussion:** The hydraulic nozzle system should be able to quickly respond to swing and stance transitions. For this reason, the developed nozzle does not induce a linear pressure change but generates rapid pressure shifts. The nozzle system endured a damping force with 2192N through adjustable nozzle, which is enough to support the knee flexion moment during stance flexion. Hydraulic nozzle system which sequentially controlled by DC motor generated proper damping forces patterns under repetitive piston displacement for normal walking (Fig 1). This work was supported by Institute for Information & communications Technology Promotion(IITP) grant funded by the Korea government(MSIP) (No.R7520-16-0005, Development of creative technology based on complex 3D printing technology for labor, the elderly and the disabled)

How many steps do we need to detect clinically relevant changes in knee and shank angle during walking?

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Introduction: Clinical gait analysis is becoming an integrated part of evaluation of ankle foot orthosis (AFO) prescription. Video analysis is often used to tune AFO shoe combinations to normalize knee and shank kinematics and kinetics. Improvements of >5 degrees in knee angle or shank to vertical angle (SVA) after tuning have been indicated to be clinically meaningful1,2. It can, however, be questioned whether such changes can be observed reliably when video analysis is performed in a standard overground gait lab. Variability in the gait pattern is relatively large in patients and the number of steps that are assessed when patients walk in a traditional gait lab is generally small (3-5 steps). To improve accuracy of measurement we developed an instrumented treadmill that can automatically detect knee angle and SVA in midstance for a large number of steps during a short walking test with minimal processing time for a therapist. In this study we evaluate the relation between the number of steps analysed and the accuracy of knee angle and SVA measurement.

Research Question: What is the effect of number of steps analysed on accuracy and minimal detectable change of knee angle and shank to vertical angle (SVA) at midstance during treadmill walking in children with and without Cerebral Palsy (CP)?

Methods: In this pilot study seven children (4 able-bodied children and 3 children with CP) performed a two-minutes walking trial at self-selected speed on a treadmill (Motekforce Link, Amsterdam, The Netherlands). This treadmill was equipped with a force plate to detect gait cycle events and two sagittal video camera's (30 Hz) to automatically track markers on ankle, knee and hip. Knee angle and SVA at midstance were derived automatically for each step. Standard error of the mean (SDmean), and minimal detectable change (MDC) for the left or most affected leg were calculated for each participant as a function of number of steps analysed using a bootstrap approach.

Results: A minimum of 50 steps was recorded for all participants during the walking test. Allowing for calculation of SDmean over 50 steps and MDC over 25 steps maximally. Left knee angle SDmean decreased from 1.95° for 3 steps to 0.4° for 50 steps, SDmean of left SVA decreased from 1.05° for 3 steps to 0.34° for 50 steps. Left knee angle MDC decreased from 7.5° for 1 step to 1.76° for 25 steps. Left SVA MDC decreased from 5.8° for 1 step to 2.09° for 25 steps.

Discussion: The number of steps analysed has an important effect on the accuracy of knee angle and SVA measurement. MDC decreases ca 65-75% by increasing number of steps from 1 to 25. Approximately 10 steps were required to reach a clinically relevant MDC of 5° for knee angle and accuracy could be improved further with increasing number of steps. We conclude that increasing the number of steps to analyse knee angle and SVA during AFO tuning, using an instrumented treadmill, can increase analysis’ accuracy to clinically relevant levels. Currently more data are collected and analysed to corroborate these findings.
References:


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Introduction: Cerebral palsy (CP) is a neuromotor disability stemming from brain damage during the prenatal, perinatal or postnatal period and is associated with sensory and or motor dysfunctions of the orofacial region, such as dysphagia, dysarthria, drooling and difficulty chewing.1 The masticatory muscles participate in complex physiological actions, such as chewing, swallowing, speech and other movements that depend on a precise balance between force, velocity and amplitude.2

Research Question: Evaluate the reliability of surface electromyography (EMG) of the masseter muscles in patients with cerebral palsy.

Methods: EMG was performed over the masseter muscles in patients with cerebral palsy in the condition the mandible at rest and during maximum clenching effort. The data were analyzed using the root mean square amplitude, mean frequency, median frequency, zero crossings and approximate entropy. Twenty-three adult patients with CP were evaluated at the Oral Special Care Clinic of the Institute of Science and Technology – Campus Sao Jose’ dos Campos/UNESP (Brazil). Only 12 individuals with spastic diparetic CP (8 males and 7 females) met the eligibility criteria. The sample was classified using the Gross Motor Functional Classification Scale (GMFCS). The EMG signals were captured using an eight-channel module (EMG System do Brasil Ltda1) consisting of a conditioner with a band pass filter with cutoff frequencies at 20–500 Hz, an amplifier gain of 1000 and a common mode rejection ratio >120 dB. All data were acquired and processed using a 16-bit analogue-to-digital converter (EMG System do Brasil Ltda1), with a sampling frequency 2 kHz per channel. Active bipolar electrodes with a pre-amplification gain of 20 times were used.

Results: In the within-day evaluations, intraclass correlation coefficients were higher (0.80–0.98) for the all EMG variables during maximum clenching effort. In the resting position, the coefficients revealed good to excellent reliability (0.61–0.95) for root mean square, mean frequency, median frequency and zero crossings and fair to good reliability (0.53–0.74) for approximate entropy. In the between-day evaluations, the coefficients revealed good to excellent reliability (0.60–0.86) for mean frequency, median frequency, zero crossings and approximate entropy. In the resting position, the coefficients revealed poor to fair reliability (0.23–0.57) for all EMG variables studied. The root mean square had the highest standard errors during maximum clenching effort (2.37–5.91) and at rest (1.47–6.86).

Discussion: Mean frequency, median frequency and approximate entropy are the most reliable variables of EMG signals of the masseter muscles during maximum clenching effort in subjects with cerebral palsy. These measures can be used to evaluate the function and behavior of the masticatory muscles in this population following oral rehabilitation and/or surgical oral procedures as well as for the study of muscles physiology. However, the ICCs of the EMG data recorded in the resting position demonstrate poor reliability in the inter-session analysis of the following variables: RMS, MDF, MNF, ZC and ApEn.

References:


Modelling locomotion periods and cadence distribution in daily life: how many days are required?

Abolfazl Soltani1, Hooman Dejnabadi1, Benedikt Fasel1, Anisoara Ionescu1, Cedric Gubelmann2, Pedro Manuel Marques-Vidal2, Peter Vollenweider2, Kamiar Aminian1

1EPFL, Lausanne, Switzerland, 2Department of Internal Medicine of CHUV, Lausanne, Switzerland

Introduction:

Monitoring human daily activity plays an important role in quantifying health status and assisting prevention, diagnosis and prediction of diseases like diabetes, obesity and cardiovascular pathologies [1-2]. For long-term daily activity monitoring based on inertial sensors, the wrist could be considered as the most appropriate sensor location [2-5].

Research Question:

The goal of the study is investigating how many days of monitoring human daily activity are enough to be able to model locomotion periods and cadence distribution of a person.

Methods:

3D acceleration at 40Hz is recorded using a data logger (GENEActiv Original, ActivInsights Ltd, United Kingdom) attached to the wrist. A locomotion detection and cadence estimation algorithm previously validated on 37 subjects, 12 hours free daily activity per person, is employed in this study. The algorithm provides a specificity, accuracy and sensitivity of 98.7±1%, 95.4±2%, and 64±15% for detecting locomotion. Moreover, its relative error for cadence estimation is 6.3±3.2%. In order to investigate locomotion diversity and between-day activity variability of a person, first, the above algorithm is applied on 244 persons each measured during 14 successive days. Second, the probability distribution function (PDF) of cadence, duration of locomotion, and onset time of locomotion of each subject are computed. Third, trends of cumulative distribution function (CDF) of the above parameters for each subject during the 14 days are calculated through comparing the difference between the CDFs of two successive days. Finally, it is investigated that after how many days of monitoring, the trends become stable. The stability happens when the area under the trends is lower than an empirical threshold.

Results:

The results of large population analysis show bi-modal or multimodal distributions for the cadence, and power-law distribution for the duration and the onset time. In addition, the modes of these distributions (associated with the preferred cadence and locomotion duration) vary from one person to another one. The CDFs of the above parameters become stable after 8 ± 1 days of daily activities observation.

Discussion:

This study demonstrated that a new-developed algorithm based on wrist acceleration data can be used to characterize long-term locomotion behavior during free-living daily activity. The bi-modal or multi-modal distributions of cadence indicates that people have different preferred cadence for different contexts such as indoor walking, outdoor walking, or running. The large sample size and long recording duration allow to demonstrate that a minimum number of eight days is necessary to capture the entire activity spectrum of a person. We hypothesize that activity patterns of a person change between workdays and weekends. Therefore, less than eight days of monitoring might not be enough to record all kinds of activities for both workdays and weekends.

References:
Development of the speed adaptive Gait control algorithm for above-knee amputees with knee & hip angle parameters

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KOREC, INCHEON, Republic of Korea

Introduction:

In this paper, we suggest a speed adaptive gait control algorithm of the SKAFO(Smart Knee Ankle Foot Orthosis) for above-knee amputees. We analysed many of gait parameters to find the relationship and more exact gait phase(swing time and stance time) in speed adaptive gait. Generally, it is difficult to define the walking speed of the amputee because they change speed for every walking time and it is different from person to person. So firstly, we quantified the walking speed in daily life and analysed the gait parameter according to the walking speed. Using gait analysis system(3D motion analyser™), we found the linear relationship between speed and hip-knee angle difference.

Research Question:

How to control the walking speed which different from person to person.

Methods:

Using metronome, we qualified the walking speed in daily life and collected the gait parameter as increasing BPM(Bit Per Minute) from 50 to 126. The following table shows the relationship between walking speed and walking in daily life. We analysed the gait parameter such as hip and knee angle as increasing the BPM. We found that the hip-knee difference angle is related to the walking speed as following figure. We also found the exact swing time is between minimum and maximum value.

<table>
<thead>
<tr>
<th>SPEED</th>
<th>BPM</th>
<th>Walking in Daily Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slow</td>
<td>50</td>
<td>seeing interesting item walking indoors</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>just look around indoors</td>
</tr>
<tr>
<td></td>
<td>70</td>
<td>just walking as looking around along the corridor</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>going to the destination along the corridor</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>just walking outside of a room</td>
</tr>
<tr>
<td>Normal</td>
<td>100</td>
<td>walking speedy indoors</td>
</tr>
<tr>
<td></td>
<td>104</td>
<td>just walking along going outside of a room</td>
</tr>
<tr>
<td></td>
<td>108</td>
<td>crossing the street with taking time</td>
</tr>
<tr>
<td>Fast</td>
<td>116</td>
<td>walking to destination keeping eyes forward outside of a room</td>
</tr>
<tr>
<td></td>
<td>126</td>
<td>walking some speedy to destination keeping eyes forward outside of a room</td>
</tr>
</tbody>
</table>

![Graph showing the relationship between walking speed and BPM](image)

Results:
The conventional KAFO is just classified walking speed qualitatively. We quantitatively redefined walking speed in daily life and found the exact swing time with hip-knee angle difference. We also found the linear relationship hip-knee angle difference and walking speed. We applied these results to the SKAFO to prove the validation.

Discussion:

We qualified the walking speed of the person in daily life and we found that the best choice of gait parameter, hip-knee angle difference is linearly related to the walking speed. But, walking speed is also change in stance state. Therefore, we need more researches to predict walking speed considering parameters in stance time as well as in swing time.

This work was supported by institute for information & communications Technology Promotion(IITP) grant funded by the Korea government(MISP)(No.R7520-16-0005, Development of creative technology based on complex 3D printing technology for labor, the elderly and the disabled).

References:[1] Frank Sup et al, Robot, the international journal of robotics research 2008;27:263-273
Development of activity classification algorithms using machine learning techniques for a trunk and thigh based system using body worn tri-axial axial accelerometers.

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Introduction: Accurate monitoring of the physical activity of older adults is important in rehabilitation medicine, as regular physical activity is central to maintaining a healthy lifestyle and evaluating quality of life.

Here we describe the development of a dual-sensor system with tri-axial accelerometers located at the upper back and anterior aspect of the thigh. A suite of algorithms have been developed using machine learning algorithm techniques using a data-set of 43.92 hours of physical activity was used to develop classification tree and neural network algorithms of varying complexity using a 33% hold-out validation.

Research Question: Can machine learning techniques improve the classification of physical activity in older adults using a dual tri-axial accelerometer based sensor system?

Methods: A total of 20 older adult participants (Age: 68-90 years (76.4±5.6 years), body mass: 56 to 93 kg (73.7±11.4 kg), and height: 1.56 to 1.81m (1.67±0.072 m) ) were recorded using video technology performing a semi-structured protocol in a laboratory setting and a free-living protocol in their own home environment (1). Physical activity data was labelled at 25fps (frames-per-second). Subjects wore two Axivity AX3’s on the upper back, between the shoulder blades and on the anterior of the left thigh. Sensors were help in place using hydrogel patches and sampled at 100Hz. The features using in the development of the algorithms include: IMA_mean, freq_magnitude, anterior_posterior_axis_angle, vertical_axis_angle, Lateral_axis_angle, vertical_acceleration_estimate, angle_dot, angle_horizontal, diff_angle_vertical, arctan_anterior-posterior_versus_vertical, vertical_velocity_estimate and displacement estimate for the trunk and thigh.

Results: Table 1 presents the comparison between simple, medium and complex decision tree algorithms and single and double stage neural networks for a variety of different categories of physical activity catalogues. The Original catalogue contains: lying, shuffling, sitting, stairs (ascending), stairs (descending), standing, transition and walking. Sit_Lying: Sitting and lying is 1 category, sitting/lying. Sit_Stand: Sitting and standing is 1 category, sitting/standing. ReClassify_Stairs: lying, sitting, standing, transition, walking. Sit_Stand_stairs: lying, sitting/standing, transition, walking. Walk: non-walking, transition, walking

Table 1. The machine learning algorithm types versus activity catalogue percentage accuracy.

<table>
<thead>
<tr>
<th>Origin</th>
<th>Sit_Lying</th>
<th>Sit_Stand</th>
<th>ReClassify_Stairs</th>
<th>Sit_Stand_stairs</th>
<th>Walk</th>
</tr>
</thead>
<tbody>
<tr>
<td>TREE simple</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TREE medium</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TREE complex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NeuralNetwork single</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NeuralNetwork double</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

80.62 81.24 80.99 85.85 87.13 88.0
85.78 84.36 83.63 88.25 88.88 88.9
86.54 85.43 84.57 89.22 89.54 89.5
87.21 86.34 84.65 89.62 90.06 90.1
87.38 86.39 85.08 89.59 90.10 90.1
Discussion: The two-stage Neural Network that detects the Walk catalogue produced the highest accuracy (90.12%), however only 3 categories are detected. Neural Network based algorithms outperform decision tree algorithms, however longer processing time is anticipated. The simple decision tree produced the poorest accuracy (80.62%).

In conclusion we have developed a suite of algorithms for the detection of physical activity in older adults using a dual sensor system consisting of tri-axial accelerometers located at the upper-back and thigh.

References:

Relationship between range of motion tests and kinematics during overarm throwing in elite handball players

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Introduction: During their handball carrier a lot of handball players experiences shoulder pain [1]. Altered shoulder mobility (increased external rotation) is found to stress the glenohumeral structures of the shoulder and thereby the disposition to shoulder pain and shoulder injuries [2, 3, 4]. However, in all these studies passive range of motion (ROM) tests are conducted (external shoulder rotation angle) and not the actual range of motion during throwing. The question rises if the measured ROM of the shoulder also influences the actual throwing kinematics in handball throwing.

Research Question: Is there a relationship between the external rotation angles during glenohumeral active and passive range of motion tests and the maximal external rotation during throwing performance in elite team handball players

Methods: Twenty-two elite team handball players (age 22.0 ± 4.2 yr, body mass 78.5 ± 10.7 kg, height 1.80 ± 0.07 m) participated in the study in which the maximal ball release velocity and maximal external rotation during standing, with run up and jump throws with circular and whip-like wind-ups were measured with a 3D motion capture system (Qualysis, Sävedalen, Sweden, eight cameras, 240 Hz). Maximal active and passive glenohumeral ROM of the external rotation was test lying supine on a bench based on the descriptions of Norkin and White [5]. Pearson correlations were conducted to investigate if there was a relationship between the passive, active glenohumeral external rotation angle measurements and maximal external rotation angle during the two wind-ups and the three different types of throw.

Results: No significant correlations were found between the range of motion of the external rotation with the maximal ball release velocity and the maximal external rotation measured during the throws.

<table>
<thead>
<tr>
<th>Maximal external rotation angle</th>
<th>Standing throw</th>
<th></th>
<th></th>
<th>Jump throw</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Whiplike</td>
<td>Circular</td>
<td>Whiplike</td>
<td>Circular</td>
<td>Whiplike</td>
<td>Circular</td>
</tr>
<tr>
<td>Passive ROM test</td>
<td>0.15</td>
<td>0.40</td>
<td>0.40</td>
<td>0.18</td>
<td>0.29</td>
<td>0.24</td>
</tr>
<tr>
<td>Active ROM test</td>
<td>0.04</td>
<td>0.35</td>
<td>0.29</td>
<td>0.10</td>
<td>0.14</td>
<td>0.18</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Maximal ball velocity</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive ROM test</td>
<td>-0.40</td>
<td>-0.16</td>
<td>-0.38</td>
<td>-0.06</td>
<td>0.02</td>
<td>-0.20</td>
</tr>
<tr>
<td>Active ROM test</td>
<td>-0.39</td>
<td>-0.10</td>
<td>-0.29</td>
<td>-0.02</td>
<td>-0.15</td>
<td>-0.16</td>
</tr>
</tbody>
</table>

Discussion: It was concluded that measuring active and passive range of motion in healthy team handball players on the bench does not give any extra information about the maximal throwing performance or the external rotation angle during throwing. In summary the present study indicates that does not give any extra information about their throwing performance. Therefore, these range of motion measurements cannot be used as a screening tool to identify potential fast throwers or recognise potential injuries combined with changed kinematics.

References:
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ANALYSIS OF HIP BIOMECHANICS IN PATIENTS WITH HIP REPLACEMENT SURGERY

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Introduction:

Hip surgery is one of most routine surgeries for orthopaedic patients. Hip surgery has two types, total hip replacement (THR) and hip resurfacing (HR). The gait analysis for hip surgery is not routine in clinical practice. There is a lack of research on the biomechanical changes that occurs postoperatively at the hip joint. Therefore, the aim of this study was to investigate the postoperative 3D gait changes at the hip joint in patients with hip surgery.

Research Question:

What biomechanical changes would be happened in total hip replacement and hip resurfacing?

Methods:

The 126 patients with hip surgery (aged 30-87 and weighted 58-120 kg), and 45 healthy subjects (aged 20-62 and weighted 50-116) were collected in the study. Their gait was measured using Vicon motion capture system and force platforms. Of the 126 operated subjects 53.2% had unilateral HR operation while 46.8% had unilateral THR. The gait data from patients were obtained in following up between 1 to 6 years. Two Kistler® force plates were used to collect the ground reaction force (GRF) while the subject was walking along the 20 m walk way. The Vicon® nexus motion capturing system with 8 MX cameras were used to capture data at 100Hz. A group of 14 mm retroreflective markers were placed on the appropriately anatomical landmarks for the subjects according to Vicon management system, and the biomechanical parameters were calculated using the Plug-in-Gait® model. For each participant, 5 good trials were selected for final statistical analysis. The biomechanical variables from the gait data were joint kinematic and kinetic variables, e.g. angle, force and moment.[1, 2] SPSS (v16) was employed to conduct statistical analysis. Significant level was set at 0.05. Data normality was checked using K-S test, and statistical methods used were independent t-test, general linear model, non-parametric test or ANOVA, depending data characteristics and distribution.

Results:

All groups displayed significantly reduced walking speed when compared to the healthy normal group. In this study the patients with hip surgeries also showed significantly reduced stride length when compared to the healthy normal group. Table 1 reports the part of results in the hip joint angles. The results showed that THR significantly increased the hip flexion as approximate 6 deg, reduced the hip extension as approximate 11 deg, and as a result the range of motion in the hip decreased approximate 6 deg. Though both surgeries have the reduced range of motion as approximately 6 deg, the HR has a similar hip flexion to the healthy and reduced the hip extension. In the hip forces, the results showed that THR and HR have reduced joint forces in the hip in compared with the healthy. In the joint moment, THR and HR shoed reduced values in compared with from the healthy. Obviously, these changes or unchanged are due to the surgeries in the hip.

Discussion:

The range of motion in the hip from THR and HR are reduced in compared with the healthy. Regarding to clinical practice, the hip kinematics and kinetics in HR and THR are acceptable. Though the patients after the surgery have their gait changed a little bit, the gait is fine for daily life.
References:
1. Wasim Raza, the PhD thesis with University of Dundee, 2014.
Inter-rater Reliability of Movement Quality During Single Limb Mini-Squat Test in Adults with Knee Osteoarthritis

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Introduction: Physical limitations and alterations in kinematics and kinetics are common manifestations of knee osteoarthritis (KOA). Clinicians rely upon clinical observation and patient performance of functional maneuvers to ascertain the impact of KOA on activities of daily living and to formulate interventions. This study assessed the inter-rater reliability among physical therapists (PTs) and orthopedic surgeons scoring video-based movement assessments of adults with KOA and healthy controls during the single limb mini-squat test (SLMS), a typical functional maneuver.

Research Question: Is there a strong inter-rater reliability of movement quality assessment during subject performance of the SLMS among orthopaedic surgeons and PTs?

Methods: In this cross-sectional study, 15 experienced clinicians who worked with patients with KOA (11 PTs and 4 orthopedic surgeons) rated movement quality of 55 motion analysis videos from 31 adults with KOA and 24 of gender and age-matched controls during performance of the SLMS. Age matching was accomplished using 5 age strata (40-49, 50-59, 60-69, 70-79, 80-89 years). Adults with KOA were eligible for the study if: they had a physician diagnosed of primary KOA and were scheduled for total knee replacement within 1 month after data collection. Subjects were excluded if: they had another previous major orthopaedic surgery in the lower extremities, total joint replacement of hip or knee within the last year, rheumatoid arthritis, diabetes mellitus, neurologic disease and/or other condition affecting walking ability. For each SLMS test, we conducted a frontal 2D video and 3D movement analysis simultaneously. Video data were collected with a digital video camera positioned in front of the subject at a distance of 2 m and a height of 1 m, resulting in a frontal view of the subject’s lower body and trunk. One video of SLMS performance per subject was selected. For adults with KOA, the video for the affected limb was selected. For controls, we selected a video of a random leg. Videos had consistent video exposure duration (10 s of squatting). Raters participated in an orientation session using 5 training videos and the movement quality scale (4-point Likert scale from 1= poor to 4 = good). Test videos were then presented in random order. Raters were blinded to the subjects’ health status and were not given guidelines on which to base their ratings. Descriptive statistics characterized the sample. T-tests, Mann Whitney U and Chi Squared tests were used to examine demographic differences between raters and subjects. A Bonferroni correction was applied to account for multiple testing. Reliability was assessed using linearly weighted, quadratically weighted and generalized kappa values for each rater pair and averaged overall rater pairs.

Results: No significant differences were observed between the surgeons and PTs in clinical experience or experience working with adults with KOA. However, orthopedic surgeons had significantly less experience with movement analysis than PTs (median = 1.5 vs median = 12.5; p <0.05). All patients had moderate to severe KOA (Kellgren Lawrence grades of 3 and 4). There were no significant differences between patients and controls with respect to gender and age. Patients had significantly higher BMI (29.5 vs 24.9; p<0.05), significantly worse passive knee joint range-of-motion and performed significantly fewer knee bendings in the SLMS test than controls (13.2 vs 28.5;p < 0.05). Clinicians rated patients’ movement quality lower compared to controls (2.0 v 3.1; p <0.05). Rater agreement was fair to moderate among all raters (linearly weighted kappa= 0.43 (0.02–0.65), quadratically weighted kappa =0.57 (0.14 – 0.80) and generalized kappa =0.29 and higher among surgeons only (linearly weighted kappa=0.51(0.44 – 0.61), quadratically weighted kappa= 0.68 (0.62 – 0.74) and generalized kappa= 0.32.

Discussion: Clinicians scored adults with KOA significantly lower on test performance than...
controls. Inter-rater reliability of SLMS performance by PTs and orthopaedic surgeons was fair to moderate across all methods used to calculate kappas. Inter-rater reliability among surgeons was higher than PTs. Low inter-rater reliability results indicate the need for more objective methods of assessing movement quality. Dedicated measures derived from 3D motion capture could potentially serve this purpose.

References:


Driving Motion of Disabled Athletes of Wheelchair Marathon

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Introduction: Wheelchair marathon is one of the famous events of Paralympic. Additionally, wheelchair marathon is a type of sport that needs many skills and techniques because of their impairment or physical function. Disabled athletes must possess a wide range of different driving techniques, which including race strategy, mental toughness, and physical exercise capacity. However, little is known about driving skills and techniques. The previous study reported driving skills and techniques about movement related velocity, acceleration and muscle [1][2]. However, there are still few comparisons between skilled and unskilled. Therefore, the purpose of this study was to investigate the driving skills and techniques of elite disabled athletes of wheelchair marathon.

Research Question: What kind of movement characteristics of the driving skills and techniques of elite disabled athletes of wheelchair marathon?

Methods: The subjects of this study were 5 Japanese disabled athletes of wheelchair marathon. Three of them were elite disabled athletes (C, D and E). The procedure was explained and an informed consent was obtained from subjects. Movements of driving wheelchair were analysed three-dimensionally with a motion analysis system (Motion Analysis, 100Hz). Segmental interactions of kinematics due to proximal to distal of upper extremity during driving wheelchair were compared with fast subjects and slow subjects.

Table 1. The speed, cycle time and cadence of each of subjects.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Speed [km/h]</th>
<th>Cycle Time [sec]</th>
<th>Cadence [cycle/sec]</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>15.6</td>
<td>0.55</td>
<td>1.82</td>
</tr>
<tr>
<td>B</td>
<td>30.8</td>
<td>0.54</td>
<td>1.85</td>
</tr>
<tr>
<td>C</td>
<td>32.0</td>
<td>0.47</td>
<td>2.13</td>
</tr>
<tr>
<td>D</td>
<td>32.0</td>
<td>0.47</td>
<td>2.13</td>
</tr>
<tr>
<td>E</td>
<td>37.0</td>
<td>0.51</td>
<td>1.96</td>
</tr>
</tbody>
</table>

Results: The cycle time of fast subjects were shorter than that of slow. Additionally, cadences of fast subjects were greater than that of slow (Table 1). Trajectories of shoulder joint were smaller than that of elbow and wrist joint in all subjects (Figure 1). Especially, trajectories of wrist joint of fast subjects indicated greater longitude axis as elliptically. On the other hands, trajectories of wrist joint of slow subjects indicated greater transverse axis as elliptically.
Discussion: In this study, driving skills and techniques of disabled athletes of wheelchair marathon were investigated. The results were different from the date summarised by Ambreen Chohan et al [3]. The results indicated that fast subjects minimized the total travel distance of wrist joint used strategy of higher cadence and greater longitude axis of wrist joint trajectory. Therefore, such as driving skills and techniques contributed to the energy efficiency driving of wheelchair. Driving skills and techniques of elite disabled athletes could result in better management of conduct training.

How does the Powers™ strap influence lower limb muscle activation in individuals with patellofemoral pain?

Henrike Greuel, Lee Herrington, Anmin Liu, Richard K. Jones

University of Salford, Salford, Greater Manchester, UK

Introduction:

The quadriceps avoidance strategy has been described as a mechanism that minimises the demand of knee extensor muscles and is commonly observed in individuals with knee injuries such as patellofemoral pain. Researchers in the USA invented the Powers™ strap that is designed to decrease knee pain and femoral internal rotation in individuals with PFP and has been shown to be successful in modifying lower limb biomechanics. However, no study investigated the influence of this brace on lower limb muscle activation and the quadriceps avoidance strategy.

Research Question:

How does the Powers™ strap influence lower limb muscle activation of the hamstrings and quadriceps muscles in individuals with PFP?

Methods:

20 individuals with PFP, 11 males and 9 females (age: 29.55± 6.44years, height: 1.74± 0.09m, mass: 70.08± 8.78kg) were recruited. Each individual was asked to run on a 15m walkway at their own selected speed during two conditions: with and without the Powers™ strap, until five successful trials were collected. Muscle activity was collected with surface electromyography (sEMG). Co-activation ratios and the net activity of the quadriceps and the hamstrings muscles were calculated. The normality was assessed using the Shapiro-Wilk test and paired sample t-tests were performed at the 95% confidence interval.

Results:

The Powers™ strap condition significantly decreased the hamstrings activity during the early stance phase (ESP) (p=0.05) and late stance phase (LSP) (p=0.05). Furthermore, the pain was significantly reduced with the Powers™ strap (p=0.01) (NPRS: without 4.05±1.96; with 2.18±2.24 the Powers™ strap).

Table 1: Differences in lower sEMG activity with and without the Powers™ strap

<table>
<thead>
<tr>
<th>Task</th>
<th>Kinematic variables</th>
<th>Condition</th>
<th>Mean±SD</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early stance phase (ESP)</td>
<td>Co-activation ratio</td>
<td>Without strap</td>
<td>0.66± 0.19</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>With strap</td>
<td>0.7± 0.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Net activation knee extensors in %</td>
<td>Without strap</td>
<td>122.3± 68.9</td>
<td>0.34</td>
</tr>
<tr>
<td></td>
<td></td>
<td>With strap</td>
<td>135.1± 93.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Net activation knee flexors in %</td>
<td>Without strap</td>
<td>40.4± 33.4</td>
<td>0.05*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>With strap</td>
<td>34.0± 25.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Co-activation ratio</td>
<td>Without strap</td>
<td>0.36± 0.3</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>With strap</td>
<td>Without strap</td>
<td>Co-activation ratio</td>
<td>Without strap</td>
</tr>
<tr>
<td>------------------------</td>
<td>--------------</td>
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</tr>
<tr>
<td><strong>Mid stance phase (MSP)</strong></td>
<td>0.39± 0.35</td>
<td>0.69</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net activation knee extensors in %</td>
<td>With strap 82.4± 55.5</td>
<td>Without strap 77.1± 46.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.27</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net activation knee flexors in %</td>
<td>With strap 41.2± 22.2</td>
<td>Without strap 43.2± 24.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Late stance phase (LSP)</strong></td>
<td>0.54</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Co-activation ratio</td>
<td>Without strap -0.29± 0.46</td>
<td>0.76</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>With strap -0.25± 0.54</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net activation knee extensors in %</td>
<td>Without strap 14.7± 27.3</td>
<td>9.7± 14.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.05*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net activation knee flexors in %</td>
<td>Without strap 12.8± 8.7</td>
<td>15.7± 10.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Discussion:

The Powers™ strap decreased significantly the hamstrings activity during the ESP and LSP. Throughout the stance phase a tendency for an overall increased quadriceps activity and for an overall decreased hamstrings activity could be identified. These results demonstrate that the Powers™ strap has not only the potential to reduce pain, but is also able to modify lower limb muscle activation and might enable the reversal of the quadriceps avoidance strategy in individuals with PFP.

References:

Effects of Kinesiology tape (KT) on VMO activation and on proprioception at the knee in adults with anterior knee pain

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Introduction: Anterior Knee Pain (AKP) is a common cause of knee pain, it can affect proprioception at the knee in adults and is a frequent reason for referral to physiotherapy. It is hypothesised that AKP may occur secondary to weakness, poor timing of contraction and poor recruitment of the vastus medialis oblique (VMO) muscle (Tumi et al, 2013). Kinesiotape® is commonly used by physiotherapists to increase muscle activation and proprioceptive awareness through cutaneous stimulation and increased muscle activity, however, there is limited research investigating the effects of Kinesiotape (KT) on VMO activation and on proprioception in AKP adults (Knoop et al, 2011).

Research Question: What are the effects of Kinesiotape® on VMO muscle activation, hip joint position sense (JPS) and postural sway (PS) in adults with anterior knee pain during a step-up and step-down task?

Methods: It was a repeated measures pre-/post-test design study of a convenience sample of twenty-five adults with a history of AKP within the past 12 months. Electromyographic (EMG) activity of the VMO, was assessed for three consecutive step-up/step-down tasks both at baseline and immediately following KT application. For JPS and PS assessment subjects balanced for up to 30s on a straight leg, then balanced with knee flexed, and were instructed to maintain the same degree of flexion (35°). KT applied as per Kase et al (2003) VMO protocol. Each subject was their own internal control for non-tape vs. tape testing. Measurements were taken using a 16-bit wireless Myon® ProPhysics surface EMG and VICON® 3-D Motion Analysis system. Paired samples t-tests were used to evaluate differences in peak VMO activity, average VMO activity, time to peak VMO activity, JPS and PS both at baseline and immediately following KT application. Significance level was set at p=0.05

Results: Kinesiotape® application to facilitate VMO activation increased peak eccentric VMO activation and average eccentric VMO activation from baseline values (Fig 1). Kinesiotape® had no significant effect on concentric VMO activation or the timing of VMO activation. There was significantly less sway (mm) from neutral in the medio-lateral (M-L) axis (straight knee) and antero-posterior (A-P) axis (bent knee) when taped, in comparison to non-taped. JPS was not significantly affected.

Discussion: Application of Kinesiotape® to facilitate VMO activation may increase eccentric VMO activity in adults with AKP during stair descent; KT tended to improve proprioceptive acuity in the knee when applied to VMO in adults with AKP. Further research on a larger sample size and with a randomised design is required to establish the clinical relevance of these findings.


Ankle kinematics and kinetics in rheumatoid arthritis postmenopausal women fallers and non-fallers

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Introduction: During the gait stance phase the foot controls the impact with the ground and transfers to the ground the internal forces generated by the dynamics of intersegmental transfer of force, propelling the body [1]. Ankle angles, ankle moment of force peak (AMP) and ankle power peak (APP) were important parameters to measure the foot function [2,3], and elderly fallers presented a significantly decreased in AMP [4]. However, the relation between falls and ankle kinematics and kinetics is not perfectly clear. Otherwise, rheumatoid arthritis (RA) patients [5] and postmenopausal women [6] show an increased fall risk although studies that evaluated the gait changes in postmenopausal women and in RA patients are scarce. In the best of our knowledge, specific comparisons between RA postmenopausal women fallers and non-fallers were not developed.

Research Question: Is there a difference between RA postmenopausal women fallers and non-fallers concerning ankle kinematic and kinetic parameters during the gait stance phase?

Methods: For this retrospective study were selected 26 RA postmenopausal women (without early RA and lower limbs prostheses). Subjects were allocated to the fallers group (subjects with at least one fall in the previous year) or to the non-fallers group after had answered to the following question: "How many times did you fall last year?". A three-dimensional motion analysis system (9 cameras; 200 Hz; Vicon®) synchronized with an AMTI force plate (1000 Hz) were used to assess ankle kinematic and kinetic parameters during the gait stance phase. Subjects walked barefoot at natural and self-selected speed, performing 7 trials for the contact of each foot on force plate. For statistical analysis were used each ankle/foot as a subject, following Derr (2006) [7]. Health Assessment Questionnaire (HAQ) was used to assess functional capacity.

Results: Thirteen subjects had at least one fall in the previous year. Fallers were older (68.2 years vs. 61.4 years; p=0.03) and had a lower functional capacity (1.3 vs. 0.8; p<0.001; HAQ score). Table 1 presents ankle kinematic and kinetic parameters.

Discussion: Falls seem to occur in older RA postmenopausal women and in subjects with lower functional capacity. Fallers also showed a lower gait speed and differences in ankle kinematic and kinetic parameters regarding non-fallers. So, a lower ankle power peak and a lower ankle moment peak was found in RA postmenopausal women fallers as well as a higher stance phase time, a higher dorsiflexion sub-phase time and a higher ankle plantar flexion at heel strike. We can speculate that these differences in gait speed and in ankle kinematic and kinetic parameters could be related with the lower functional capacity observed in RA postmenopausal women fallers and may be associated to a strategy to ensure a safer gait pattern.

Bilateral and multi-joint strength in patients with painful knee osteoarthritis: a case-control study

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¹NTNU, Trondheim, Norway, ²Umeå University, Umeå, Sweden, ³Diakonhjemmet Hospital, Oslo, Norway

Introduction: Individuals with long-term, painful knee osteoarthritis (OA) are known to exhibit muscle weakness [1-4] and to respond well to strength exercise therapy [1]. Case-control studies have assessed mostly the quadriceps muscle for the affected knee [3], seldom the hip muscles [4] and barely the ankle muscles. No studies have yet assessed strength comprehensively across the entire kinetic chain of the lower extremity for both legs in individuals with knee OA and controls without knee complaints [3,4]. We argue that broad and objective data, including all major muscles groups of both lower limbs, offer potentially important information for understanding movement impairments, prerequisites for functional movements, and to design optimal therapeutic interventions for individuals with painful knee OA.

Research Question: What are the differences in comprehensive strength between patients with chronic knee OA and matched healthy controls?

Methods: In this cross-sectional case-control study, patients 45 to 70 years old, scheduled for physiotherapy, with knee pain duration > 1 year, and radiographic verified OA, as well as matched healthy controls, are tested on strength for all major muscles of both lower limbs. A Biodex Dynamometer linked protocol 1-5 and a Hand Held Dynamometer protocol 6, are applied. The respective protocols include 1) Knee Extension/Flexion, 2) Ankle Eversion/Inversion, 3) Ankle Dorsal/Plantar Flexion, 4) Hip Internal/External Rotation, 5) Hip Flexion/Extension, and 6) Hip Ab/Adduction. In particular the first protocol tests concentric and eccentric peak strength, as well as endurance strength; protocols 2-5 test isokinetic, concentric peak strength; and protocol 6 tests peak isometric strength. Torque data will be normalized to body weight and presented by descriptive statistics and differences with 95 % confidence intervals.

Results: Intermediate results on strength will be presented on the upcoming ESMAC-2017 Conference. Data collection is ongoing.

Discussion: In knee OA, not only strength across the knee joint, but also strength across the adjacent joints, i.e. hip and ankle, are considered essential to enable proper alignment of the kinetic chain for functional movements as well as for optimal joint loading conditions. Eccentric strength of the quadriceps and hamstrings are seldom assessed (in patients), although being pivotal particularly to normal stair decent. Endurance strength might explain increased perceived exertion and decreased performance during climbing a floor of stairs. In view of knee OA as a long-term condition affecting the body as a system, our upcoming results, data on bilateral lower-limb-kinetic-chain strength, including different contraction modes, all in one sample, may improve basic understanding of movement impairments in individuals with chronic painful knee OA. Additional protocols assessing motor control issues in gait and posture will provide answers to how deficits in lower extremity strength influences motor strategies for functional tasks in gait and posture.

Stability assessment during running in nonprofessional runners – evaluation of the intrasession reliability

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Introduction: Stability assessment is becoming a more and more used tool during gait in order to enhance fall risk prevention [1,2]. This approach has also been applied to running to assess stability aspects that could be related to possible risk of injuries [3,4]. When aiming at assessing running stability, it is relevant to take into consideration that subject fatigue can influence the evaluation [4] and that, at the same time, several task repetitions are needed to ensure reliable assessment.

Research Question: How many trials of over-ground running are required to ensure reliable stability assessment while taking into consideration possible fatigue-induced changes?

Methods: Fifteen healthy young adults (mean age 22.4 years) participated in this study. None of the participants practised running at professional level.

Participants performed three running sessions in an indoor athletic track, each at different speed – preferred, faster (120% of preferred), slower (80% of preferred). The speed was controlled by photocell gates. Ten trials were performed at the preferred and slower speed, five at the faster speed. Participants were asked to run a distance of 70 meters while wearing a tri-axial accelerometer (Trigno wireless system, Delsys Inc., Natick, MA, USA) attached to the lower trunk around L5 vertebra. Acceleration data along the three axes were recorded while participants were running in the middle 50 meters of the track. From original time series, root mean squares (RMS) and sample entropies (SEN) [5] were computed. For SEN computation, an equal number of 2000 samples was used in all trials.

The intrasession reliability was assessed by intra-class correlation coefficients type ICC(2,1) (ICC). The computations were performed for increasing number of trials; from two to five trials for fast speed, from two to ten trials for preferred and slow speed.

Results: The results showed that for preferred running speed, three trials produced the highest ICC and were optimal for assessment. SEN ICC ranged from 0.688–0.966, RMS ICC ranged similarly from 0.689–0.976. The values increased from two to three analysed trials, however, rapidly decreased with further increasing number of trials.

At faster speed, ICC reached considerably higher values showing excellent reliability regardless of number of trials used (SEN: 0.945–0.992; RMS: 0.943–0.989).

At slower speed, five trials seemed to be the best choice for number of repetitions. SEN ICC values ranged from 0.911–0.967, RMS ICC from 0.925–0.982. The values followed a trend to slowly decrease with increasing number of trials beyond five.

Discussion: The results of this study showed that the assessment of stability during over-ground running using SEN and RMS is reliable with good to excellent results. The highest reliability was reached in induced speed of running. The explanation could emerge from the instability of the pace at preferred running speed connected to the relationship between stability measures and speed shown in gait [6]. In conclusion, to ensure that the reliability of these measures remains sufficiently high when evaluating running, 3 trials are needed for the assessment of running performance at preferred speed, 5 trials at slower and 2–5 trials at faster speed.

Increased Femoral Anteversion Related Biomechanical Abnormalities: Lower Extremity Functionality, Falling Frequencies and Anterior Knee and Low Back Pain.

Gokce Leblebici, N. Ekin Akalan, Adnan Apti, Shavkat Kuchimov, Ismail Bacak, Fuat Bilgili, Yener Temelli, Kubra Onerge, Freeman Miller

Introduction: Increased femoral anteversion (IFA) is a transverse plane problem which may affect lower extremity functions, activities of daily living and falling frequencies. Additionally, IFA may cause anterior knee and low back pain, which may also be genetic transition. Therefore, the aim of this study was to describe the influences of IFA on lower extremity function, falling frequencies and anterior knee and low back pain.

Research Question: Does IFA influence lower extremity functions, increase falling frequency and cause anterior-knee and low-back pain?

Methods: Sixty-seven neurologically intact children with IFA (age: 8.62±3.18) and twenty-four typically developing children (TDC) with no IFA (mean age: 9.97±3.15) 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. For all children with IFA, internal rotation angle were ≥65° (70.7±5) and external rotation was ≤20° (14.63±5.54) and for TDC group, hip internal rotation was ≤50° (43.26±6.13). For all participants, lower extremity function was evaluated by Lower Extremity Functional Scale, anterior knee pain and low back pain were assessed by Kujala Score and Oswestry Disability respectively. Participants’ parents evaluated daily falling frequencies by four point likert scale in which greater points are meaning “lower falling frequency”. For comparison, Student’s t-test was used (p<0.05).

Results: Lower Extremity Functional Scale score was greater in participants with IFA (10.83±8.8) than TDC group (5.18±7.4) (p<0.005). Compared to healthy controls (3.63±0.55), for participants with IFA (3.19±0.79) daily falling frequencies is higher (p<0.005). Eventually, there was no significant difference between participants for Kujala Score and Oswestry Disability Index.

<table>
<thead>
<tr>
<th></th>
<th>TDC with IFA</th>
<th>TDC with no IFA</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Extremity Functional Scale</td>
<td>10.83±8.8</td>
<td>5.18±7.4</td>
<td>0.002</td>
</tr>
<tr>
<td>Falling Frequencies</td>
<td>3.19±0.79</td>
<td>3.63±0.55</td>
<td>0.003</td>
</tr>
<tr>
<td>Kujala Score</td>
<td>81.71±15.4</td>
<td>77±12.46</td>
<td>0.93</td>
</tr>
<tr>
<td>Oswestry Disability Index</td>
<td>18.12±17.91</td>
<td>18.22±15.58</td>
<td>0.97</td>
</tr>
</tbody>
</table>

Discussion: In this study, investigated the effects of IFA on lower extremity function, falling frequencies and anterior knee and low back pain. According to our results, children with IFA have lower extremity function, as agreed with the literature (1), and higher falling frequency than healthy peers. These children may have difficulty in daily living and recreational activities and also sportive activities. Therefore children with IFA have a great potential to have injuries in sports branches, which dominates lower body parts such as soccer. Therefore, IFA should be carefully evaluated while selecting the appropriate sports branch for these children. Although, as disagreed with the literature (2), anterior knee pain and low back pains are not significantly different for these
children. However, older than the mean age in this study, low back and anterior knee pain may appear in older ages in children with IFA, which should be investigated in future studies.

Acknowledgement: This study was supported by Scientific and Technological Research Council of Turkey (TÜBİTAK), No:214S049.

References:

The Role of Speed and Incline on the Spontaneous Choice of Technique in Classical Roller-Skiing

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Introduction:

The terrain conditions (particularly incline and speed) under which particular techniques in cross-country skiing are preferred are reasonably well known. However, the few studies (Cignetti et al., 2009; Pellegrini et al., 2013) that have targeted this issue in cross-country were not designed to identify, independent of workload, the task related control parameter, i.e., incline or speed, for the transition of technique. Identifying which parameter plays the key role for technique transitions (as in gait: walking versus running), is important for understanding the mechanisms and organismal variables that trigger transitions.

Research Question:

The aim of this study was to investigate whether speed or incline acted as control parameter for techniques shifts during classic style roller skiing at constant work rate. Identifying task related control parameters for spontaneous technique shifts assists elucidating which mechanisms are active for triggering technique transitions. In this study, we kept the exercise intensity constant while changing two potential control parameters (speed and incline). Thus, any effect of workload was excluded.

Methods:

Eight male competitive cross-country skiers performed roller skiing on a treadmill while incline was altered from 3 to 11% and back to 3% each minute by 1% and speed changed accordingly to obtain a constant work rate. This protocol was performed at three submaximal steady state intensities (170, 200, and 230 W) to obtain various combinations of speed and incline.

The athletes were free to choose their technique (double poling, double poling with kick and diagonal stride), which was identified using continuous phase analysis on the motion of the skis. Physiological response (heart rate, oxygen uptake) was recorded continuously. At the lowest intensity (170 W), the protocol was also performed using one technique (double poling with kick; ‘forced’ protocol) only as reference for physiological response.

Results:

The athletes shifted technique at one consistent incline (ANOVA repeated measures; p > 0.2) and different speeds (p < 0.001) depending on the work rate. No effect of order (increasing versus decreasing incline) was found for transitions. The physiological response decreased with incline. Heart rate and oxygen uptake tended to be higher in the ‘forced’ protocol at incline-speed combinations where other techniques than double poling with kick were preferred in the main protocol. Compared to the effect by technique, cycle rate was only marginally affected by incline and only in double poling.

Discussion:

The findings indicate that the mechanism triggering technique transitions is related to body configuration and possibly dynamics of propulsion rather than speed and duration of propulsion periods. This is strengthened by the small incline dependent change in cycle rate in double poling, showing that the athletes were able to address potential limits of thrust time.

Furthermore, energy consumption plays a role (likely keeping it low as an ‘end goal’) in the choice of technique. These findings are of interest with regard to furthering our understanding of how we control gait, not only in cross-country skiing, but also in general.
References:


Gait condition in patients after primary total hip replacement one year after surgery

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¹Palacky University Olomouc, Olomouc, Czech Republic, ²University of Central Lancashire, Preston, UK

Introduction: Total hip replacement (THR) is one of the most common orthopaedic surgical procedures. Intensive rehabilitation occurs a few weeks after THR [1], with the main goal to re-educate walking pattern to physiological normal gait pattern. In practise, however, gait pattern asymmetries are often observed clinically, even after one year after surgery and beyond. These patients are rarely offered further physical therapy which may improve such asymmetries, especially if the review of the X-rays appears satisfactory.

Research Question: Are there any measurable kinematic or temporal-spatial differences between operated and non-operated limb one year after total hip replacement?

Methods: Nineteen patients (11 women, 8 men), aged 61.9 sd 13.9 years, height 168.2 sd 8.0 cm, weight 77.4 sd 10.6 kg who were on the surgical list for a primary unilateral total hip replacement were recruited. In addition, a control group of nineteen age and gender matched group healthy individuals were recruited (11 women, 8 men, age 59.3 sd 7.5 years, height 170.0 sd 8.3 cm, weight 82.7 sd 19.0 kg). Gait assessments were performed 1 day before surgery and at approximately 12 months post-surgery (12.8 months sd 1.2). Analyses of kinematic and temporal-spatial parameters were performed using a 7 camera Vicon optoelectronic system. A (2x2) mixed methods ANOVAs were performed comparing pre and post-surgery data with age match healthy subjects for the operated and non-operated limbs.

Results: The comparison pre and post-surgery were significant changes all the temporal spatial parameters (p < 0.005) with the exception of velocity. Cadence and step length were increased, double support and step time were decreased after surgery for both limbs. Ranges of motion (ROM) for the knee and hip in sagittal plane were also significant higher, and the pelvis ROM in sagittal plane was significantly decreased after surgery. For operated limb there was a significant increase in hip ROM in frontal plane and pelvis elevation. Post-surgery the velocity, cadence and step length were lower and step time was higher in comparison to control group. In addition, the sagittal ROM for pelvis was reduced post-surgery to values approaching those of the control group, and increased for hip and knee post-surgery again moving towards the values for the control group. However, the operated limb had significant lower knee extension in stance phase and pelvis drop obliquity and a significant increase in forward pelvic tilt post-surgery.

Discussion: The most of changes were found in sagittal plane showed significant improvements in hip motion and a reduction in compensation of the pelvis. However, compensation still persists even 1 year after surgery, with a greater pelvic motion due to lower hip motion, and differences remain between the operated and non-operated limbs show that there exists asymmetry in gait performance which could affect the lumbar spine and account for THR patients reporting lower back pain post THR.

Differences in Tackle biomechanics between elite young and adult Rugby players

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¹Università degli Studi di Padova, Padova, Italy, ²Federazione Italiana Rugby, Roma, Italy

Introduction:

Rugby is characterized by high force development and high speed hits, injury rate is therefore higher than in other non-contact sports. The tackle has been recognized as the task leading to the higher number of injuries, and thus to the higher recovery time. [1, 2] Young players have been reported, while performing a tackle, to place more interest on effectiveness, rather than on own safety [3]. Although injury rate has been correlated with athletes’ age [4], no researches are present in literature comparing executive technique between young and experienced players. Acceleration at contact, along with a correct body posture are needed to deliver a great force on the opponent, to perform an effective and safe tackle. Finally, to regain a quick standing posture after grounding is essential to strive for the ball possession.

Research Question:

The present study aims to investigate experience-correlated executive differences while assessing, directly on-field, the tackle efficiency.

Methods:

5 athletes belonging to the Benetton Rugby Treviso 1st XV (mean ± standard deviation (SD) BMI: 29.26±4.41, age: 24.20±4.49), and 5 athletes from the U18 XV of the Italian Rugby Federation (FIR) Academy (mean±SD BMI: 28.32±2.96, age: 17.13±0.64) took part in the study. Subjects, after signing informed consent, performed 4 repeating side-on tackles in the rugby field at 2 different heights between: the knee and the hip (KH) and the hip and the pelvis (HP). Video sequences and plantar pressure (PP) distribution were acquired by means of a Novel Pedar system and 4 synchronized cameras (GoPro Hero3+); peak PP (PPP), peak vertical ground reaction force (PV), hip, knee and ankle joints kinematics were determined [5,6] and their position with respect to the tackle task evaluated with a purposely developed Matlab code. Specific features were tracked bilaterally directly on the motion sequences [5]: acromion, C7, L5, anterior iliac spine, posterior iliac spine, greater trochanter, lateral femoral epicondyle, calcaneus, two points on the shoe matching 1st and 5th metatarsal head. Key instants were recognized as: left foot PV, right foot PV, contact. Tackler’s centre of mass (CM) acceleration have been calculated basing on 2D trajectory reconstruction; CM acceleration peaks have been recognized in three phases of the task: start-contact (PC), contact-grounding (CT), and grounding-ball retrieve (TR). Kruskal-Wallis test has been performed to highlight differences between groups.

Results:

Main findings, reported in fig.1, highlighted differences between the two groups both for kinematics and kinetics in term of PV.

Figure 1: Acceleration patterns and packs, and joints angles during the tackle (* = p<0.05)
Discussion:

The differences, both in posture and acceleration patterns, could help to understand the gesture learning process, offering a support for technique learn programming, thus offering a faster acquisition of a safer and more effective tackle execution.

References:

Pre-ACL surgery drop-jump test as assessment of injury related biomechanics alterations.

Federica Cibin¹, Davide Pavan¹, Annamaria Guiotto¹, Fabiola Spolaor¹, Alessandra Colangelo¹, Antonio Pavanello², Marino Baldo², Tiziano Casagrande², Giorgio Sbrocco¹,², Zimi Sawacha¹

¹Università degli Studi di Padova, Padova, Italy, ²Federazione Italiana Rugby, Roma, Italy

Introduction:
Screening methods for ACL injury risk should be linked to the mechanical etiology of ACL injuries in order to be effective in identifying ‘at-risk’ athletes [1]. Injuries to the ACL occur when the forces applied to the ligament are greater than the loads it can withstand [2]. Joint mechanics therefore play an important role in the ACL injury mechanism and should be taken into account when developing screening methods for ACL injuries prevention. Excessive knee valgus rotation, knee internal rotation moments and large anterior tibial translation have been identified like the most likely mechanisms for ACL injuries [2,3]. Therefore screening method for ACL injury prevention should take this biomechanics variables into account.

Research Question:
The aim of the present study is to assess differences between the injured and the healthy knee biomechanics of two elite rugby union players while performing a drop jump task, prior to surgery.

Methods:
2 ACL injured subjects participated in the study (mean ± standard deviation (SD) BMI: 32.1±3.2, age: 29.5±3.5 years). Both the athletes take part in international fixtures. After signing informed consent, subjects performed 3 repeating single leg drop-jumps per each side, and 3 repeated double leg drop-jumps from a 32cm height. Ground reaction forces (GRF) were acquired by means of a force platform (Bertec, FP2060, 960 Hz), along with bilateral EMG signals (Free 1000 BTS, 1000 Hz) from: rectus femoris (RF), biceps femoris caput lungus (BF), tibialis anterior (TA) and gastrocnemius lateralis (GL). A stereophotogrammetric system (6 cameras, 60 – 120 Hz, BTS) registered the 3D trajectories of markers positioned following the IOR-Gait protocol [4]. Collected data were hence elaborated using purposely developed Matlab code to compute knee joint angles and torques, EMG envelopes. Data comparison were carried out applying a Wilcoxon non-parametric test between healthy and injured side of each athlete.

Results:
Main findings, reported in figure 1, showed differences between injured and healthy knee, both for kinematics and dynamics on each subject. Differences were observed in term of muscle function between sides for the following muscles: RF, BF, GL.
Discussion:

Results confirmed the suitability of drop jump task in assessing ACL injury related biomechanics alterations. Furthermore, by considering the observed differences between the two legs of each athlete during the task, also the hypothesis of a relationship between muscles impairment and ACL injuries seems to be confirmed. Results could be used in order to evaluate efficacy of surgery and the subsequent rehabilitation protocol in restoring the injured knee biomechanics.

References:

Introduction:
Wearing high heels shoes change walking kinetics and kinematics and can establish potentially harmful effects on the body. Footwear design, including cushioning, toughness, stiffness, heel width and height, can change walking biomechanics. Higher heel heights contribute to slower self-select walking speeds, shorter stride lengths [1-3] and greater knee flexion, plantar flexion, anterior pelvic tilt, and trunk extension [3-5]. Our goal was to determine the effect of heel height on net joint moments at the hip, knee, and ankle with special precision placed on the knee moment.

Research Question:
How heel height affects joint moments at the hip, knee, and ankle with OpenSim software?

Methods:
Nine youthful healthy females participated in this study. Kinematic data were captured at 200 Hz using 5-camera motion analysis system (S Infrared, Vicon camera, Oxford metrics, Oxford, UK) as participants walked on the ground. Five successful trials, for each condition were obtained. The order of the test conditions was randomized. Participants use footwear with heel heights of 4.9 and 9.1 cm and barefoot in this experiment.

Results:
Ankle moments were affected by changes in heel height. For the barefoot, the ankle moment was a low magnitude inversion moment during the first 82% of stance before becoming reversal in nature during late stance. Under the 4.9 and 9.1 cm heel conditions, the ankle moment was reversal moment for nearly all of stance phase (Figure 1).

Discussion:
In support of our idea, ankle moments enhanced in magnitude as heel height enhanced. Particularly, peak ankle reversal moment was notably higher for the 4.9 and 9.1 cm heel heights compared to the barefoot conditions. On the other hands, the inversion moment at the ankle considered for the barefoot condition was not considered in the 4.9 and 9.1 cm conditions, which

Figure 1: Kinetics magnitude from OpenSim results for Hip, Knee and Ankle joint in gait cycle
is firm with the detection of Kerrigan et al. [6]. Kinetic changes at the ankle with growing heel height may also chip in larger loads at the knee. Also, putting on high heels, exclusively those with higher heel heights, may put females at majority of risk for joint decline and increasing knee osteoarthritis.

References:


The Influence of kinesthetic and verbal biofeedback on pain in women with patellofemoral pain syndrome during single leg squats

Amir dos Reis¹, Fabiano Politti¹, Nayra Rabelo¹, André Bley¹, João Correa¹, Gretchen Salsich², Paulo Lucareli¹

¹Universidade Nove de Julho, São Paulo, Brazil, ²Saint Louis University, Saint Louis, USA

Introduction: Patellofemoral pain (PFP) is one of the primary musculoskeletal injuries affecting women and young adults. Its presence is related to biomechanical disorders of the lower limb that make the hip and/or the trunk move in an altered manner during some functional activities. Among the biomechanical derangements, dynamic knee valgus and decreased trunk range of motion in the sagittal plane during closed kinetic chain activities are the main characteristics presented. Of the ways to correct the derangement, biofeedback has been highlighted in the literature as a good method of treatment for women with patellofemoral pain. The aim of this study was to compare the effects of improvement in lower limb and trunk movement pattern through kinesthetic and verbal biofeedback in the immediate symptoms of women with PFP during squatting.

Research question: Kinesthetic and verbal biofeedback are able to control hip adduction and trunk flexion movements and decrease pain during squatting in women with PFP?

Methods: This cross-sectional study included 44 women mean age (24.0 ± 4.6), Anterior knee pain scale AKPS (69.0 ± 11.0), Numerical Pain Rating Scale (5.8 ± 1.5) and presenting visual dynamic knee valgus. We collected 3D kinematics (Plug-in Gait model) of 5 sessions composed by 3 single leg squat: (1) usual self-selected squatting (SLSU); (2) real time trunk flexion graph with target set to reach 20% more than the SLSU (SLSTB); 3. real time hip adduction graph with target set to reach 20% less than the SLSU (SLSHB); (4) verbally asked to increase trunk flexion (SLSTV) and 5. verbally asked to decreased hip adduction (SLSHV). The conditions 2,3,4 e 5 was randomized. Data was collected and processes using Vicon Nexus 2.2 and for biofeedback used the Kinematic Fit method. Between each of the volunteer, the participants were asked to demarcate the intensity of their pain during that particular squat on the NPRS.

Results: There were no statistically significant differences between any of the forms of squats. There were no statistically significant differences in the comparison between SLSTV X SLSTB and SLSHV X SLSHB conditions.

Discussion: The results obtained in the present study confirm those found by Salsich et al.[1] who evaluated the influence of improved dynamic knee valgus on the immediate pain response of women with PFP during unipodal squatting and also found no reduction in symptoms. Adding different types of biofeedback like the ones tested in this study do not seem to change this scenario in terms of immediate effects.

Title: Kinematic sensitivity and specificity to detect differences between women with patellofemoral pain and healthy women during the lateral step down test?

André Silva¹, Fabiano Politti¹, Aline Novello¹, Cintia Ferreira¹, Nayra Rabelo¹, N Ekin Akalan², Paulo Lucareli¹

¹Universidade Nove de Julho, São Paulo, Brazil, ²Istambul University, Istambul, Turkey

Introduction: Patellofemoral pain (PFP) is described as anterior pain in the knee, aggravated by climbing and descending stairs, squats, running and prolonged sitting. Proximal changes such as trunk, hip, pelvic drop, adduction and medial rotation of the femur may cause pain. Recently, new studies have indicated that distal changes influence PFP [1]. The aim of this study is to analyze the kinematics of the trunk, lower limbs, rearfoot and forefoot during the beginning of the movement, 15°, 30° and 45° of knee flexion and their discriminatory capacity between patients with PFP and healthy on the lateral step down.

Research question: Are proximal and distal factors sensitive and specific to detect differences between women with patellofemoral pain and healthy women during the lateral step down test?

Methods: Thirty-four healthy sedentary women (23.85 ± 3.87) and thirty-four women with PFP (25.59 ± 6.84) were evaluated in three-dimensional kinematics during Lateral Step Down at the beginning of the movement, 15°, 30° and 45° of knee flexion. The kinematic variables that obtained an intermediate effect and large effect were selected and the ROC curve was performed to obtain values of sensitivity and specificity to identify the discriminatory capacity of the variables between the groups with patellofemoral pain and healthy individuals.

Results: Differences were found between the groups being more evident at 30° and 45° of knee flexion in the PFP group in the trunk and lower limbs.

<table>
<thead>
<tr>
<th>Cut-off Point</th>
<th>AUC</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>30° Knee Flexion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abduction of the hip</td>
<td>0.78</td>
<td>83.5</td>
<td>75.0</td>
</tr>
<tr>
<td>Adduction of the hip</td>
<td>0.84</td>
<td>89.3</td>
<td>72.6</td>
</tr>
<tr>
<td>Pronation of the rearfoot</td>
<td>0.77</td>
<td>82.4</td>
<td>74.8</td>
</tr>
<tr>
<td>Supination of the rearfoot</td>
<td>0.71</td>
<td>75.0</td>
<td>78.5</td>
</tr>
<tr>
<td>45° Knee Flexion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abduction of the hip</td>
<td>0.78</td>
<td>83.5</td>
<td>75.0</td>
</tr>
<tr>
<td>Adduction of the hip</td>
<td>0.84</td>
<td>89.3</td>
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<tr>
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<tr>
<td>Supination of the rearfoot</td>
<td>0.71</td>
<td>75.0</td>
<td>78.5</td>
</tr>
</tbody>
</table>

Discussion: Our results indicate that at 30° and 45° knee flexion the attention should be greater proximally and distally, as it is at these moments that the main kinematic alterations occur. We must consider that the best discriminatory capacity is in pelvic drop, hip adduction, rearfoot evasion in relation to the ground, forefoot pronation in relation to the rearfoot at 30° knee flexion and in eversion of the rearfoot in relation to the ground at 45° knee flexion. The importance of addressing these points during rehabilitation in patients with PFP is a possible understanding of which alterations lead to the onset of pain, and outline the best approach, being proximal or distal.

Dynamic joint stiffness of the ankle in rheumatoid arthritis postmenopausal women fallers and non-fallers

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¹CICANT/MovLab/ULHT, LISBON, Portugal, ²PORTUGUESE INSTITUTE OF RHEUMATOLOGY, LISBON, Portugal

Introduction: Rheumatoid arthritis (RA) pathogenic process may modify the viscoelasticity of the structural joint components leading to alterations of joint stability. Changes in ankle joint stability may explain gait alterations between fallers and non-fallers and may be a possible reason to the increased fall rates showed by RA patients [1] and postmenopausal women [2]. Joint stiffness plays an important role in joint stability [3], which can be studied by the dynamic joint stiffness (resistance that muscles and other joint structures manifest during inter-segmental displacement, as a reaction to an external moment of force) [4]. Dynamic joint stiffness is represented by the corresponding slope of the joint moment of force plotted as function of the joint angle [5]. Several investigations [5-7] studied the “ankle moment of force-ankle angle” relation during the gait stance phase and split the “moment of force-angle” plot into three sub-phases, namely controlled plantar flexion (CPF), controlled dorsiflexion (CDF), and powered plantar flexion (PPF). These sub-phases correspond to the three angular displacements of the ankle that happen during normal and functional stance phase (plantar flexion, dorsiflexion, and plantar flexion). However, in the best of our knowledge, the relation between falls and dynamic joint stiffness of the ankle (DJSankle) was not yet study.

Research Question: Is there a difference between RA postmenopausal women fallers and non-fallers concerning DJSankle during the gait stance phase?

Methods: The 26 RA postmenopausal women selected for this retrospective study (without early RA and lower limbs prostheses) answered the question: “How many times did you fall last year?”. Subjects were allocated to the fallers group (subjects with at least one fall in the previous year) or to the non-fallers group. Gait was assessed by a three-dimensional motion analysis system (9 cameras; 200 Hz; Vicon®) synchronized with an AMTI force plate (1000 Hz). Subjects walked barefoot at a natural and self-selected speed, performing 7 trials for the contact of each foot on force plate. Stance phase was split into three sub-phases (CPF, CDF, and PPF). A linear model represented each sub-phase and computed the DJSankle (N.m/kg/º). Coefficient of determination (R²) represents how elastic is the joint behaviour once it shows how well data fit to a linear model.

Results: Thirteen RA postmenopausal women had at least one fall in the previous year. For statistical analysis were used each ankle/foot as a subject, following Derre (2006) [8]. In both groups, R² values of the three sub-phases were higher than 0.85. RA postmenopausal women fallers showed a lower DJSankle during the CDF. There were no statistical difference between groups in the others sub-phases. Gait speed was lower in RA postmenopausal women fallers (0.82 m/s vs. 1.10 m/s, p<0.001).

<table>
<thead>
<tr>
<th></th>
<th>Fallers (n=13) mean (sd)</th>
<th>Non-fallers (n=13) mean (sd)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>DJSankle-CPF</td>
<td>0.097 (0.037)</td>
<td>0.055 (0.031)</td>
<td>0.820</td>
</tr>
<tr>
<td>DJSankle-CDF</td>
<td>0.090 (0.013)</td>
<td>0.062 (0.014)</td>
<td>0.002</td>
</tr>
<tr>
<td>DJSankle-PPF</td>
<td>0.054 (0.016)</td>
<td>0.055 (0.012)</td>
<td>0.546</td>
</tr>
<tr>
<td>R²-CPF</td>
<td>0.893 (0.078)</td>
<td>0.913 (0.070)</td>
<td>0.343</td>
</tr>
<tr>
<td>R²-CDF</td>
<td>0.908 (0.048)</td>
<td>0.894 (0.055)</td>
<td>0.319</td>
</tr>
<tr>
<td>R²-PPF</td>
<td>0.979 (0.014)</td>
<td>0.988 (0.018)</td>
<td>0.023</td>
</tr>
</tbody>
</table>

Discussion: In RA postmenopausal women, the three sub-phases of the gait stance period can be translated into a linear moment-angle relationship (R²>0.85). RA postmenopausal women fallers showed lower values of DJSankle during CDF as well as a reduction in gait speed. A previous study pointed to a speed dependence of the DJSankle (an increase in gait speed conduct to higher values of DJSankle during CDF) [7]. So, we do not know if this change in DJSankle will be a factor that contributes to falls or a consequence of them (i.e., changes to ensure a safer gait pattern). Further studies will be necessary.
THE RELATIONSHIP BETWEEN PROPRIOCEPTION OF UPPER AND LOWER EXTREMITIES, DYNAMIC BALANCE AND CORE STABILIZATION

Veysel AKDUMAN, Zübeýir SARI, Zehra Betul KARAKOC

MARMARA UNIVERSITY, ISTANBUL, Turkey

Introduction: The core includes the lumbopelvic hip joint complex and its surrounding musculature, which function synergistically to produce force, reduce force and provide dynamic stabilization throughout the kinetic chain (1). Core stabilization is an ability to control movement and position of the trunk. As the primer muscles are lumbar spine and pelvis stabilizers, there is a relationship between activity of trunk muscles and movement of lower extremity and upper extremity. Therefore, It has been pointed out in many studies that core stabilization increases the risk of injury of lower extremity and upper extremity. However, there is no study of whether the proprioception of the upper and lower extremities and dynamic balance can affect the core stabilization or not.

Research question: Is there any relationship between the endurance of the core muscles and the proprioception of the extremities and dynamic balance?

Methods: This study included sixty (37 female, 23 male, mean age 20.9 ± 2.46) healthy volunteers. McGill Core Endurance Test -trunk anterior flexor test (TAFT), right lateral plank test (RLPT), left lateral plank test (LLPT), trunk posterior extensor test (TPET)- was applied to assess core stabilization (2). Pedalo® was used for dynamic balance measurement. MarvaJed was used for proprioception measurement. Specific angles were shown to participants. It was asked to find these angles with their eyes closed and the divergence angle recorded. “In case of finding the desired angle, the proprioception was saved as 0”. Spearmann correlation test was used to determine the relation between the parameters.

Results: Correlation between the parameters are shown in table 1. Furthermore, there was a correlation between parameters of McGill Core Endurance Test.
DOES PHYSICAL ACTIVITY LEVELS IN UNIVERSITY STUDENTS EFFECT CORE STABILIZATION?

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Introduction: Core stabilization is an ability to control movement and position of the trunk. It has been observed that the increase in core stabilization is effective in reducing back pain risk and prevent injuries. Core muscles are used in daily activities such as sitting, lifting, walking as well as sportive activities. Therefore, it is an important muscle group that should be strengthened in posture disorders, back pain and sports activities (1). Coordination of these muscles is important to spinal stabilization. Physical activity focused on these groups of muscles could contribute to pain alleviation and spinal functional improvement.

Research question: Does Physical Activity Levels in University Students Effect Core Stabilization?

Methods: The cross-sectional study included 350 students (181 females and 169 males) with a mean age of 19.8 ± 1.9 years. The period of core stabilization was determined using plank test in which the body is stand flat from shoulder to heels on foot and forearm and side plank test in which sitting on the forearm and standing on one side of the body with the legs parallel and the feet perpendicular and the body is held flat from the shoulder to the heels. It was wanted to stand on the dominant side to all participants in the side plank test. The duration of these tests is measured by a chronometer (2). Physical activity level was evaluated by the short form of the International Physical Activity Questionnaire (IPAQ). IPAQ is a scale to be recorded at different levels of physical activity time in the last week. IPAQ is a scale to be recorded at different levels of physical activity time in the last week. The short form (9 items) provides information on the time spent walking (IPAQ5), in vigorous (IPAQ1) and moderate-intensity (IPAQ3) activity and in sedentary activity (IPAQ7). Individuals whose score is lower than 600 MET are described as inactive, between 600-1500 MET are described as minimal active and higher than 3000 MET are described as active (3).

Results: The parameters that determine a correlation are shown in table 1. Between core stabilization tests (plank and side plank test) and walking (IPAQ 5) and sedentary activity (IPAQ 7) was not found any significant correlation (p>0.005). Additionally, In this study, the average of plank test duration was 77.0 ± 43.8 (sec), while the mean of the side plank test duration was 43.9 ± 28.0 (sec). According to the short form of IPAQ, %14.8 percent of students were found inactive, % 48.1 percent of students were found minimal inactive and %37.1 percent of students were found active.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Significance</th>
<th>IPAQ 1</th>
<th>IPAQ 3</th>
<th>IPAQ 5</th>
<th>IPAQ Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plank test</td>
<td>r</td>
<td>,654*</td>
<td>,236*</td>
<td>,061</td>
<td>,269*</td>
</tr>
<tr>
<td></td>
<td>p-value</td>
<td>,000</td>
<td>,011</td>
<td>,283</td>
<td>,000</td>
</tr>
<tr>
<td>Side plank test</td>
<td>r</td>
<td>,214*</td>
<td>,434*</td>
<td>,452*</td>
<td>,195*</td>
</tr>
<tr>
<td></td>
<td>p-value</td>
<td>,000</td>
<td>,012</td>
<td>,193</td>
<td>,001</td>
</tr>
</tbody>
</table>

Table 1
Discussion: Core stability remains a key component in clinical rehabilitation, the training of competitive athletes and the training programs of individuals who are endeavoring to improve their health and physical fitness (4). In this study, it was found that vigorous and moderate intensity physical activity improve core stabilization. For this reason, it is necessary to give an importance vigorous and moderate intensity activity in order to improve core stabilization. This is the first study that investigates the relationship between physical activity levels and core stabilization. Further studies should be carried out to interpret that link more accurately by increasing the number of cases.

References:


ARE THERE ANY CORRELATIONS BETWEEN FPI AND STATIC, DYNAMIC, FUNCTIONAL VALUES OF FOOT?

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¹MARMARA UNIVERSITY, ISTANBUL, Turkey, ²TURKIYE SPASTIK COCUKLAR VAKFI, ISTANBUL, Turkey

Introduction: Foot posture should be affected by alignment of lower extremities, bodies and upper extremities. Foot Postur Index (FPI) is a common useful assessment tool for describing foot position by clinicians don't require specific instrument. Previous studies have shown that an excessively pronated foot or a highly supinated foot may alter standing balance in healthy young adults, but limited evidence has been reported regarding whether similar findings exist for older adults. Different types of foot postures may present with different limitations in the musculoskeletal properties. For this reason, it is important to determine the foot posture.

Research Question: Are There Any Correlations Between FPI and static, dynamic, functional values of foot?

Methods: Fifteen female and 15 male totally 30 young adults (age range between 20-25 years) were included in the study. Static foot postures of subjects were assessed by using the 6-item Foot Posture Index (FPI) (1). Pedobarography system (EMED-M,38×42cm, four sensors per square centimeter, 50Hz;NovelGmbH.Munich,Germany) was dynamically and statically performed to retrieve walking patterns at self-selected speed Maximum pressure(N and %BW), peak pressure (kPa), contact area (mm) were obtained per foot. Center of pressure excursion index(CPEI) (2), Chippaux-Smirak Index(CSI), Keimig Indices Index(KI) and Alpha Angle(AA) were calculated (3). While ankle joint proprioception(AJP) was measured using the Biodex System 4 Pro(BiodexMedicalSystem,Inc.,NY,USA), postural stability(PS) was assessed with Pedalo. Independent T test was used to compare neutral and prone foot types. Pearson correlation test was used to investigate whether there was a significant relationship between FPI scores and other measurements. Significance was determined as p<0.05.

Results: Correlation between the parameters are shown in table 1 and table 2.

Table 1

<table>
<thead>
<tr>
<th>FPI</th>
<th>PS</th>
<th>AI</th>
<th>AJP 10° inversion</th>
<th>AJP 10° inversion</th>
<th>AJP 20° inversion</th>
<th>CSI</th>
<th>SI</th>
<th>AA</th>
<th>CPEI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>r</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>p</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>r</td>
<td>0.263</td>
<td>-0.006</td>
<td>-0.056</td>
<td>-0.222</td>
<td>0.117</td>
<td>-0.017</td>
<td>-0.023</td>
<td>-0.252</td>
<td>-0.054</td>
</tr>
<tr>
<td>p</td>
<td>0.021</td>
<td>0.482</td>
<td>0.336</td>
<td>0.044</td>
<td>0.417</td>
<td>0.448</td>
<td>0.430</td>
<td>0.026</td>
<td>0.342</td>
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</table>

Table 2

<table>
<thead>
<tr>
<th>FPI</th>
<th>AA</th>
<th>SI</th>
<th>CSI</th>
<th>AJP 20° inv.</th>
<th>AJP 10° inv.</th>
<th>AJP 10° ever.</th>
<th>Al</th>
<th>CPEI</th>
<th>PS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neutral</td>
<td>49.00±7.36</td>
<td>0.51±0.13</td>
<td>0.33±0.07</td>
<td>2.65±2.20</td>
<td>3.78±3.48</td>
<td>4.24±4.43</td>
<td>17.62±7.14</td>
<td>0.25±0.02</td>
<td>75.69±13.09</td>
</tr>
<tr>
<td>p-value</td>
<td>p:0.094</td>
<td>p:0.985</td>
<td>p:0.891</td>
<td>p:0.145</td>
<td>p:0.154</td>
<td>p:0.889</td>
<td>p:0.164</td>
<td>p:0.850</td>
<td>p:0.382</td>
</tr>
<tr>
<td>Prone</td>
<td>45.14±7.60</td>
<td>0.51±0.14</td>
<td>0.33±0.01</td>
<td>3.75±3.13</td>
<td>2.37±1.91</td>
<td>4.07±2.51</td>
<td>20.57±5.73</td>
<td>0.25±0.05</td>
<td>79.00±8.88</td>
</tr>
</tbody>
</table>
**Discussion:** The results showed that CPEI, CSI, KI, AA and AJP did not differ between neutral and prone foot posture in whole foot. FPI was significantly correlated with PS (p=0.021, r=0.263), AJP 10° inversion (p= 0.044, r = -0.222), AA (p=0.026, r=-0.252). Different cut off values may be required when using the FPI-6 to screen for individuals with prone and neutral feet participants identified by FPI-6 classifications. We found that there is no relation between FPI and CPEI, CSI, KI, AA and AJP in our study. These results may be due to little sample size. Further studies should be carried out to interpret that link more accurately by increasing the number of cases.

References:


Musculoskeletal activity monitoring using near-infrared spectroscopy

Mireille van Beekvelt

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Near-infrared spectroscopy (NIRS) has shown to be a valuable tool to monitor skeletal muscle oxygenation during various modes of activity. The non-invasive NIRS technology enables direct in vivo evaluation of oxidative metabolism in a relatively easy manner and has, over the past decades, been progressively used to study a wide range of applications within sport, health and clinical sciences. However, despite this progressive use of NIRS in often highly complex studies, many of the methodological questions remain e.g. with respect to the accuracy and reliability of the method. This study focused on some of the basic aspects of monitoring skeletal muscle oxygenation during various types of exercise and addresses issues as to how exercise mode and exercise intensity affect muscle oxygenation in various muscles with different roles in the exercise task. Whole body and isolated muscle work will be presented. It was shown that blood volume changes in the legs during a (mainly) upper body exercise task were in favour of the upper body muscles. This in contrast to the blood volume changes occurring in a (mainly) lower body exercise task. Muscle desaturation/deoxygenation was most pronounced in the muscles that were considered the main motors of the exercise task. However, even though exercise was performed at high/max intensity, desaturation/deoxygenation did not reach maximum values for desaturation/deoxygenation as obtained during vascular occlusion. In conclusion, these data show that near-infrared spectroscopy is able to monitor the functional heterogeneity of O2 delivery and O2 consumption between various muscles and various tasks. This heterogeneous dynamic adaptation depends on the muscle monitored, the exercise task performed as well as on exercise intensity.
Unintentional drifts during quiet stance and voluntary body

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Introduction: Unintentional drifts in motor performance have been shown in young, healthy individuals when visual feedback is withdrawn, even though they were supposed to continue doing what they have been doing. Previously, these observations were related to limitations of motor memory, which supported by clinical studies and brain imaging. However, recent studies have challenged this interpretation [1]. For example, memorizing and reproducing force is not followed by force drift to lower magnitudes [2]. Recently, an alternative explanation has been suggested within the physical approach for control of movements (referent coordinates hypothesis) [3], which views the documented force drop as a reflection of the natural tendency of physical systems to move toward minimum of potential energy.

Research Question: Are there unintentional drifts in a highly functional task (i.e. standing) combined with steady-state or sway tasks after removal of visual feedback?

Methods: Eleven young healthy individuals participated in this study. They stood quietly on a force platform and performed voluntary body sway with metronome at 0.5 Hz both in the anterio-posterior (AP) and medio-lateral (ML) directions. Visual feedback on the center of pressure (COP) coordinate was presented and then removed. In all the tasks, subjects performed the first 10 s with visual feedback and then without visual feedback. During steady-state trials, subjects shifted initial COP coordinate by 3 cm to the anterior, posterior, right, and left from the coordinate during natural standing, and simultaneously contracted the right tibialis anterior to 30% of its maximal voluntary contraction. During cyclical voluntary sway task, subjects swayed with sway amplitude of 4 cm at one of the four mentioned conditions. Moreover, motor equivalent and non-motor equivalent inter-cycle motion components were quantified within the space of muscle groups (muscle modes) under visual feedback and at the end of the period without visual feedback.

Results: In the steady-state tasks, removing visual feedback led to COP drifts, which could be in opposite directions across subjects but there was a consistent drop in the activation level of tibialis anterior. In cyclical voluntary sway tasks, removing visual feedback caused a consistent increase in the sway amplitude and a drift of the midpoint. In general, there were large motor equivalent motion components, which increased during the period without visual feedback.

Discussion: The current study shows that unintentional drifts exist in both steady-state and voluntary cyclical sway tasks of posture. The findings indicates that two main factors define directions of COP drifts including drift of the body referent coordinate toward the actual coordinate (it can cause fall) and an opposite drift to ensure body motion to a safer location. In addition, analysis of motor equivalence suggests that postural stability is not compromised during unintentional drifts in performance because of the vital importance of postural stability for everyday activities.

Importance of vision for minimizing postural sway evidenced through a battery of simple standing balance tasks and a chest-worn accelerometer

Philippe Terrier, Fabienne Reynard

Clinique Romande de Réadaptation, Sion, Switzerland

Introduction: During quiet standing, the continuous adjustment of the position of the center of gravity within the base of support is defined as the postural sway. In order to minimize that sway, visual, somatosensory, and vestibular feedbacks combine to modulate the central control of postural muscles. Many diseases and conditions alter balance control by interfering with those sensory feedbacks, inducing a larger postural sway and, hence, a higher fall risk. For this reason, the measure of the postural sway is a privileged diagnostic tool. Furthermore, the manipulation of visual inputs is often employed to assess the weight of the different sensory modalities in balance control.

Aiming at rapid balance evaluation in clinical settings, we propose to measure postural sways with a simple accelerometer during a short trial that includes various standing tasks realized either with eyes open or eyes closed. Here, we present a preliminary analysis that focuses on vision effects. The objective was to document the increase in postural sway amplitude due to visual deprivation and task difficulty. In addition, directional effects were also assessed.

Research Question: How much healthy adults rely on vision to minimize postural sway when performing standing tasks of increasing difficulty?

Methods: 100 healthy adults (50 men, 50 women, mean age: 44yr.) wore a 3D accelerometer at chest level sampling their trunk acceleration at 100Hz. In a random order, they performed 4 standing tasks of increasing difficulty lasting 30sec each, first with eyes open and then with eyes closed: standing still feet apart; standing still feet together, standing still feet together on compliant foam; standing still on one foot (dominant leg). The average amplitude of trunk sway was assessed through the root mean squared (RMS) of the acceleration signals recorded along the anteroposterior (AP) and the mediolateral (ML) direction.

Results: The table shows the medians and interquartile ranges (IQR) of the AP and ML postural sways (RMS, earth acceleration unit (g x 1000)) across the four standing tasks. Bold values indicate significant changes (Wilcoxon signed rank test, p<0.05).

<table>
<thead>
<tr>
<th></th>
<th>Standing feet apart</th>
<th>Standing feet together</th>
<th>Standing on foam</th>
<th>One foot standing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AP sway</td>
<td>ML sway</td>
<td>AP sway</td>
<td>ML sway</td>
</tr>
<tr>
<td>Eyes open</td>
<td>12.4</td>
<td>6.2</td>
<td>13.8</td>
<td>7.1</td>
</tr>
<tr>
<td>IQR</td>
<td>(4.6)</td>
<td>(2.9)</td>
<td>(4.7)</td>
<td>(2.8)</td>
</tr>
<tr>
<td>Eyes closed</td>
<td>13.2</td>
<td>6.3</td>
<td>15.6</td>
<td>9.4</td>
</tr>
<tr>
<td>IQR</td>
<td>(5.0)</td>
<td>(2.4)</td>
<td>(5.8)</td>
<td>(2.7)</td>
</tr>
<tr>
<td>Relative increase</td>
<td>7%</td>
<td>2%</td>
<td>13%</td>
<td>33%</td>
</tr>
</tbody>
</table>

Discussion: Outstandingly, the effects of visual deprivation on postural sway rose sharply with task difficulty. Quiet standing on one foot depended on vision very strongly. Indeed, a 3-5.5x increase of the postural sway amplitude between conditions was observed. In contrast, standing still feet apart had similar sway amplitudes with or without vision. This may indicate that vision is particularly helpful in correcting large deviations induced by unsteady conditions.
Directional effects are particularly evident in bipedal tasks: sway amplitudes were larger in sagittal plane (AP) as compared to the frontal plane (ML). This may result from the ankle strategy that acts prominently in the AP direction. On the other hand, the absence of vision tended to increase the ML sways more than the AP sways. One explanation could be that vision dominates the control of the ML balance as compared to other sensory feedbacks, whilst it is less the case for the AP balance.

From a methodological point of view, the assessment of postural sway amplitude with the chest-worn accelerometer seemed sensitive enough to differentiate among task difficulties, to evaluate the impact of visual deprivation, and to highlight directional effects. Results can constitute reference values against which abnormal values measured in patients could be compared. Further analyses are in progress to assess the reliability of the method.
Immediate effects of spinal manipulation on dynamic electromyographic activity of nonspecific chronic low back pain subjects

Walkyria Vilas Boas Fernandes, Fabiano Politti, Fernanda de Córdoba Lanza, Paulo Garcia Lucareli, João Carlos Ferrari Corrêa

Nove de Julho University, São Paulo/São Paulo, Brazil

Introduction: Low back pain can cause considerable suffering, with possible disability as well as reduction in quality of life and productivity. The aim of the study was to evaluate the immediate effect of manipulative intervention on pain and electromyographic (EMG) activity of the paraverterbral muscles in patients with nonspecific chronic low back pain (NCLBP).

Research Question: What's the immediate effects of the spinal manipulation in the electromyographic amplitude of the paraverterbral muscles, pain intensity and disability index of individuals with chronic low back pain?

Methods: Forty patients with NCLBP were randomized into two groups, manipulation (n =20) and control (n =20). While the manipulation group received bilateral high-velocity spine manipulation, the control group received a sham manipulation. They remained lying in the same position of the spinal manipulation for 10 seconds on each side. Numerical Pain Rating Scale (NPRS) (range: 0 to 10) and surface EMG were performed before and after the treatment by an assessor blinded to group allocation of the patients. EMG was used to verify activity in the right and left paraspinal muscles (L4-L5 level) during trunk flexion-extension cycles (Flexion Relaxation Phenomenon).

Results: A four-way ANOVA with repeated measures was used to evaluate the effect of the intervention on EMG amplitude (RMS normalized by maximal voluntary contraction). A significant difference was observed between groups (F=5.43, p < 0.02). The post hoc Bonferroni test revealed a significant decrease in EMG activity in the flexion (p<0.0001), rest (full flexion) (p=0.01) and extension (p=0.01) phases and no differences were found in control group (p>0.05). Wilcoxon test revealed significant decreases after treatment in NPRS for the manipulation group (mean difference: -1.60, IC95%: -2.09 to -1.10; p<0.0001) and no statistical difference in control group was found (mean difference: -0.50, IC95%: -1.25 to 0.55; p=0.19).

Discussion: This study demonstrated the immediate effects of the high-velocity spine manipulation decreases in the electromyographic activity of the paraverterbral muscles during the flexion relaxation phenomenon and pain intensity in patients with nonspecific chronic low back pain.

References:


Dynamic surface electromyography response in nonspecific chronic low back pain treated by spine manipulation – A randomized, placebo-controlled, clinical-trial

Walkyria Vilas Boas Fernandes, Fabiano Politti, Fernanda de Córdoba Lanza, Paulo Roberto Garcia Lucareli, João Carlos Ferrari Corrêa

Nove de Julho University, São Paulo/São Paulo, Brazil

Introduction: The electrical activity of the trunk muscles can be used to observe effects of therapeutic interventions and also to differentiate individuals with low back pain from asymptomatic individuals. People suffering from low back pain have higher electromyographic signals compared to asymptomatic individuals. The purpose of the study was to investigate the effect of manipulative treatment on the electromyographic (EMG) activity of the paraverterbral muscles, pain intensity and lumbar disability index in patients with nonspecific chronic low back pain (NCLBP).

Research Question: Does the manipulative intervention influence the electromyographic amplitude of the paraverterbral muscles, pain intensity and disability index of individuals with chronic low back pain?

Methods: Thirty-six patients with NCLBP were randomized into two groups: manipulation (n =18) and control (n =18). While the manipulation group received bilateral high-velocity spine manipulation, the control group received a sham manipulation. They remained lying in the same position for 10 seconds on each side. We assessed Numerical Pain Rating Scale (NPRS) (range: 0 to 10), the Oswestry disability index (ODI) and electromyography (EMG) activity of the paraverterbral muscles (L4-L5 level) pre and post six sessions of treatment by an assessor blinded to group allocation of the patients. The EMG signal was collected during the trunk flexion-extension motion (Flexion relaxation phenomenon), and the NPRS always after this movement.

Results: The four-way repeated measures analysis of variances (ANOVA) revealed significant difference between groups (F=16.21, p < 0.0001) in EMG amplitude signal. The post hoc Bonferroni test revealed a significant decrease in EMG activity in the flexion (p<0.0001), rest (full flexion) (p=0.0001) and extension (p=0.0001) phases in the Manipulative group. In the control group, no differences were found after six sessions of treatment in the flexion (p=0.06) and the rest (p=0.08) phase, only in the extension phase the differences were significant (p=0.03). Wilcoxon test revealed significant decreases after treatment in NPRS (mean difference: -2.30, IC95%: -3.53 to -1.06; p <0.0001) and ODI (mean difference: -8.36, IC95%: -12.24 to -4.48; p<0.0001) for the manipulation group and the control group no statistical difference was found for NPRS (mean difference: -0.35, IC95%: -1.25 to 0.55; p=0.41) and ODI (mean difference: -3.59, IC95%: -8.01 to 0.83; p = 0.10) variables. The individual who missed the last session was analyzed with intent to treat.

Discussion: This study found decreased electromyographic amplitude of the paraverterbral muscles (L4-L5 level) during the flexion relaxation phenomenon. The ODI and pain intensity also decreased in patients with nonspecific chronic low back pain treated with manipulative intervention during six sessions.

References:

Upper limb three-dimensional motion analysis: A comparison between children with unilateral cerebral palsy and typically developing children using Statistical Parametric Mapping

Cristina Simon-Martinez¹, Eirini Papageorgiou¹, Ellen Jaspers², Lisa Mailleux¹, Kaat Desloovere¹, Els Ortibus³, Katrijn Klingels¹,₄, Hilde Feys¹

¹KU Leuven, Department of Rehabilitation Sciences, Leuven, Belgium, ²Neural Control of Movement Lab (ETH Zurich), Zurich, Switzerland, ³KU Leuven, Department of Development and Regeneration, Leuven, Belgium, ⁴University of Hasselt, Rehabilitation Research Center, Hasselt, Belgium

Introduction:

Upper limb (UL) three-dimensional motion analysis in children with unilateral cerebral palsy (uCP) has thus far been investigated using various tasks, vastly challenging the comparison between studies. Moreover, studies mainly focused on feature analyses of waveforms by extracting scalars or performing point-by-point comparisons, thereby ignoring the dependency between the time-points of the waveforms. Statistical Parametric Mapping (SPM) overcomes these limitations by using random field theory to identify field regions while taking the covariance between time-points into account. Furthermore, the comparison between UL kinematics between uCP and typically developing children (TDC) has so far been done with summary indices that might be insufficient to elucidate in which part of the waveform the movement deviation is present.

Research Question:

To understand UL movement pattern deviations in children with uCP by comparing UL kinematic waveforms between TDC and children with uCP in 8 tasks. The ultimate goal is to select the tasks that best fit for studying UL motion analysis in children with uCP.

Methods:

Sixty children with uCP (mean age 10y4m±2y5m), 35 boys, 18 MACS I, 28 MACS II, 14 MACS III) and 60 age-matched TDC (mean age 10y3m±3y2m), 36 boys) were included. Children sat in a custom-made chair and were instructed to perform three reaching tasks (reaching forwards (RF), sideways (RS), upwards (RU)), two reach-to-grasp tasks (grasp a sphere (RGS), grasp a vertical cylinder (RGV)) and three functional tasks (hand-to-head (HTH), hand-to-mouth (HTM), hand-to-shoulder (HTS)). The non-dominant UL in TD and impaired UL in uCP were tested. SPM1d was used to compare the waveforms of both groups in 13 joint angles (trunk, scapula, shoulder, elbow and wrist). Statistical significance was set at alpha < 0.01.

Results:

SPM(t) tests identified statistically significant differences between uCP and TDC in all tasks for at least eight joints (18-100% of the curve). Compared to TDC, trunk movement patterns of the uCP-group were characterized by outward rotation in RGV, HTM and HTS (78-100%, z=3.05-3.12, p < 0.0001); the scapula remained more anterior, protracted and medially rotated during all tasks, but differences were most evident in HTS (37-100%, z=2.98-3.03, p < 0.001). During all three functional tasks, the uCP-group moved with increased external shoulder rotation (67-74%, z=2.98-3.05, p < 0.001), whilst they had a more frontal arm elevation during RF, RU, RGS and RGV (88-100%, z=3.04-3.10, p < 0.0001). Differences between groups were strongest distally, with increased pronation and wrist flexion in the uCP-group (100%) in all tasks, except RS; as well as increased elbow flexion for all tasks, though most pronounced during RGS, RGV (78-100%, z=3.12-3.15, p < 0.0001).

Discussion:

We identified specific percentages of the waveforms where children with uCP show abnormal UL movement patterns for the wrist, elbow, shoulder, scapula and trunk during different tasks. RGV, HTH and HTS systematically showed most differences between both groups, which points to their
discriminative value. Our results highlight the added value of SPM1d to further understand UL movement pathology in uCP.

References:


Muscle weakness impacts negatively upper limb movement patterns in children with unilateral cerebral palsy

Cristina Simon-Martinez1, Eirini Papageorgiou1, Ellen Jaspers4, Lisa Maileux1, Kaat Desloovere1, Els Ortibus2, Katrijn Klinges1,3, Hilde Feys1

1KU Leuven, Department of Rehabilitation Sciences, Leuven, Belgium, 2KU Leuven, Department of Development and Regeneration, Leuven, Belgium, 3University of Hasselt, Rehabilitation Research Center, Hasselt, Belgium, 4Neural Control of Movement Lab (ETH Zurich), Zurich, Switzerland

Introduction:

Upper limb three-dimensional motion analysis (UL-3DMA) in children with unilateral CP (uCP) has thus far been investigated using various tasks, vastly challenging the comparison between studies. Based on Statistical Parametric Mapping (SPM1d), we previously highlighted the value of reach-to-grasp a vertical cylinder (RGV), hand-to-head (HTH) and hand-to-shoulder (HTS) to study UL movement pathology in uCP. SPM1d takes into account the dependency between the time points of the waveform, by using random field theory, which allows identifying areas in the waveform where the differences are present or where a specific parameter may interfere. Muscle weakness has been shown to impact negatively on activity measures of UL function in children with uCP, though it remains unknown to what extent this motor impairment impacts on UL movement pathology.

Research Question:

To examine the role of elbow and wrist muscle weakness on kinematic waveforms during three tasks (RGV, HTH and HTS).

Methods:

Sixty children with uCP (mean age 10y4m (SD 2y5m), 25 girls, 29 right-hemiplegia, n=18 MACS I, n=28 MACS II, n=14 MACS III) participated in this study. Children were recruited via the CP-care program from University Hospitals Leuven. The affected UL was measured using a 3DMA during the execution of three tasks: RGV, HTH and HTS. Manual Muscle Testing (score 0-5) was used to evaluate muscle strength in elbow and wrist extensors and elbow supinators. Individual muscle scores were summed to calculate the overall score (range 0-25). SPM1d was used to perform a linear regression analysis between the kinematic waveforms and muscle weakness (overall score). Statistical significance was set at alpha< 0.01.

Results:

Elbow and wrist weakness significantly explained the increased elbow flexion and pronation during RGV in 44% and 75% of the curve, respectively (flexion, z=3.21, p=0.0012; pronation, z=3.21, p < 0.0001). Muscle weakness also accounted for increased pronation during more than half of the movement of HTH (64%, z=3.26, p < 0.0001) and HTS (60%, z=3.23, p < 0.0001). Also, muscle weakness explained increased wrist flexion of the entire movement for all three tasks (RGV, z=3.35, p < 0.0001; HTH, z=3.29, p=0.0001; HTS, z=3.24, p < 0.0001). Last, increased shoulder elevation was also explained by muscle weakness for all tasks (RGV, z=3.25, p=0.003; HTH, z=3.24, p=0.006; HTS, z=3.28, p < 0.0001), though weakness did not contribute to shoulder rotation and elevation plane movement pathology.

Discussion:

We used a linear regression in SPM1d to identify for the first time the adverse impact of muscle weakness on the kinematic waveforms of the elbow, wrist and shoulder during three different UL tasks. The results show that SPM1d could be of clinical relevance to increase our understanding of the relation between UL impairments and movement pathology. In the long run, such insights will contribute to further optimization of UL rehabilitation in uCP.
References:


Trunk inclination during walking in people with knee osteoarthritis

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Introduction: An increase in sagittal trunk inclination (forward lean) during walking will create an anterior shift in the centre of mass position and this will lead to corresponding changes in lower extremity joint moments. For example, it has been shown that people who habitually walk with increased trunk inclination exhibit an increase in the magnitude and timing of the hip extensor moment [1]; a change which is likely to be accompanied by changes in hamstring activation.

Previous research has demonstrated that people with knee osteoarthritis (OA) stand with increased trunk inclination [2] and also exhibit altered lower extremity joint moments during walking [3]. Given the changes which will accompany increased trunk inclination, it is possible that the previously observed biomechanical characteristics of people with knee OA may be the result of differences in upper body position during walking. However, to investigate this idea, it is first necessary to understand whether there are clear differences in trunk inclination during walking between healthy people and individuals with knee OA.

Research Question: What is the differences in trunk inclination during walking between people with knee osteoarthritis and healthy individuals?

Methods: Kinematic and force data was collected during walking from 10 participants with knee OA and 10 healthy subjects. Participants with knee OA were instructed to walk at their self-selected speed and healthy participants instructed to walk at a speed which matched the knee OA subjects. Mean ages, weights and heights were almost identical between the two groups. A trunk segment was defined using markers placed over the greater trochanters and the acromions and tracked using markers placed over the jugular notch, T2 and T8. Following data collection, an ensemble average trunk inclination was derived for each participant and the mean inclination calculated over the period 15-25%. This period was selected as it corresponds to the period of maximal knee loading. Trunk inclination was compared between the two groups using independent t-tests.

Results: The mean trunk inclination in the knee OA group was 4.5°, which was 2.3° greater than the mean of the healthy participants (Figure 1). However, this difference was not significant (p=0.17).

Figure 1: Mean (SD) trunk inclination for healthy participants and those with knee osteoarthritis

Discussion: In their recent study, Turcot et al. [2] observed people with knee OA to exhibit an average of 2.9° more trunk inclination than a healthy control group. Although this difference (in standing) is similar in magnitude to the difference observed during our study (in walking), our data did not achieve statistical significance. Nevertheless, there were only a small number of participants in this present study (n=10 each group) and therefore further (ongoing) work is required to establish if this trend of increased trunk inclination is a true characteristic of walking in people with OA.

References:


Fall Risk of Community-dwelling Cancer Survivors With Objective Measures of Gait and Balance

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Introduction:

Falls are the leading cause of injuries, hospital visits, nursing home admissions, and reduced quality of life in older adults; resulting in $35,000 average hospital cost per fall and a total of $34 billion in medical costs. Recent reports suggest that falls increase by 25-50% in cancer patients both during and after cancer treatment. Cancer and cancer treatments often cause loss of strength, decreased coordination and sensation, and decline in balance and gait. Yet, falls in cancer patients remain largely unrecognized and under-treated, likely because there are no easily obtained clinical metrics which indicate fall risk that have been validated in the oncology setting. While there is a consensus that impaired balance and gait are the basis for most falls, it is difficult for oncology providers to evaluate these complex abilities during routine cancer care.

Research Question:

Determine the sensitivity of balance and gait metrics to predict falls in community-dwelling cancer survivors.

Methods:

The study population is post-treatment, community-dwelling cancer survivors where persistent side effects and symptoms lead to increased falls beyond the risk imposed by aging. We analyzed data from 50 post-treatment women cancer survivors enrolled in a clinical fall prevention exercise trial (The GET FIT trial; 1R01CA120123) to examine the relationship between balance and gait metrics with falls at enrollment. Falls were determined by monthly surveys for 12 months after baseline. Each subject was labeled as either a faller (1 or more falls in 12 months) or non-faller. We applied stepwise logistic regression on 27 predictor variables that were selected by the investigators based on their experience and results from the literature. Variables were only added to the model if the p-values were <0.05. Likewise, all variables with p-values >0.05 were removed.

Results:

Three of the subjects did not successfully complete the balance test at baseline, leaving 47 subjects for the analysis. Of these, 29 subjects reported one or more falls over the twelve-month follow-up period. The model selection procedure produced a model based on just two variables: the root mean square of the anterior-posterior sway acceleration [1-2] and the stride length as a percentage of stature [2-5]. This model attained an area under the receiver operator characteristic curve of 0.75 and had a sensitivity of 47.4% at a specificity of 96.4%.

Discussion:

The two predictor variables selected by the model are consistent with the results of other groups in other fall risk populations. These results demonstrate the potential of instrumented and objective assessment methods providing early indications of fall risk that may ultimately lead to better clinical decisions, frequent monitoring and early detection of fall risk, timely intervention with therapeutic interventions, such as physical therapy, and the ability to measure responsiveness to traditional or new fall prevention approaches. These results warrant further investigation of instrumented measures of fall risk.

References:


Postural stability does not distinguish between active elderly fallers and nonfallers

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Introduction: Time behaviour measurements of the centre of pressure of a person positioned on a force plate is one of the most commonly used tool to investigate a balance. However, the findings of the studies focused on the relationship between postural stability and fall risk are not uniform. The aim of this study was to assess the ability of postural stability assessment to distinguish between elderly nonfallers and fallers.

Research Question: Is there any difference in a mean velocity of centre of pressure during quiet stance among elderly fallers and nonfallers?

Methods: A prospective study design was used. The observed group consisted of 151 participants with age 71.2 ± 6.6 years, height 162.8 ± 7.7 cm and body weight 76.4 ± 13.4 kg. At the baseline, velocity of centre of pressure in medial-lateral and anterior-posterior direction during 30 s of quiet standing was assessed in four conditions (open eyes and closed eyes, firm and foam surface). In addition, the Activities-specific Balance Confidence (ABC) Scale questionnaire was fulfilled by the participants. Falls occurrence was recorded using prospective daily recording with a minimum of two-week telephone interview for a period of one year. After that, participants were divided into three groups as follows: nonfallers (N), fallers (F) – one fall occurrence in one year, multiple fallers (MF) – two or more fall occurrences during one year.

Results:

No significant difference in centre of pressure velocity between N, F and MF groups was found in all measured conditions and directions (Table). No significant difference was found for ABC scale (N: 86.0 ± 13.3, F: 85.2 ± 12.3, MF: 79.7 ± 17.6).

<table>
<thead>
<tr>
<th>Vision</th>
<th>Surface</th>
<th>Direction</th>
<th>N (n = 92)</th>
<th>F (n = 41)</th>
<th>MF (n = 18)</th>
<th>p values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eyes Open</td>
<td>Firm</td>
<td>ML</td>
<td>4.5</td>
<td>4.6</td>
<td>4.9</td>
<td>0.877</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AP</td>
<td>10.8</td>
<td>10.7</td>
<td>10.5</td>
<td>0.919</td>
</tr>
<tr>
<td></td>
<td>Foam</td>
<td>ML</td>
<td>11.9</td>
<td>11.0</td>
<td>12.1</td>
<td>0.428</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AP</td>
<td>22.8</td>
<td>21.0</td>
<td>22.1</td>
<td>0.479</td>
</tr>
<tr>
<td>Eyes Closed</td>
<td>Firm</td>
<td>ML</td>
<td>6.2</td>
<td>5.5</td>
<td>7.3</td>
<td>0.287</td>
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<td></td>
<td>AP</td>
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<td>15.5</td>
<td>18.5</td>
<td>0.332</td>
</tr>
<tr>
<td></td>
<td>Foam</td>
<td>ML</td>
<td>19.4</td>
<td>18.6</td>
<td>21.4</td>
<td>0.751</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AP</td>
<td>44.9</td>
<td>40.4</td>
<td>45.7</td>
<td>0.110</td>
</tr>
</tbody>
</table>

Legend: N – nonfallers, F – subjects with 1 fall, MF – subjects with two or more falls, SD – standard deviation, ML – medial-lateral direction, AP – anterior-posterior direction

Discussion:
Our findings showed no difference in postural stability between groups with and without fall occurrence. One possible explanation is the high level of physical functioning of observed individuals, which was shown by ABC scale. Scientific studies also suggest that postural control in relation to fall risk as measured during quiet stance must be quantified and combined with other
risk factors for falls such as drug side effects, muscle weakness, visual acuity, temporary illness, locomotor instability and environmental factors [1].

Postural control during single leg stance in slackliners and controls

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Introduction: A new recreational sport known as ‘slacklining’, has recently become popular especially with young adults. Balancing on a highly elastic slackline places high demands on motor control and the musculoskeletal system [1]. Training on a slackline, which requires reducing medial-lateral oscillations, improves postural control [2]. Due to these requirements, slacklining represents also a preventive (physiotherapeutic) training tool for the maintaining or improving of postural stability. The aim of this study was to assess postural stability during single leg stance in slackliners and controls.

Research Question: How does regular slacklining affect postural stability in single leg stance under static and quasistatic conditions?

Methods: Fifteen slackliners (age 23.7±3.4 years, mass 69.9±6.5 kg, height 177.5±8.4 cm) who could walk over a 60-m long slackline and fifteen controls (age 22.4±1.5 years, mass 73.5±9.5 kg, height 177.7±7.3 cm) who had no slacklining experience participated in the study. A force platform (200 Hz) was used to collect the postural stability data. Three trials in single leg stance (for each leg) were recorded while standing on the firm surface (a force platform) and on a wobble board placed on the force platform. At the beginning of each trial, some stabilization time was given to the participants and then the 60-s recording was started. A custom MATLAB script was used to compute sway and mean velocities of the center of pressure (COP) translation.

Results:

<table>
<thead>
<tr>
<th></th>
<th>Firm surface</th>
<th>Wobble board</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dominant leg</td>
<td>Non-dominant leg</td>
</tr>
<tr>
<td>Sway X (mm)</td>
<td>6.5±0.9</td>
<td>6.4±1.0</td>
</tr>
<tr>
<td>Sway Y (mm)</td>
<td>8.2±1.8</td>
<td>6.9±1.0</td>
</tr>
<tr>
<td>vX (mm/s)</td>
<td>27.4±6.0</td>
<td>27.6±5.0</td>
</tr>
<tr>
<td>vY (mm/s)</td>
<td>22.0±5.0</td>
<td>21.7±5.0</td>
</tr>
<tr>
<td>v (mm/s)</td>
<td>38.6±8.0</td>
<td>38.6±7.0</td>
</tr>
</tbody>
</table>

Sway X (Sway Y) = COP sway in the medial-lateral (anterior-posterior) direction; vX (vY) = COP mean velocity in the medial-lateral (anterior-posterior) direction; v = total COP mean velocity. *statistically significant difference from the control group.

Discussion: Pfusterschmied [3] found that four weeks of slackline training improved medial-lateral balance performance primarily during perturbed single leg stance. In our study the control group exhibited lower COP sway and velocity compared to the slackliners in all the parameters where significant differences were detected. These results are in accordance with those of Granacher [4] who did not find any improvement in static or dynamic postural control in COP.
movement parameters obtained in single leg stance after a 4-week slackline training. The reason why the control group in our study had lower COP movement parameters could be that single leg stance on the firm surface activates mostly ankle joint muscles, whereas slacklining activates muscle groups of ankle, knee and hip joints simultaneously.

Evolution of upper limb co-activations in two patients with C5 and C6 tetraplegia following biceps-triceps and posterior deltoid-triceps tendon transfers

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Introduction: Patients with C5 or C6 tetraplegia have paralysis of the triceps brachii, the main elbow extensor. Elbow extension can be surgically restored by transferring a preserved muscle’s tendon onto the paralysed triceps brachii’s tendon. Rehabilitation after this surgery is complex and may last up to 5 months, during which the transferred muscle adapts to its new function. To increase the integration of the new function, rehabilitation techniques such as motor imagery or electromyofeedback are being developed. However, functional outcome of the surgical restoration is measured by clinical assessments, lacking sensitivity and providing insufficient information on upper limb muscle function.

Research Question: To propose a quantitative analysis of upper limb muscle activation and co-activation (CA) for better management of rehabilitation and outcomes after surgical restoration of elbow extension in patients with tetraplegia.

Methods: Two patients with C5 and C6 tetraplegia underwent a biceps-triceps and posterior deltoid (post. deltoid.)-triceps tendon transfer (subjects A and B resp.). Electromyofeedback was used during rehabilitation of subject A to help dissociate brachioradialis (brachio.) and biceps. Subjects A and B pre-op and 5 months post-op, and a healthy adult (subject C) underwent movement analysis while performing active elbow extension/flexion (EF) with different degrees of shoulder abduction imposed by an operator (from 30° to 120°). Upper limb kinematics was computed, and muscle activation was recorded from the surface EMG signals of the biceps, brachialis (brachia.), brachio., triceps and post. deltoid. CA was calculated as the common area of two antagonist muscles during extension or flexion, divided by their total activation during the entire EF cycle (%).

Results: Before their surgery, subjects A and B were not able to actively extend their elbow and had weak flexion and extension maximal velocities from 90° of shoulder abduction. After their surgery, both subjects A and B became able to actively extend their elbow up to 120° of shoulder abduction (resp. 58.7° and 45.7° of elbow extension), with flexion and extension maximal velocities similar to subject C. During the trial at 90° of shoulder abduction, triceps activation during extension for subject C was 78% of the total activation during the flexion-extension cycle. Similar or higher proportion was found for the biceps of subject A post-op (80%) and the post. deltoid of subject B post-op (96%). Flexor/extensor CAs are summarized in Table 1:

<table>
<thead>
<tr>
<th>Subject A post op</th>
<th>Subject B post op</th>
<th>Subject C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Brachio/biceps:</strong>&lt;br&gt;Ext:10%/Flex:18%</td>
<td>Biceps/post.&lt;br&gt;Ext:26%/Flex:3%</td>
<td>deltoid: Biceps/triceps:Ext:24%/Flex:14%</td>
</tr>
<tr>
<td><strong>Brachia/biceps:</strong>&lt;br&gt;Ext:35%/Flex:18%</td>
<td>Brachio/post.&lt;br&gt;Ext:1%/Flex:2%</td>
<td>deltoid: Brachio/triceps:Ext:19%/Flex:8%</td>
</tr>
<tr>
<td><strong>Brachia/post.</strong>&lt;br&gt;Ext:1%/Flex:3%</td>
<td>deltoid:</td>
<td>Brachia/triceps:Ext:16%/Flex:8%</td>
</tr>
</tbody>
</table>

Figure 1: Non-normalized flexor/extensor CA (blue area) in subject A(left), B(middle), and C (right)
Discussion: For both subjects A and B, the restoration of elbow extension was a success. Both biceps of subject A and posterior deltoid of subject B have adapted well to their new function. However, higher brachia/biceps CA was found for subject A post-op during extension, while brachio/biceps CA was low and similar to subject C. The brachia.’s antagonist activation occurred at the time of maximal extension velocity; however it did not seem to have a functional impact. An explanation could be that during the rehabilitation program of subject A, electromyofeedback was used to learn to dissociate the brachio. and the biceps, but the brachialis was not recorded. Monitoring muscle activation and co-activation is therefore necessary for a better management of rehabilitation after surgical restoration of elbow extension in patients with tetraplegia.
Increased femoral anteversion related biomechanical abnormalities: Posture and trunk symmetry

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Introduction: For developing children who has no neurologic problem, increased femoral anteversion (IFA) is characterized by toe-in gait pattern, “W” sitting position, frequently falling (1). As influencing gait parameters, IFA may have connections with postural abnormalities, which may deteriorate posture and trunk symmetry (scoliosis).

Research Question: Describing the influences of the increased femoral anteversion on posture and trunk symmetry and investigate the correlations of these influences with IFA for neurologically intact children.

Methods: Eighty-five children with increased femoral anteversion (Av. Age: 8.6±2.9, Height: 138 ± 16.6cm, Weight: 32.1±12.5kg) and forty-six age-matched children with typically developing femoral anteversion (TDC) were participated in this study. IFA was defined by measuring hip internal rotation >65° (71.4±4°) and external rotation <20°(17±1.2), thorocanteric prominence angle (TPAT) >30° (48.3±7.1). Participants with increased tibial torsion, which by measuring thigh-foot angle was excluded (mean thigh-foot°: 4.0±9.4). Sagittal and coronal (anterior, posterior) body views were analyzed by 2D, posture analysis system (Body analysis kapture (BAK), Milletrix soft. Italy). The interested postural parameters were curves (cervical-dorsal-lombar), head (tragus symmetry, cranio-vertebral angle (CVA)), shoulder, scapular, pelvic, knee and ankle asymmetries (2). Posterior Trunk Symmetry Index (POTSI) (3) was used for trunk asymmetry. Participants with >27.5% was defined as asymmetry, and it is indicated to be orthopedically followed (4). The correlations between interested parameters and hip internal rotation angle were also analyzed according to Cohen’s guidelines (The moderate relationship was interpreted as r=0.30-0.50). Student-t test was used for comparison in statistical analysis (p<0.05).

Results: According to the results, tragus (3.57±2.16° in IFA, p<0.001, r=0.31), shoulder (2.08±1.41° in IFA, p<0.001, r=0.25), scapular (3.02±2.29° in IFA, p<0.001, r=0.21), pelvic (2.6±2.° in IFA, p<0.001, r=0.35), knee (2.58±2.16° in IFA, p<0.001, r=0.30), malleolar (3.1±3.3° in IFA, p<0.001, r=0.25) asymmetry and Q (22.8±7.3° in IFA, p<0.001, r=0.50) in frontal plan, CVA (47.71±4.62° in IFA, p<0.001, r=0.22), cervical lordosis (68.93±14° in IFA, p=0.001, r=0.38), knee hyperextension (184.89±6.61° in IFA, p=0.001, r=0.23) angle in sagittal plane were found significantly different in IFA group than TDC (1.7±1.81, 1.1±1.1, 1.55±1.29, 0.8±0.9, 1.52±1.63, 1±1.43, 17.21±6.47, 51.7±4.7, 79.56±16.7, 181±4.73 respectively). POTSI scores were found significantly higher in IFA group (20.5±8.78%) than in TDC (11.4±6.75) and moderate relationship (r=0.44) with femoral anteversion. Twenty-three participants in IFA were found as >27.5%, who should be followed by orthopedic department.

Figure-1: Demonstration of Cranio-Vertebral Angle (CVA) evaluation and calculation.

Discussion: Children with IFA have some postural asymmetries such as lateral head, shoulder, scapular, knee malleol-level and pelvic asymmetries. The moderate correlation was found in head asymmetries between femoral anteversion as Q angle, cervical lordosis, pelvic and knee asymmetries. Although, CVA, knee hyperextension, shoulder asymmetries and malleolar asymmetries were found significantly different in IFA group than TDC, poor correlation was found with femoral anteversion. Additionally, These children have a great potential of developing
scoliosis, which should be medically monitored and may be treated by physiotherapy program, even though they have neurologically intact. This study supported by the Scientific and Technological Research Council of Turkey (TÜBİTAK), No:214S049.

References:
The Relationship Between Plantar Flexor Spasticity and Kinematics of Ipsilateral Upper Extremity in Children with Hemiplegic Cerebral Palsy

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Introduction: In children with hemiplegic cerebral palsy (CP) the stance phase duration is shorter than the swing phase at the affected side during walking. Additionally, temporal-spatial parameters are also altered (1). The planar flexors spasticity may one of the contributors of these changes for children with hemiplegic CP who have type 2 gait pattern (2). Upper limb movements may also altered due to compensate abnormal gait pattern on the affected side and/or reduced gait velocity (3).

Research Question: Is there any relationship between plantar flexor spasticity and ipsilateral upper extremity kinematics in children with hemiplegic CP?

Methods: 35 children (age: 6.9, 20 girls, 15 boys) with hemiplegic CP who have Type 1 and Type 2 gait pattern according to Winters classification recruited to the study. Plantar flexor spasticity was assessed according to Modified Tardieu Scale (4). 3-D gait analysis were utilized for all participants (modified Helen Hayes model). In gait analysis, ankle power generation and kinematic values of upper extremity, which are shoulder abduction-adduction excursion, peak shoulder flexion, extension, abduction, adduction and elbow flexion-extension excursion, peak flexion and extension were investigated. The relationship between plantar flexor spasticity and upper extremity kinematics were analysed by Spearman Correlation Test. The correlation coefficients were interpreted as < 0.20, poor; 0.21–0.40, fair; 0.41–0.60, moderate; 0.61–0.80, good; 0.81–1.00, very good.

Results: According to the statistical results, there was a fair level negative correlation between the plantar flexor spasticity of the affected side and ipsilateral shoulder flexion-extension excursion (rho: -0.359; p = 0.034) (Fig. 1). There was no correlation between plantar flexor spasticity and other kinematic values of upper extremity. Statistically significant moderate-level positive correlation was found between shoulder flexion-extension excursion and the ankle power generation in preswing phase (rho: 0.452; p: 0.006) (Fig. 2).

Discussion: Although both increased plantar flexor spasticity, and decreased shoulder flexion-extension ROM can be considered as the two main components of the abnormal walking pattern for hemiplegics these two parameters have fairly correlated. However, unsurprisingly, plantar flexion power and shoulder flexion are found moderately correlated. As agreed with the literature, increased in plantar flexor spasticity reduces the ankle power generation in preswing phase, which, reduces the forward propulsion of the body during walking (5). Slow walking pattern, and reduced stance duration on the ipsilateral side in hemiplegic patients may contribute reduced shoulder excursion (6). Opposite side’s upper extremity kinematics may correlate with plantar flexor spasticity and/or power generation, which should be investigated in future studies.
First results of spinal segment-related motion analysis in human gait using rasterstereography

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Introduction:

Back pain is still one of the big health problems in the world. The majority is of functional genesis, which could not be sufficiently investigated so far. Rasterstereography has been proved a valid and reliable high precision technique to analyze the shape of surfaces quantitatively. Orientated on visible anatomical landmarks a suitable algorithm can be used for combining the back shape data with an estimation of the corresponding spinal segment. Up until now this was used for static measurements. To enable future research in the area of the back pain we have tried to extend this method to the dynamic analysis of the shape of surfaces.

Research Question:

Is it possible to analyze spinal segment-related movement in gait via rasterstereography?

Methods:

The DIERS Formetric III 4D analyzing system works on rasterstereography and has been used for our study. Highly standardized we have examined a total of 134 pain free and healthy male and female subjects with an age range from 18 to 70 years. Three complete gait cycles per participant walking on a treadmill at a speed of 2, 3, 4, and 5 km/h were analyzed with 60 pictures per second. For every single frame the spinal segment-related geometry in three dimensions was calculated based on more than 400,000 spatial coordinates referring to the backside trunk shape. Measurement results were standardized by performing a linear transformation of the time interval of each step [0%, 100%], thus making steps comparable even if speed or length of the step differed. Spline interpolation was used to obtain positions at specified points (0% to 100% in 1% increments) for each participant at each speed. At all of the specified points median, 2.5th and 97.5th percentiles were obtained from our sample.

Results:

The results are graphically displayed for a standardized gait cycle, beginning with the right foot initial contact (0%). As an example we present the results for T8 rotation in four different speeds:

Figure 1: Ordinate axis shows degrees of the amplitude and rotation direction for T8 over a whole gait cycle (positive values show rotation of the vertebral body to the right and vice versa). Abscissa
reveals 1% increments (0-100%) of the time interval for a complete gait cycle. The magnitude of the vertebral body rotation increases with the speed of the movement.

Discussion:

We are able to present first data for the spinal segment-related motion analysis of healthy people walking at different speeds using the DIERS Formetric III 4D analyzing system. This data will be utilized as a basis for discussion about strengths and weaknesses as well as future perspectives of the method and the definition of the useful next steps with the eventual objective of clinical applications.

References:
Functional assessment of the spine through an optoelectronic system

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Introduction: The individual shape, mobility and functional assessment of the spine is an essential predictor for different lumbar degenerative pathologies. Considering the importance of checkups to monitor rehabilitation and clinical state of the disease the analysis of the lumbar spine and pelvis during standing and in full flexion, it is not possible to use X-ray as the stochastic and organic risks are important [1] [2].

Research Question: Is it possible to evaluate the kinematics of the spine through a clinical non-invasive protocol with the optoelectronics system?

Methods: 55 healthy subjects were scheduled for analysis. The experimental protocol required the positioning of 22 optical passive markers, 3 onto 7th cervical, 3th-7th-12th thoracic,3th-5th lumbar vertebrae. Were also posed 4 markers in correspondence to both the anterior and posterior superior iliac spines. The subjects performed a flexion at natural speed from standing to the maximum joint excursion, and back. All the recorded signals were filtered and interpolated (when necessary), exported to MATLAB® that has been used to perform all statistical analyses. Across the study we obtained 2 independent samples. First sample composed by 15 subjects for the evaluation of the significance of the inter operator reproducibility and operator exchangeability, for each subjects 8 markerization were made, 4 by each operator, functional tests were executed after each markerization. Second sample composed by 40 subjects for the normality study.

Results: Operators did not obtain significantly different values; errors SD[m] reproducibility 0.49 e-3 and exchangeability 1.9 e-5. The graph show the trend of the centre marker of each vertebra, on the anteroposterior axis.

Discussion: Comparing the graphs of each subject we found a standard behaviour, ie the bending movement of the spine is more decisive and coordinated, compared to the return of flexion which is less coordinated. All the subjects present also an overshoot for all the vertebrae leaving and reaching the standing position. The calculated reproducibility and exchangeability errors suggest that these phenomena can be neglected for the profile analysis. Each test requires short time, that can be performed within 15 minutes; the proposed strategy results particularly suitable for a daily use in clinical practice to identify possible pathologic conditions of the subject, the effectiveness of rehabilitative treatments and follow-up.

Functional assessment of the spine through an optoelectronic system in spinal disorders

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Introduction: Trunk movements play an important role in many human activities, contributing to the motion of the whole body. For a deepened comprehension of spine's functionality is important to study forward bending because it is a frequent in daily activities. Clinical assessment is generally based on the X-ray imaging technique but these are scarcely repeatable and limiting the patient follow-up.[1]

Research Question: It's possible, with an optoelectronic system, analyze forward bending in subjects with low back pain and to create a database of these to compare them to healthy subjects?

Methods: 72 patients with spinal disorders are recruited: 63 with chronic low back pain and 9 with spondylolisthesis. The experimental protocol required the positioning of 23 markers: 3 onto 7th cervical, 3th- 7th- 12th thoracic, 3th-5th lumbar vertebrae, 4 markers in correspondence to both the anterior and posterior superior iliac spines and 1 on sacrum bone. Initially, the patient compiled Oswestry Disability Index (OSW) and Numerical Rating Scale (NRS). The subject is asked to perform forward bending from initial standing to the maximum excursion and to go back. All the recorded signals were filtered and exported to MATLAB® that has been used to perform all statistical analyses. Data were compared with normal curves on healthy subjects previously developed.

Discussion: The series of graphs of each subject are examined and provide us qualitative information (symmetry, slope and mobility) about the movement pattern. 280 tests for chronic low back pain subjects and 39 for spondylolisthesis subjects are analyzed. The results of the analysis of chronic low back pain graphs are: 100% of subjects presents asymmetric graphs, 81.6% of subjects presents changing or discontinuous slope and 86.8% of subjects presents worsening or constant mobility. The results of the analysis of spondylolisthesis graphs are: 100% of subjects presents asymmetric graphs and nobody worsens in relation to mobility. Association between graphs, questionnaires and personal data we achieve that high NRS score is not always correlated to an asymmetric graph; high Body Mass Index value is associated to scarce mobility; high BMI and high OSW score reveal a pathological condition in which graphs result different by healthy ones. The graph represent the overlap between the traces of a healthy subject and of a chronic low back pain subjects.
Balance exergames increase cortical activity in frontal areas of the brain

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Introduction:

Exercise videogames – or exergames – are increasingly used to train both physical and cognitive functions [1]. However, it is unknown whether additional cognitive elements in an exergame lead to increased demands on executive functioning, or whether exergames are inherently cognitive demanding. Previous research has shown that EEG can measure brain activity related to executive functioning, and that frontal theta activity in particular is associated with executive functions in cognitive [2,3] and motor control [4] tasks. The current study addresses frontal cortical activity while playing a balance exergame.

Research Question:

Is it feasible to measure brain activity using EEG while participants play a balance exergame? If so, do additional cognitive elements lead to increased demands on executive functioning as indicated by increased frontal theta activity?

Methods:

Twenty-four injury-free young adults (mean age 24.6 ± 2.1 yrs) repeatedly shifted their weight mediolaterally in 3 different conditions: 1) self-paced without exergame guidance, 2) while playing a simple puzzle balance exergame that presents 1 piece at the time, and 3) while playing the same balance exergame choosing between 2 pieces. Puzzle pieces are chosen by leaning to the appropriate side. Brain activity in all conditions was recorded using a 64-channel EEG system and EOG electrodes (SynAmps RT, Compumedics Neuroscan, US). Data from 22 participants was further processed using EEGLAB v14 [5] and consisted of filtering, sampling, re-referencing and manual artefact rejection. Ocular and muscular stereotypical artefacts were removed by independent component analysis. For data analysis, mean spectral power was calculated for theta activity (4-7 Hz) in a predefined frontal region of interest (F3, F1, Fz, F2, F4). Statistical analysis consisted of paired samples t-tests.

Results:

Frontal theta activity increased from self-paced sideways movements to exergaming. Both puzzle conditions with choice and without choice demonstrated significantly higher theta power compared to the condition without exergame guidance (both p’s<.05). Theta power was found to be highest in the puzzle game with choice, but the difference between the choice and no choice exergame conditions was not significant.

Discussion:

The findings of this study indicate that it is feasible to monitor and quantify EEG in a laboratory-based exergame protocol. Significantly higher frontal theta activity was found in the exergame conditions compared to self-paced mediolateral movements. Moreover, increased cognitive demand in the exergame protocol was demonstrated to be mirrored in increased frontal theta activity. As theta increase in the medial prefrontal cortex (mPFC) is presumed to be associated with attentional control and error monitoring [6,7], our results indicate that exergaming may inherently require attention-related involvement of the mPFC and therefore might be able to train executive functioning. Ongoing analyses focus on source localization and brain network dynamics during exergaming in order to further corroborate these interpretations.

References:
Balance exergames improve movement characteristics of body weight transfer

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Introduction: Independent gait in daily life requires repeated transfer of body weight from one leg to the other. For people suffering from an orthopaedic injury or a neurological disease, body weight transfer toward the injured or paretic leg can be impaired [1,2]. Moreover, incorrect weight transfer is one of the most important risk factors for falls in older adults [3]. Many balance and weight shifting exercises and programs have been developed, but adherence to self-regulated training is generally low due to poor motivation and enjoyment [4]. Video-based exercise games, or exergames, are increasingly used to increase motivation and enjoyment, but little is known about the effect that exergames have on actual movement characteristics while exergaming.

Research Question: Do balance exergames change the characteristics of mediolateral weight transfer compared to unguided mediolateral weight transfer?

Methods: Twenty-four injury-free young adults (24.6 ± 2.1 yrs) repeatedly shifted their weight mediolaterally in three conditions: 1) 3-min self-paced trial without exergame guidance (SP1), 2) 4 blocks of 5 trials each playing a simple puzzle exergame that requires sideways weight transfer to select puzzle pieces (EX), 3) 1-min self-paced trial without exergame guidance (SP2). Ground reaction forces from two force plates (Kistler) were recorded at 100 Hz, and used to calculate amplitude, velocity, and smoothness (calculated as jerk) of the centre of pressure (CoP) traces. The effect of condition was tested using 1-way repeated measures ANOVAs, with pairwise comparisons with Bonferroni corrections as post-hoc follow-up.

Results: Mean CoP amplitude increased significantly from SP1 (33.0 ± 7.1 cm) to the EX trials (39.6 ± 5.2 cm), p<.005. There was a small decrease in mean amplitude from EX to SP2 (39.3 ± 5.0 cm) that was not significant (p=.85). Mean CoP amplitude in SP2 was significantly higher than in SP1, p<.005, reflecting an after-effect of the exergaming. CoP traces were significantly smoother in the exergames trials compared to both self-paced trials, both p's<.05. There was no difference in smoothness between the two self-paced trials (p=.22). Mean CoP velocity increased slightly in the last self-paced trial (from .18 to .21 m/s), but there was no significant effect of condition on mean CoP velocity (p=.10).

Discussion: The characteristics of mediolateral weight transfers changed when performing them in the context of an exergame compared to self-paced weight shifts without external guidance. Amplitude of the weight transfer increased significantly, which carried over to the subsequent self-paced trial. Smoothness improved when weight transfers were performed in the context of an exergame, without an immediate after effect. The velocity of weight transfer did not change significantly. These results indicate that even a simple balance exergame can improve the quality of weight transfer movements during balance training, as compared to repeated, self-paced weight transfers without exergame guidance. More advanced exergames that tailor difficulty level dynamically to the player and provide appropriate feedback may have the potential to further increase quality of the performed exercises.

Quantification of mirror activity in finger movements post-stroke by 3-dimensional motion analysis

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Introduction:

Mirror activity (MA) in the non-affected hand while performing unilateral movements with the affected hand is a common sequel post stroke (PS), causing interference when performing bimanual tasks. Objective and detailed measurements of the presence and degree of MA is lacking which can further the understanding of the occurrence of MA in relation to lesion locality PS.

Research Question:

Can MA be quantified and graded by optic 3D motion analysis during unilateral finger movements (both the ipsilesional and contralesional fingers) in persons with a chronic stroke diagnosis (post-stroke, PS) with visually identified MA on an individual level and in comparison to PS participants with no MA (NoMA) and able-bodied controls (C).

Methods:

We included 14 persons PS divided into two groups based on the presence of visually identified MA (N = 8; M age= 66 years; 4 women) or not (N = 6; M age= 63 years; 2 women), and an age and gender matched C group (n = 8; M age= 69 years; 4 women). The ability to perform unimanual individualized finger movements and the effect of vision of the hands were evaluated. Participants were seated with forearm support and wrist extension ~10° and instructed to at a self-paced speed move a specific finger in cyclic flexion-extensions keeping the other fingers still, (4 trials for each hand [10 s each], 2 with vision of the hands and 2 without). Reflective markers were affixed to each finger and recorded by optoelectronic cameras. Based on the speed of the instructed finger a mirror activity index (MAI) was calculated by dividing the mean speed of the corresponding inactive finger with the mean speed of the instructed finger: 0 = no co-activation, 1 = the inactive finger had a mean speed = the active finger, and a value >1 = inactive finger had a mean speed > that of the active finger.

Results:

Preliminary analyses confirmed that the MA group had significantly higher MAI compared to NoMA when both the affected (A) and non-affected (NA) side was active and both with and without vision of the hands (both NoMA and C having MAI values close to 0). In addition, the side of
coactivation, effect of vision, finger specificity, and degree of coactivation differs markedly between individuals in the MA group. Three participants had a degree of co-activation that was most marked, two showing increased activation in the A side while performing with their NA side (MAI-A = 0.01; MAI-NA = 0.27 and MAI-A = 0.02; MAI-NA = 0.23) and one displaying activity in the NA side when the A side performed (MAI-A = 1.5; MAI-NA = 0.02). These three participants had left sided lesions to subcortical structures in the corticospinal system. The remaining three MA participants had less evident coactivation on the MAI.

Discussion:
A method for objective investigation and quantification of the degree of MA post-stroke was developed and successfully applied. The developed MAI is feasible for identification, quantification, and grading of MA in the fingers. MA with lower speed, occurring in the initiation process, and/or if sporadic, was more difficult to capture by the MAI, thus, further methodological development is warranted to capture the apparent individual variation.
Three dimensional kinematic analyses of finger movement control and association to brain activity responses – a pilot study on healthy individuals

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Introduction:
An increased knowledge of how the brain control finger movements give us keys to understand the recovery of motor function after a brain injury. This knowledge is crucial for the development of reliable and valid assessment methods in the clinical evaluation of hand function.

Research Question:
How are individual finger movements represented in the brain? Investigating the associations between kinematics and brain activity responses in healthy individuals.

Methods:
keeping the others still. Finger movements were performed lying in the MR scanner in order to register brain activity response during the task. Optoelectronic cameras simultaneously monitored the positions of reflective markers affixed to each finger. The marker position data were used to calculate each finger’s movement frequency (MF), movement independence (“Individuation Index”, II), stationary ability (Stationarity Index, SI). fMRI data was analyzed by contrasting the finger movements against its active rest.

Results:
Preliminary analyses showed that 1) the finger movements primarily activate sensorimotor areas in the contralateral hemisphere (Fig 1A), 2) that use of kinematic parameters in the fMRI analyses improved spatial specificity and 3) II engage a number of cortical areas, while MF engage fewer areas (Fig 1 B-D). Further analyses will further explore activations maps for each individual finger.

Discussion:
The inclusion of movement parameters in the fMRI analyses improves the specificity in the derived activation map, increasing the interpretability of the neural correlates of movement
control. This advancement carries the promise for the development of better assessment methods of the recovery of function post-stroke with usability in rehabilitation practices.

References:

Introduction: Passive dynamic mechanical walkers (PDMWs) have been shown to be proxies for the study of human gait [1,2]. Both humans and walkers can be modelled as inverted pendulums wherein the center of mass (COM) pivots passively over the foot. Previous studies have largely examined similarities in energy efficiency and stability based on Lyapunov exponents computed on various gait parameters [1,2]. This study examines the similarities between human and a PDMW using normalized deviation of the COM, $D_N$. $D_N$ measures the excursion of the COM in a coordinate system defined by the line joining the feet (IFL) which is the approximate center of the base of support during tripping and slipping [3]. Since balance loss via tripping or slipping induces a rotation of the subject, moment of inertia (MOI) considerations also play a role. Due to safety limitations required with human subjects in slipping and tripping trials, PDMWs may provide a useful way to study balance safely.

Research Question: Are measures of dynamic balance in PDMWs including MOI and $D_N$ similar enough to humans that PDMW can be used in place of humans in balance studies?

Methods: A wooden PDMW was built and marked with 10 retroreflective markers for three dimensional motion capture. The walker was filmed using an eight camera Motion Analysis Corporation Eagle system at 120 Hz. At the start of a trial, the walker was rocked gently to induce it to begin walking down a ramp inclined at 30 degrees. Nine trials were collected comprising 32 complete gait cycles. COM position, $D_N$, and MOI about the IFL and the axes of each foot were calculated for the walker. Ensemble moment of inertia [3] and $D_N$ [4] results from previous work involving 66 typically developing children (TD) were used as a basis for comparison with the data gathered from the walker.

Results: Mean $D_N$ curves for both the walker and the human subjects showed similar shapes during stable gait with no significant difference found where the error bars overlapped (right). Minimum $D_N$ occurred during heel strike, and maximum was during mid-swing. For both TD subjects and for the walker, the MOI about the IFL was smallest (left). However, the MOI data was otherwise dissimilar between walkers and humans.
Discussion: The two most common modes of falling involve tripping and slipping, both of which involve rotation. We have considered three likely axes about which falls can occur, the IFL, and the long axes of the feet (LAF). For lateral falls, one would expect rotation about the LAF. However, the MOI about these is larger than that about the IFL for both humans and for the walker implying that the IFL is the preferred axis of rotation. The double humped structure of the MOI curves is mirrored in the shape of the \( D_N \) curves. Where MOI is lowest, so too is \( D_N \) implying that the COM is directly between the feet at such times. It is thought that the decreased amplitude of the walker's \( D_N \) curve and the flattened shape of its MOI curve are related to more limited degrees of freedom in motion, and that using a more sophisticated walker may result in more similar curves between humans and PDMWs.

Is kinematic analysis useful as a clinical test during whiplash associated disorders recovery? A clinical study.

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Introduction:

Kinematic analysis of cervical movement provides relevant information to assess whiplash associated disorders. Continuous cyclical movement trials provide relevant information to distinguish normal pattern, altered pattern and simulated pattern (malingering) with high sensibility and specificity (1). WAD is very important in the context of compensation liability (2, 3). For this reason, to apply methods of objective assessment in a real context of application would be interesting (1).

Research Question:

The main aim of this study is to prove the usefulness of biomechanical assessment in a rehabilitation clinic for WAD. Secondary objectives are: S1. Describe the patterns of whiplash recovery after the accident; S2. To assess the usefulness of biomechanical tests for the physician.

Methods:

A descriptive study was carried out in which a cohort of 91 people with posttraumatic cervicalgia due to traffic accident was followed during their rehabilitation. All were remitted by an insurance company in the first 45 days after the accident. Cases with concomitant lesions of greater severity were ruled out. Each participant was assessed at the beginning of rehabilitation, once a week and at the end. Each assessment consisted of a kinematic analysis of the cervical spine with the Baydal et al. methodology (1). An expert in biomechanical assessment made a clinical report and summarized the results of each assessment in: normal function, lightly altered function, altered function and not collaborator. The doctor did not know the result until the end of the prescribed rehabilitation. His opinion about the usefulness of the biomechanical test was collected in the final session.

Results:

The sample consisted of 54% women and 46% men, with a mean age of 38 years. Most of the accidents were by rear collision. From the results of the biomechanical assessment, different profiles are distinguished: 1. People with normal functionality at the beginning of rehabilitation (29%) 2. People who recover normal functionality during rehabilitation (36%), 3. People who complete (13%) 4. People who complete their recovery with functional impairment (7%) and 5. People who do not collaborate during the biomechanical evaluations performed (15%). Functional stabilization is usually achieved after two or three weeks after the start of rehabilitation. The doctors considered the tests useful in 92% of the cases. Especially, when making the decision to discharge.

Discussion:

The suitability of the biomechanical assessment in the rehabilitation of people with posttraumatic cervicalgia after traffic accident has been verified. It has been carried out in real experience and has proved its usefulness to the physicians involved in the process. The recovery patterns obtained point to the interest of using the kinematic analysis following the methodology described as complementary tests to make the prescription of rehabilitation programs more efficient and to improve care for the injured.

References:


Functional assessment in a case of meniscopathy. Usefulness of an application to evaluate gait, single-limb support and the climb and descent of stairs in front of isolated gait studies in the biomechanical characterization of the knee.

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Introduction: A 48-year-old woman presented with acute onset pain in the left knee after a bad gesture. No episodes of knee pain in the past were referred. A diagnostic MR was performed with medial menisci rupture, and so she underwent an arthroscopic partial meniscectomy. Six months after, she complained of remaining left knee pain mainly on the medial joint line and instability. Examination revealed full range of motion and strength, with no signs of instability and McMurray’s Test inconclusive; tenderness on the medial joint line.

Research Question: Our objective is to show, by presenting a clinical case, the usefulness of an application designed to perform a complete biomechanical evaluation of the knee by assessing gait, single-limb support and stairs.

Methods: We carried out a functional evaluation of gait and performed a single-limb support balance test by measuring dynamic parameters using a force platform. Additionally, we tested the activity climbing & descending stairs, measuring kinetic and kinematic parameters generated by means of two force platforms and 3D photogrammetry with an eight-camera motion analysis system. For these tasks we used the application “NedRodilla / IBV”, which allows the assessment of these activities and integrates the information registered, analysing data and comparing the parameters obtained with a database that contains a healthy control segmented by age, gender and presence of footwear. The software eventually summarizes results in a final index.

Results: Single-limb support test and gait analysis were normal, with a Gait Normality Index of 98% and 96% for left and right limb respectively (normal above 90%). There were neither abnormalities in speed nor in 3D ground reaction forces during stance phases; no asymmetries in support times were seen. For the Stairs Test, however, a mild bilateral functional alteration was seen, more obvious on the left side and especially during the descent, where a lower extension moment (especially in the initial support phase) and lower peak adduction moment were seen, as well as a smaller vertical reaction force at the initial contact (see yellow arrows at Figure 1; blue line represents left side).

Discussion: The findings shown above are similar to some mentioned in the bibliography revised, pointing out a lower extension moment and lower vertical reaction force during stairs descent(1) and a smaller peak adduction moment(2) in patients with meniscopathy. Climbing and Descending Stairs represents a more complex and demanding activity than gait, and thus provides complementary kinematic and kinetic data that can be useful in the clinical field. This enables us to study certain biomechanical patterns in pathologies that doesn’t affect gait functionality. With this software(3) we can combine data obtained from the analysis of three activities: gait, single limb support and stairs.

References:


Effect of bilateral transcranial direct current stimulation combined with gait training in a child with hemiparetic spastic cerebral palsy: Case report

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Introduction: Recent studies have demonstrated that unilateral anodal transcranial direct current stimulation (tDCS) over the primary motor cortex enhances the results of treadmill training in children with hemiparetic and diparetic spastic cerebral palsy [1,2]. However, studies addressing the effects of tDCS on stroke survivors with hemiparesis demonstrate important benefits stemming from anodal stimulation over the motor cortex ipsilateral to the brain lesion concomitantly to contralesional cathodal stimulation [3]

Research Question: Is ipsilesional anodal tDCS and contralesional cathodal tDCS capable of altering the Gait Profile Score in a child with hemiparetic spastic cerebral palsy?

Methods: An eight-year-old child with right-side hemiparetic spastic cerebral palsy was the subject of this case report. The intervention consisted of ten sessions of treadmill training (20 minutes per session at a velocity determined based on the child’s performance, without body weight support or inclination of the treadmill). Gait training was combined with tDCS (current: 1 mA) over the primary motor cortex. The anode was positioned over C3 and the cathode was positioned over C4. Three-dimensional gait analysis was conducted before the intervention, after the intervention and one month after the end of intervention. The Gait Profile Score (GPS) was determined based on kinematic gait variables (normal range: 5-7).

Results: No adverse effects were observed during the follow-up period. GPS values of the paretic and non-paretic limbs diminished between the initial evaluation and the both the post-intervention and follow-up evaluations. Initial GPS values were 15.7 and 8.6 for the right and left lower limbs, respectively; post-intervention GPS values were 11.4 and 9.7 for the right and left lower limbs, respectively; and GPS values one month after the intervention were 8.0 and 7.1 for the right and left lower limbs, respectively.

Discussion: The results of the present case report demonstrate that the combination of bilateral tDCS and treadmill training was capable of bringing the GPS values of the paretic and non-paretic limbs closer to the range of normality for the population in the same age group. This finding indicates a balance in the activity between the lower limbs, which was the aim of the intervention. Although this is the report of a single case, which limits generalizations regarding the results, the findings are promising and can be used for the basis of further studies.


EFFECT OF TRANSCRANIAL DIRECT CURRENT STIMULATION ON MOTOR CONTROL DURING REACHING MOVEMENT IN A CHILD WITH DOWN SYNDROME – CASE REPORT

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Introduction: Down Syndrome (DS) results in neurological impairment that affects selective motor control, compromising the acquisition of motor skills and functional independence, and is also one of the most frequent causes of cognitive impairment, accounting for approximately 20% of all mental disabilities. Adequately planning intervention strategies to optimize the movements and functionality of the upper limbs requires ample knowledge of all dysfunctions. Anodal transcranial direct current stimulation (tDCS) is a promising therapeutic modality in the paediatric neurorehabilitation process that may optimize upper limb motor control and functionality in children with DS.

Research Question: What variables of the kinematic analysis of upper limb movement can be optimized with a single session of anodal or sham tDCS over the primary motor cortex bilaterally combined with upper limb motor training with the aid of virtual reality?

Methods: This study received approval from the Human Research Ethics Committee of UNINOVE, Brazil (process number: 1.517.470). A six-year-old child with DS was submitted to two intervention protocols (sham and active tDCS) and evaluated through a three-dimensional analysis of upper limb movement before and immediately after the intervention protocol. The 3D analysis was performed using the SMART-D 140® system and processed using the SMART Analyzer program (BTS, Italy). The child was instructed to reach for a target placed at a distance corresponding to 80% of arm length and return to the initial position. The kinematic analysis was performed considering temporal variables, smoothness, velocity and precision of the reaching movement. The intervention consisted of a single virtual reality training session combined with anodal tDCS (active and sham). Two anodal electrodes were positioned over the primary motor cortex (C3 and C4) following the international 10-20 electroencephalogram system and the cathode was positioned over the right deltoid muscle. Stimulation was performed with a current of 1 mA for 20 minutes during motor training of a reaching task involving the Sports game of Xbox.

Results: Table 1 displays the pre-intervention and post-intervention kinematic variables for the upper limbs. Significant differences occurred in two variables following active stimulation: accuracy, with a 41% reduction in the adjustment phase (Adj sway) of the left arm, and average jerk, with a 30% reduction in JERK of the right arm. After sham stimulation, a significant difference only occurred for one variable (smoothness), with a 16% reduction in movement units of the right arm.
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<td>115.6 66.60</td>
<td>34.20 54.90</td>
<td>76.30 59.70</td>
</tr>
<tr>
<td>dx sx</td>
<td>0.57 0.56</td>
<td>0.63 0.55</td>
<td>0.43 0.43</td>
<td>0.48 0.45</td>
</tr>
<tr>
<td>dx sx</td>
<td>1.08 1.08</td>
<td>1.01 1.05</td>
<td>0.82 0.79</td>
<td>0.79 0.79</td>
</tr>
</tbody>
</table>

**Discussion:** Although DS is one of the most incident conditions in the paediatric population, no previous studies have analysed the effects of tDCS in this population. However, studies involving tDCS in the rehabilitation of patients with cerebral palsy suggest that this method is clinically relevant and safe, potentiating mobility and functional training. In the present study, significant improvements in accuracy and dexterity were found following active stimulation, which have direct repercussions regarding the improvement of motor control during the reaching task. No adverse effects or complaints related to stimulation occurred. The findings demonstrate that anodal tDCS combined with upper limb training involving virtual reality was able to potentiate motor control during a reaching movement in a child with Down syndrome.

EVALUATION OF ELECTROENCEPHALOGRAPHIC SIGNAL DURING A MOTOR ACTIVITY BEFORE AND AFTER TRANSCRANIAL STIMULATION IN A CHILD WITH DOWN SYNDROME: CASE STUDY

Isabela Marques Miziara, Jamile Benite Palma Lopes, Renata Calhes Franco de Moura, Roberta Delasta Lazzari, Manuela Galli, Veronica Cimolin, Bernard A. Conway, Claudia Santos Oliveira, Eduardo Lázaro Martins Naves

Introduction: Down syndrome (DS) is the result of a genetic alteration that affects approximately 1.3% of live births in Brazil. Individuals with this syndrome can have a normal life, but with some motor and cognitive impairments. Neuromotor learning is one of the issues investigated in cases of DS, but few studies have associated this process with the behaviour of the electroencephalographic (EEG) signal. According to the literature, anodal transcranial direct current stimulation (TDCS) has demonstrated satisfactory results with regard to motor learning in children with cerebral palsy and it is believed that the same can be achieved in children with DS.

Research Question: What is the behaviour of the EEG during a motor training task in a child with DS before and after TDCS?

Methods: This study received approval from the local ethics committee (process number: 1517470). A male six-year-old child with DS was submitted to a protocol composed of an intervention and two evaluations (before and after the intervention). During the evaluations, the volunteer was instructed to perform a reaching movement and touch a predetermined target. Each evaluation was composed of six trials (three for each limb). During the session, the EEG signal and the kinematic data of the movements were captured. The EEG signals were captured using the BrainNet BNT36 electroencephalograph (EMSA) and cap with 20 electrodes positioned using the international 10-20 system. The kinematic data were captured using the SMART D 140® system (BTS Engineering) composed of eight cameras and reflective markers positioned on the bone extremities of the upper limbs. The intervention involved a single 20-minute session of TDCS with a current of 1 mA during a motor training activity. For such, the anode was positioned over the C3 and C4 region following the international 10-20 system and the cathode was positioned over the right deltoid. The kinematic data were processed using the SMART Analysyer (BTS Engineering) and used for the demarcation of the beginning and end of the movement. The EEG signals were processed using the EEGLab toolbox developed for the Matlab platform. The signal was filtered and submitted to FFT to obtain the median frequency for each region of the brain cortex. The statistical analysis initially involved the Shapiro-Wilk, which demonstrated non-normal distribution of the data. The nonparametric Wilcoxon test for independent samples was used for the comparisons, with a 95% confidence interval.

Results: The graph illustrates the median frequency of the EEG of each region of the brain cortex. No statistically significant differences between evaluations were found.
Discussion: The population with DS has particular EEG characteristics, such as low frequency waves in the frontal and central regions, which comprise the motor cortex, and a greater concentration of high frequency waves in the occipital, temporal and parietal, which comprise the somatosensory cortex. Although TDCS did not lead to significant differences, which is in agreement with data described in the literature, an increase was found in the frequency of the waves in the parietal region, which is responsible for the interpretation of sensory stimuli and proprioception. The analysis of a larger number of volunteers could determine more significant results and lead to more relevant conclusions regarding the effects of TDCS.

Evaluation of the walking performance between 3D-printed and traditional fabricated ankle-foot orthoses—A prospective study

Yi-Chen Lin, Kuang-Wei Lin, Chen-Sheng Chen

National Yang-Ming University, Taipei, Taiwan

Introduction: Ankle foot orthosis (AFO) is widely used to prevent drop foot in individuals with neuromuscular disorders such as cerebral palsy and stroke. Some handcraft AFOs are expensive and time consuming. Currently, 3D-printing technique can be applied to produce customized products in a short time and lower cost. The purpose of this study was to compare the walking performance between 3D-printed (3DP) (Figure 1B) and traditional ankle-foot orthoses (TAFO) (Figure 1A).

Research question: Is the walking performance of individual wearing 3DP and TAFO comparable?

Material and methods: A healthy subject was recruited to this study. We obtained the geometry of lower extremity using 3D scanner, and created an AFO model. The AFO was printed using 3D printing machine with fused deposition modeling. Kinematic data were collected during walking at self-selected velocity by Vicon motion capture system.

Results: As to the 3DP and TAFO, the walking speed (367 vs. 389 mm/s), stride length (583 vs. 598 mm), and cadence (76 vs. 78 steps/min) were similar. In swing phase, the range of motion (ROM) of knee joint in flexion in both orthoses exhibited a similar trend (Figure 2). However, in stance phase, wearing TAFO demonstrated more extended in knee joint than wearing 3DP (30%-60% of gait phase).

Discussion: The results were similar under two different conditions except the knee extension during stance phase. This may be due to the fact that the footplate of 3DP is reserved to the first metatarsal head, whereas TAFO is reserved in full-length. Therefore, wearing the 3DP SAFO would provide a little heel lift and consequently decrease ROM of knee extension in stance phase.
A systematic clinical reasoning tool to support gait analysis interpretation: an SDR case example

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1Dept. of Rehabilitation Medicine, VU University Medical Center, Amsterdam Movement Sciences, Amsterdam, The Netherlands, 2Delft University of Technology, Dept. Biomechanical Engineering, Delft, The Netherlands

Introduction: The process of clinical gait analysis interpretation is complex and subject to the experience and professional background of the gait analyst. Here we present a novel, systematic way of reasoning, to bridge the critical gap between identifying abnormal gait features and finding their underlying impairments [1], to be addressed by a therapeutic intervention. The method is illustrated using a clinical case of a 7yo girl M. with spastic diplegic cerebral palsy, GMFCS level II, due to periventricular leucomalacia associated with prematurity (26+2 weeks).

Research Question: Can a systematic clinical reasoning tool assist in treatment decision making for an individual patient?

Methods: M. received pre-treatment 3D gait analysis using a 28 marker set (Vicon Nexus, ISB anatomical definitions [2]), complemented with force plate measurements (AMTI), 16-channel EMG, and standardized physical examination (PE). Kinematic gait features were identified manually.

For our clinical reasoning tool, two tables were developed to help group gait features and relating them to their underlying impairments. Table A contained 30 common gait features identifiable from 3D gait graphs or video, each described by side, variable, type, and timing; as well as 1 to 9 potential causes (impairments) for each of these features. Table B was developed as the reverse of Table A, containing 22 potential impairments, each with 1-7 accompanying gait features. In total, 56 gait feature-impairment pairs were listed. These pairs were based on a combination of clinical experience, biomechanical reasoning and available literature.

The systematic reasoning approach consisted of the following steps: 1) select one prominent abnormal gait feature from the gait graphs or video, e.g. ‘right ankle plantar flexion increased in stance’ (see figure, Pre SDR); 2) search in Table A for potential underlying impairments and select one, e.g. ‘soleus spasticity’; 3) search in Table B for other gait features related to this impairment (e.g. ‘knee extension movement in loading response’ and ‘knee hyperextension in late stance’) and check their presence in the gait graphs or video. If present, this strengthens the likelihood of this impairment limiting the gait; 4) search for additional evidence in PE, kinetic and EMG data; 5) if the impairment not likely, repeat from step 2 until a likely impairment is found; if the impairment is likely, repeat from Step1 until all features are explained.

Using this systematic approach, spasticity in soleus, gastrocnemius, hamstrings, and adductors were identified as the main limiting impairments for M., each with a strong effect on gait. These impairments could explain almost all of the abnormal gait features. Combined with additional criteria such as sufficient strength, selective motor control, and motivation, as well as evidence from literature [3-5], a treatment decision for selective dorsal rhizotomy (SDR) surgery was made.

Results: One year post surgery, all gait features related to spasticity were improved (see figure for knee and ankle angles).
Discussion: This systematic reasoning approach is a promising tool for novel gait analysts to help develop their skills, as well as for experienced users to verify the consistency of their decisions. Further (literature) study is needed to extend the developed tables including possible interactions, and to validate each of the gait feature-impairment pairs. The gait feature-impairment pairs can form the basis of a (semi-) automated reasoning tool.

Case study: Can we explain the increased tip-toe gait in a 10-year old boy with Duchenne Muscular Dystrophy by the combination of gait analysis, strength measurements and muscle imaging data?

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Introduction: 3D gait analysis (3DGA) is often used to assess motor performance in children with a neurological disease. However, in children with Duchenne Muscular Dystrophy (DMD), the use of 3DGA to understand the motor development is less common. The plantar flexion pattern at the ankle is known as a typical and progressive gait pathology in this group [1,2]. However, a direct link to potential contributing factors, such as passive range of motion (ROM), strength assessment and alterations in muscle structure, has not yet been analysed. Subject S is a 10-year old boy diagnosed with DMD. His treatment consists of night braces, physiotherapy 3/week and longitudinal corticosteroids.

Research Question: Does the combination of different evaluations (gait, muscle strength and intrinsic muscle morphology) and follow-up measurements provide us with important information on the pathogenesis of tip-toe gait in this boy with DMD?

Methods: S received a 3DGA at the age of 9y10m, including kinematics and kinetics (12 Vicon camera’s, AMTI forceplates) and EMG (Zero Wire Cometa) at spontaneous walking velocity (v1) and while walking as fast as possible (v2). Strength measurements of the ankle plantar flexors (PF) and dorsiflexors (DF) were collected during maximal voluntary isometric contraction (MVIC) using a telemetric MicroFet® 2 hand-held dynamometer. The primary strength parameter was the averaged joint torque of three representative trials (Nm/kg). Other evaluations involved ROM and 3D freehand ultrasonography (3DfUS) to define absolute and normalised muscle volume (MV and NMV resp.), muscle-tendon-length ratio and echogenicity intensity (EI) of medial gastrocnemius (MG) and tibialis anterior (TA). Measurements were repeated one year later.

Results: 3DGA of the first evaluation demonstrated increased plantar flexion over the entire gait cycle. Kinetics showed decreased plantar flexion moment and power generation at the ankle at push off. Increased walking velocity (v2) was obtained by increasing power generation at the ankle. At the second evaluation, deterioration of ankle kinematics was observed, both in stance and swing phase. Only minor changes were observed for the ankle kinetics, except for an increased power absorption during loading response. Increasing walking velocity resulted in decreased power at the ankle and the hip during push-off compared to v2 of the first evaluation. Results on ROM, MVIC and 3DfUS of the right side are presented in table 1.

<table>
<thead>
<tr>
<th>Age</th>
<th>ROM DF (°)</th>
<th>MVIC PF (Nm/kg)</th>
<th>MVIC DF (Nm/kg)</th>
<th>MV MG</th>
<th>NMV MG</th>
<th>MV TA</th>
<th>NMV TA</th>
<th>Norm. Muscle Length MG</th>
<th>Norm. Tendon Length MG</th>
<th>EI MG*</th>
</tr>
</thead>
<tbody>
<tr>
<td>9y</td>
<td>-5</td>
<td>0.349</td>
<td>0.120</td>
<td>52.1</td>
<td>2.15</td>
<td>21.0</td>
<td>0.87</td>
<td>0.59</td>
<td>0.41</td>
<td>150.5</td>
</tr>
<tr>
<td>10y</td>
<td>0</td>
<td>0.125</td>
<td>0.110</td>
<td>66.2</td>
<td>2.57</td>
<td>31.6</td>
<td>1.22</td>
<td>0.58</td>
<td>0.42</td>
<td>142.0</td>
</tr>
</tbody>
</table>

* echogenicity intensity (EI) of top third of CSA at 50%ML

Table 1: Compared to TD children, more increase in muscle volume, a comparable growth of the muscle-tendon unit, but a longer muscle with shorter tendon and higher echo intensity was observed in the MG as well as the TA.
**Discussion:** S showed an increase in tip-toe gait, as described in literature [1,2], which could not be explained by a decrease in ROM of DF. Strength of PF decreased, while the reduced strength of DF remained stable, despite the significant increase in MV and NMV. This suggests the relative decrease in contractile tissue, with increase of fibrofatty tissue, which may explain the decrease in dorsiflexion in swing phase. By employing a tip-toe position during stance, the ground-reaction force can be positioned closer to the ankle-, but also to the knee- and hip joint centres, resulting in lower net joint torques. This pattern is most likely a compensation for the generalized muscle weakness in children with DMD. Although the large decrease in strength of PF, only minor changes were observed at the kinetics of the ankle. However, a decrease in walking speed was observed. We can therefore conclude that the compensatory mechanism remains efficient, but assume that walking becomes more exhausting for this child with DMD, as PF strength decreases over time. In this case, the integration of different assessments on different time instants helps to delineate the underlying mechanisms of tip-toe gait. Similar analyses have been performed for the proximal joints.

Case report: atypical gait pattern in a child with dystonic CP

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Introduction: Classification of gait pattern in CP never reached an international consensus. Different justifications were advanced: the incomplete information on body segment rotation, the scarce information on the natural history of gait evolution [1], the scarce integration with clinical information. Indeed, sensory-motor gait pattern can be considered a common final path emerging from different configurations of the complexity of the biological system.

Research Question: Case report on atypical gait can be useful to define appropriate clinical question to be studied with ad-hoc protocols.

Methods: Gait analysis on a 8 years old child with dystonic CP was conducted. A plug in gait full body model was resolved on a optoelectronic systems (Vicon, UK) with 8 cameras, two force platforms (AMTI, US) and 8 channels wireless s_EMG (Noraxon, US) on a 10 meters pathway. 5 trials were extracted and their average is reported in Fig 1. Considering the peculiar pattern observed a different task was requested to the child: jumping on the spot (Fig 2).

Results: The observed gait pattern was mainly characterized by relevant ankle plantar flexion during all the gait cycle (mean -22°±3), increased knee extension in stance and increased hip flexion in swing, double bump of pelvic tilt associated with increased ante-version and evident sagittal out phase oscillation in extension of the head (mean -40°±5) respect to the pelvic tilt and ankle dorsal flexion. During jumping trials it is possible to recognize the same head-pelvic-ankle pattern used during gait stance and the attempt to introduce component of jumping inferred from observation of other peoples, like trunk or knee flexion or upper limb elevation, but always out of phase.

Discussion: The gait pattern can emerge from a peculiar use of information, that is, instead of stabilizing the head the child seems to use the vestibular information as a trigger to synchronize the gait dynamic synergy (basal ganglia dysfunction?). In that case probably the oculo-vestibular reflex is set to reach a full gain in order to stabilize anyway the optical flow. We need to introduce gaze study in future observation. The use of the same coordination during the jumping on the spot can be interpreted as a sharing modules strategies between tasks. The sequence of critical piece of jumping task, always out of phase, can be interpreted as a behaviour mediated by the cognition of the task but inferred by the inability to construct the correct sequence. Summarizing:
unusual pattern, atypical use of the information, previous experiences, peculiar cognitive procedures are involved in that gait, that is, implicit and explicit motor control strategies are involved into a mechanism of cooperation/competition.

Gait analysis may identify femoral retroversion

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Clinic for Orthopaedic and Trauma Surgery, Pediatric Orthopaedics, Neuroorthopaedics and Foot Surgery, Heidelberg University Hospital, Heidelberg, Germany

Introduction:

Femoral retroversion is a predisposing factor for development of hip osteoarthritis. Early identification of femoral retroversion during childhood or adolescence is crucial to determine regular follow-up examination and timely intervention to prevent early osteoarthritis. However, since early diagnosis of femoral retroversion is difficult because pain is a late symptom, it is a question if gait abnormalities in children with increased hip external rotation are indicators for femoral retroversion. In the clinical routine, it is difficult to detect external rotation gait.

Research Question: Is gait analysis helpful in detecting femoral retroversion?

Methods: The case of a 17-year-old young woman is presented. Due to pain in the right knee and an uncommon gait pattern she was sent to the orthopaedic sports department. The pre-hospital diagnosis was instability of the right knee. The patient was examined in the sports department including MRI of the knee but no instability or knee pathology was found. The patient was referred to the paediatric orthopaedic department for further examination. During gait observation, an abnormal knee flexion during mid-stance was seen where the knee normally is performing extension. A three-dimensional gait analysis was recommended to further investigate this abnormal gait pattern. A three-dimensional gait analysis with a 12 camera VICON system and dynamic EMG was done according to a standardized protocol.

Results: Three-dimensional gait analysis showed an abnormal hip flexion and subsequent knee flexion during single support on the right side. The hip showed external rotation on both sides but with the right side being involved severely. At the same time when the hip and the knee showed the abnormal flexion the hip was externally rotated the most. Furthermore, both knees showed valgus with the right side being sounded (Figure 1, solid line right side, dashed line left side, grey band=norm). The results of three-dimensional gait analysis indicated femoral retroversion, especially on the right side, which was supported by torsional MRI. After surgical correction of retroversion (femoral internal/varisation osteotomy) the abnormal gait pattern vanished (Figure 2).
Discussion:

Three-dimensional gait analysis helped to identify femoral retroversion. The gait pattern observed can be attributed to prevent hip impingement. Taking into account the results of gait analysis, the correction of femoral retroversion resulted in a correction of the abnormal gait pattern and pain relieve. This case clearly underlines the importance of gait analysis for the treatment of dynamic disorders. The kinematic findings of femoral retroversion need to be further investigated in a future study.

References:
Kinematic Changes in Pregnant Women during Gait

Shougo Kashima¹, Yoko Tsuji², Shigehito Matsubara³

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Introduction: Low back pain (LBP) is one of the functional minor troubles during pregnancy. Hormonal changes such as loosen joint and relax the ligaments that attach pelvic bones to spine occur in pregnancy. This can make pregnant women feel less stable and cause pain when walk, stand, sit for long periods, roll over in bed, or lift things. Most often the pain appears in the later months or becomes worse as pregnancy progresses. However, little is known about effects of hormonal changes to activities of daily living. The previous study reported movement changes during pregnancy [1][2].

Research Question: What kinds of kinematic changes occur in pregnant women during gait?

Methods: The subject of this study was a pregnant woman. The procedure was explained and informed consent was obtained from subject. Three-dimensional coordinates of reflected markers attached to the subject were obtained with an optical motion capturing system with 6 cameras operating at 100Hz, which synchronized with two force platforms (100Hz). Spatio-temporal parameters were compared with prenatal and postpartum (2 month, 4 month and 6 month) during gait.

Results: Table 1 shows comparison of spatio-temporal parameters between prenatal and postpartum. There were strong positive correlation between cadence and step width in prenatal and postpartum.

Table 1: Comparison of spatio-temporal parameters between prenatal and postpartum

<table>
<thead>
<tr>
<th>Walking parameters</th>
<th>prenatal</th>
<th>2 month</th>
<th>4 month</th>
<th>6 month</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Std Dev</td>
<td>Mean</td>
<td>Std Dev</td>
</tr>
<tr>
<td>Velocity (m/s)</td>
<td>1.183</td>
<td>1.298</td>
<td>1.214</td>
<td>1.352</td>
</tr>
<tr>
<td>Step length (m)</td>
<td>0.621</td>
<td>0.035</td>
<td>0.623</td>
<td>0.072</td>
</tr>
<tr>
<td>Step width (m)</td>
<td>0.086</td>
<td>0.002</td>
<td>0.098</td>
<td>0.015</td>
</tr>
<tr>
<td>Cadence (step/min)</td>
<td>114.379</td>
<td>4.622</td>
<td>125.054</td>
<td>3.684</td>
</tr>
</tbody>
</table>

| Amount of movement COP (m) | Horizontal | 0.024 | 0.022 | 0.016 | 0.001 |
|                           | Vertical   | 0.024 | 0.001 | 0.020 | 0.003 |

| Peak COP velocity (m/s) | Horizontal | 0.107 | 0.015 | 0.080 | 0.024 |
|                        | Vertical   | 0.132 | 0.019 | 0.138 | 0.020 |

Discussion: In this study, mechanical changes of pregnant women during gait were investigated. Previous study reported that negative correlation between cadence and step width in healthy subjects. However, there were positive correlation between cadence and step width. These results indicated that mechanical changes during gait remains for 6 month at least. Therefore, mechanical changes of pregnant women during gait might be focused not only prenatal but also postpartum.

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Kinetic Changes in Pregnant Women during Gait

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Introduction: Low back pain (LBP) is one of the functional minor trouble during pregnancy. Hormonal changes such as loosen joint and relax the ligaments that attach pelvic bones to spine occur in pregnancy. This can make pregnant women feel less stable and cause pain when walk, stand, sit for long periods, roll over in bed, or lift things. Most often the pain appears in the later months or becomes worse as pregnancy progresses. However, little is known about effects of hormonal changes to activities of daily living. The previous study reported kinetic changes about movement related muscle during pregnancy [1][2]. Kinetic changes of pregnant women could result in better management of rehabilitation.

Research Question: What kind of kinetic changes occur in pregnant women during gait?

Methods: The subjects of this study was a pregnant women. The procedure was explained and an informed consent was obtained from subject. Three dimensional coordinates of reflected markers attached to the subject were obtained with an optical motion capturing system with 6 cameras operating at 100Hz, which synchronized with two force platforms (100Hz). Subject’s kinematics and kinetics of hip, knee and ankle joint during gait were calculated using by inverse dynamics (MATLAB, MathWorks). Kinetic parameters were compared with prenatal and postpartum (2, 4 and 6 month) during gait.

Results: Figure 1 shows comparison of hip joint torque and power between prenatal and postpartum during gait. Not only prenatal and 6 month but also 2 and 4 month hip joint torque and power were similar.

Discussion: In this study, kinetic changes of pregnant women during gait were investigated. It’s interesting note that hip joint torque and power at 2 and 4 month were smaller than that of prenatal and 6 month. These results indicated that gait efficiency reduced after 2 and 4 month. Especially, gait efficiency recovered as prenatal at 6 month. Therefore, kinetic changes of pregnant women during gait might be focused not only prenatal but also postpartum.

ACUTE KINEMATIC EFFECTS OF WHOLE BODY VIBRATION IN SPASTIC EQUINUS DEFORMITY.

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Introduction:

Spastic equinus deformity (SED) is a common gait disorder usually founded in children with Cerebral Palsy (CP).

According to the literature, surgical treatment could be an option to consider when all the conservative approaches failed. Anyway, the decision making process needs solid information in order to offer the more accurate treatment for each children.

The clinical case presented showed an alternative method for the evaluation of contractures in children with CP.

Research Question:

Is WBV helpful for SED decision making?

Methods:

A 7 y.o. children with SED related to prematurity (25 weeks) was studied using conventional clinical examination and 3D Gait Analysis.

Whole Body Vibration (WBV) (Galileo Home) was used as a stretching device applying WBV at 27 Hz and 2 mm of amplitude, on a closed loop chain performing passive ankle dorsiflexion.

2 sets of 1 minute were applied to check the kinematic changes during gait.

Results:

The acute kinematic effects at the ankle joint are presented in figure 1. Comparative right Gait Deviation Index (GDI) and right ankle Gait Variables Score showed an improvement after receiving 1 minute intervention. (Figures 2 and 3). The results supported the conservative treatment as the next therapeutic step to follow with this child.

Discussion:

3DGA is commonly used for clinical decision making, but it must be considered as part of the clinical reasoning of the therapeutic team.

WBV could be used as an evaluation tool in the clinical routines of the gait laboratory. It could be helpful for muscle contracture evaluation and fatigue induction. These facts lead 3DGA to a more realistic way of evaluation of gait disorders.

References:

Effect of 3D-printed foot orthoses on center of pressure for adults with functional flat foot – a prospective study

Chia-Jung Hu, Kuang-Wei Lin, Wen-Wen Yang, Chen-Sheng Chen

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Introduction: Functional flat foot is a common musculoskeletal disease of lower extremity. It causes abnormal center of pressure (CoP) during gait. Customized foot orthoses (FO) are recognized for treatment of foot and lower limb pathology [1]; however, they are expensive and higher time cost. The 3D-printing technology is rapid-prototyping, low-cost and highly-customized. Therefore, the study aimed to conduct a 3D printing technology to fabricate FO for functional flat foot.

Research Question: Do the 3D-printed foot orthoses (3DPFO) (Fig. 1) alter CoP during gait in adults with functional flat foot?

Methods: One young adult with functional flat foot was recruited in this study, and was asked to walk in two different conditions including standard shoes with or without 3DPFO. Prior to the beginning of the tests, foot model of the participant was created by 3D scanning method and then 3DPFO was fabricated by means of 3D-printing device. The CoP was measured during each condition. Then, the CoP lateral excursion area of left foot (Fig. 2), which was defined as the area between the lateral side of the foot midline and the CoP trajectory, was analysed.

Results: The CoP lateral excursion area was larger in 3DPFO than in non-3DPFO conditions (516.66 vs. 396.55 mm²) (Fig. 3).

Discussion: The current study set out to determine whether the 3DPFO alters CoP lateral excursion area for adults with functional flat foot during walking or not. A previous study has shown that the more pronated foot posture, the smaller the lateral excursion area of CoP [2]. This study found that after using the 3DPFO, there are the larger lateral excursion area of CoP in the
participant with functional flat foot, because of the change in foot posture toward a supinated position.

Effect of sensorimotor insoles in children with flexible flatfoot: A pilot study

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Palacký University Olomouc, Olomouc, Czech Republic

Introduction:

Sensorimotor insoles (SMI) is a concept of orthopaedic insoles that, besides mechanical effects, influence muscle function in a way of changing muscle activation patterns [1,2]. By influencing motion control system, the SMI intervention effect is anticipated to remain even when SMI are not present anymore. The objective of this study is to assess whether there is an effect of SMI intervention on gait kinematics in asymptomatic flexible flatfoot children. This is a pilot study prior to the randomized control trial (RCT).

Research Question:

What is the effect of sensorimotor insoles on gait kinematics in children with flexible flatfoot?

Methods:

The subject was twelve years old boy with asymptomatic flexible flatfoot diagnosis. Data were collected during two sessions with one-month SMI intervention between the sessions. Data were collected during barefooted level walking using Vicon MX system. In order to minimize possible errors, the same person placed markers in both sessions. Data were collected during barefooted walking in order to determine whether there is lasting effect of SMI when they are not currently present. Several trials were performed for familiarization and five trials for analysis. The mean values were estimated from these five trials and then the difference between the range of motion (ROM) during gait cycle in pre-intervention and post-intervention session were compared (S2 - S1). As significant difference was considered value greater than 3°.

Results:

<table>
<thead>
<tr>
<th>ROM diff. (S2 - S1)</th>
<th>L Pelvic tilt</th>
<th>R Pelvic tilt</th>
<th>L Pelvic obl.</th>
<th>R. Pelvic obl.</th>
<th>L. Pelvic rotation</th>
<th>R. Pelvic rotation</th>
<th>L. Hip flex./ex.</th>
<th>R. Hip flex./ex.</th>
<th>L. Hip ab./add</th>
<th>R. Hip ab./add</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,3°</td>
<td>1,6°</td>
<td>4,3°</td>
<td>-0,6°</td>
<td>2,4°</td>
<td>1,3°</td>
<td>8,3°</td>
<td>5,4°</td>
<td>4,8°</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ROM diff. (S2 - S1)</th>
<th>R. Hip abb./add</th>
<th>L. Hip rotation</th>
<th>R. Hip rotation</th>
<th>L. Knee flex./ex.</th>
<th>R. Knee flex./ex.</th>
<th>L. Knee ab./add</th>
<th>R. Knee ab./add</th>
<th>L. Knee rotation</th>
<th>R. Knee rotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1,4°</td>
<td>-0,7°</td>
<td>4,7°</td>
<td>11,8°</td>
<td>5,3°</td>
<td>4,8°</td>
<td>4,7°</td>
<td>-2,6°</td>
<td>-0,4°</td>
<td></td>
</tr>
</tbody>
</table>

Discussion:

As this was a pilot study conducted on one person and aiming to debug the testing protocol in the first place, results are more likely tendencies. Also intervention was only one month lasting instead of four months planned for RCT. However, as for significant difference was considered value greater than 3°, there are eight out of sixteen parameters suggesting that ROM is greater after SMI.

References:
