INTRODUCTION
Wearable inertial sensors may allow objective and reliable evaluation of gait abnormalities in patients with multiple sclerosis (MS), as suggested by previous studies on balance and Timed Up and Go data [1]. This study aimed to identify those characteristics that can reliably discriminate between the gait of patients with mild/moderate (mMS), and severe (sMS) MS and as such play a role as biomarkers of disease progression.

METHODS
Fifty-nine patients with secondary progressive MS (26 mMS and 33 sMS; 19 males; age: 56.1 ± 9.1 years) and twenty-four healthy controls (CG: 8 males; age: 49.8 ± 8.2 years) were asked to perform a six-minute walking test. Six inertial sensors (Opal, APDM) were attached to wrists, sternum, lumbar spine and ankles and used to extract various gait measures, including spatiotemporal parameters and accelerometric features. Between session reliability (Intra-Class Correlation coefficient, ICC) was calculated over two sessions (7-14 days apart) and only those variables that had ICC>0.8 were further investigated. Differences between CG, mMS, sMS were tested using a non-parametric Mann-Whitney U Test (p=0.05) and a post hoc analysis with Bonferroni correction.

RESULTS
When compared to the CG, the MS patients walked with significantly longer step/stride time, increased step/stride time variability, increased asymmetry, reduced step and stride regularity and less smooth trunk accelerations (except for the medio-lateral axis). Moreover, they showed lower attenuation of anterior-posterior accelerations between pelvis and shoulder. These patterns were magnified in the sMS with respect to the mMS, as shown by the radar plots in Figure 1.

DISCUSSION
A set of reliable sensor-based measures has been identified, which allowed to characterise the differences between groups of patients with different MS severity. Longitudinal data are now being collected to verify sensitivity to disease progression. This study was partially funded by the UK EPSRC and NIHR (Sheffield Biomedical Research Centre and Clinical Research Facility).

REFERENCES
Application of confirmatory factor analysis to verify gait models in people with Parkinson’s Disease

I. Arcolin¹, M. Godi¹, M. Giardini¹, A. Nardone¹,², S. Corna¹
¹Istituti Clinici Scientifici Maugeri Spa SB (IRCCS), Italy; ²University of Pavia, Pavia, Italy.

INTRODUCTION
Baropodometric walkways allow to easily measure a large number of spatial-temporal gait variables. In order to easily analyze gait in healthy subjects (HS), reducing the number of gait variables to be handled, models of gait that included from three to five different factors (e.g. “pace”, “rhythm”, “variability”) were validated through exploratory factor analysis [1-4]. Gait is a strong indicator of health, and poor gait is a predictor of risk of falls and mortality [5]. One of the major functional disabilities in people with Parkinson’s Disease (PwPD) is gait disorder. However, at variance with HS, there are no agreed standardized protocols for measuring gait in PwPD. The aim of this study was to reduce the number of gait variables in PwPD, identifying the most relevant model describing gait abnormalities. Therefore, we (1) assessed the reliability of all the variables showed by previous models for HS and (2) analyzed the validity of these multifactorial models of gait in PwPD.

METHODS
250 PwPD were evaluated with a baropodometric walkway. The spatial-temporal variables of gait were averaged over four trials, in which patients were asked to walk at their usual velocity on the walkway. To verify if the models proposed in HS were applicable in our sample of PwPD, confirmatory factor analysis (CFA) was carried out using the structural equation modelling.

RESULTS
None of the four models of gait considered in HS [1-4] achieved the convergence when CFA was performed on data of PwPD. Only 15 of the 33 variables considered showed good reliability (Fig. 1). Most of the variables regarding asymmetry and variability, the latter calculated as Standard Deviation (SD) [1,4] or Coefficient of Variation (CV) [2,3], showed poor reliability.

DISCUSSION
Models of gait considered in HS were not valid for PwPD. The non-convergence between models could be due to the fact that each analyzed model included about 25-60% of variables of gait that proved to be not reliable in our sample of PwPD.

REFERENCES
DYNAMIC ELECTROMYOGRAPHY GUIDED - TREATMENT WITH BOTULINUM TOXIN OF DYSTONIC ANTEROCOLLIS IN PARKINSON’S DISEASE

M. Bacchini 1, G. Chiari 1, M. Rossi 1, C. Rovacchi 1

1 Don Carlo Gnocchi Foundation - Onlus - S. Maria ai Servi Center, Parma, Italy

INTRODUCTION

The mechanisms of anterocollis in Parkinson’s disease (PD) are considered to be neck dystonia or unbalanced muscle rigidity in most cases and focal myopathy in rare cases. Even if the clinical pictures are apparently similar at first physical examination, they are underlain by a different pathophysiology [1]. Dynamic and needle electromyography (EMG) investigates the synergies of cervical muscles and identifies affected muscles to be inoculated with botulinum toxin for specific protocol of rehabilitative treatment [2].

METHODS

18 patients (11 females and 7 males; the average age was 67 years) were studied prospectively and were performed to look for electrophysiological dystonic activity. The patients were studied using dynamic EMG (Pocket EMG, BTS, Milan, Italy) signals from sternocleidomastoid, splenius capitis, trapezius, cervical paravertebral and needle EMG signals from longus colli, anterior scalenus, semispinalis, levator scapulae. All patients underwent clinical investigation with Cervical Dystonia Disability Scale of Tsui, X-rays and EMG on two occasions: at inclusion and 1 month after botulinum toxin injection. The measurements were performed in “on” conditions 1 h after the regular morning antiparkinsonian drug administration. We identified three EMG distinct patterns within the patient group (Figure 1): the abnormal tonic hyperactivity with potential of more than 100 μVolts/sec. for more than 500 msec. at rest and during movements; the level of EMG hyperactivity much higher (more than 200 μVolts) in neck flexor/erector; fibrillations with short-duration (<2.0 msec.) voluntary motor units, low amplitude motor unit potentials with early recruitment in cervical paraspinal muscles. The weakness of the neck extensor was also confirmed by the detection of a decremental response with maximal decrement of 14% at rest, in repetitive nerve stimulation of the trapezius muscle at 3 Hz. Under EMG and ultrasound-guidance, we injected botulinum toxin (Dysport, 120 U in 1.0 mL physiologic solution) into the dystonic muscles in six sites using 20 U per site. In addition the patients underwent a rehabilitation programme consisting of individual 90-minute daily sessions, 5 days a week for 4 weeks.

RESULTS

After the treatment, the score of Tsui showed a mean significant improvement of 8 points. Significant decrease of X-ray degree of cervical kyphosis (33.6° ± 5.7° vs. 45.8° ± 9.1°) was observed. Dynamic electromyography: reduction of abnormal tonic hyperactivity of the inoculated muscles, associated with an increase in cervical spine strength.

DISCUSSION

We describe three different patterns of muscular activation in PD patients with anterocollis: typical dystonic activation; continuous activity related to muscle contracture; myopathic changes in the erector cervical spinae muscles. Anterocollis with an underlying dystonic pattern would be treatable with botulinum toxin injections, while anterocollis showing other patterns not only would not respond to botulinum toxin injections but it could be even counterproductive [3].

REFERENCES

The Association Between Prefrontal Cortex Activity and Turning Behaviors in People With and Without Freezing of Gait.

V. Belluscio¹,², S. Stuart ², E. Bergamini¹, G. Vannozzi¹, M. Mancini²

¹ Università degli Studi di Roma Foro Italico, Roma, Italy
² Department of Neurology, Oregon Health and Science University, Portland, Oregon, USA

INTRODUCTION

A hallmark of mobility disability in Parkinson’s disease (PD) is the significant conscious attention required to balance and walk. In fact, the ability to automatically control walking while talking or performing a concurrent secondary task (DT) is impaired in PD, suggesting that the basal ganglia plays an important role in motor automaticity. Those impairments likely cause an increased demand on the prefrontal cortex (PFC) to execute basic motor tasks via attentional processes. Turning impairments often appear before gait impairments and, in addition, turning seems to elicit most of the Freezing of Gait (FoG) episodes [1]. PFC activity during balance and walking has been shown to be altered in PD compared to healthy controls [2] and although an association between FoG status and increased PFC activity has been found [3], the relationship between turning and PFC activity is still not clear. Therefore, the aim of this study is to examine a 360° turning-in-place task to investigate associations between PFC activity and turning behaviors in patients with and without FoG. The effect of single/dual task conditions was also assessed.

METHODS

Thirty-five subjects with PD in the “off” medication state and 10 healthy control subjects participated in the study. Of the 35 PD subjects, 18 were classified as freezers, FoG+, based on a score >0 in the New Freezing of Gait Questionnaire (NFOGQ), (age 68.3±6.0 years, Unified Parkinson’s Disease Rating Scale (MDS-UPDRS) Part III = 33.8±11.4), and 17 were classified as non-freezers, FoG-, based on a NFOGQ score = 0 (age 67.2±4.9 years, MDS-UPDRS Part III = 46.7±12.4).

Subjects were asked to perform a 2-minute turning-in-place test (alternating 360° turns to the right with 360° turns to the left) in single task (ST) and dual task (DT) conditions (Modified AX-Continuous Performing Task, where participants had to give the target response when the cue letter “A” was followed by the target probe “I”). Each participant was equipped with 3 inertial sensors located at the waist and on both feet and a functional near-infrared spectroscopy (fNIRS) system to examine PFC activity. The following outcome measure were obtained: HbO2 changes while turning from a standing baseline, number of turns, average turning duration, average turning peak velocity, average turning jerkiness, and FoG ratio (indicator of FoG severity) [4]. Pearson correlation analysis was performed to assess the relationship between turning patterns and PFC activity (α = 0.05) in all groups.

RESULTS

When merging FoG+ and FoG- in one group, changes in HbO2 were significantly associated to average turning peak velocity (r = -.563, p = .029) only for the DT condition. Conversely, when separating FoG+ and FoG-, changes in HbO2 were significantly associated to the FoG Ratio (r = .769, p = .043) only for the FoG+ group in both ST and DT. In addition, no association between changes in HbO2 and turning parameters was found in healthy controls. Significant associations were also found among turning duration, velocity and number of turns, in PD and in healthy control (r > .478, p<0.05). Finally, FoG ratio was related to turning jerkiness, independently from FoG status (r > .533, p < 0.05).

DISCUSSION

Our findings suggest an association between prefrontal cortex activity and turning behaviors in patients with and without freezing of gait, highlighting a relationship between PFC activity and FoG severity: specifically, the increase of PFC activation could be related to the loss of automaticity in FoG+. Understanding the cortical activation involved in turning actions and its association with the relevant behavioral parameters could support the development of personalized treatment in subjects with Parkinson disease through an increased understanding of the basic mechanisms underlying FoG, toward an overall improvement of their autonomy and quality of life.

REFERENCES

Characterization of Motion Tracker wireless accuracy and analysis of error propagation in the INAIL Shoulder and Elbow Outpatient (ISEO) protocol

A. Berardi 1,2, M. Muraccini 1,3, A. Varini 2, M. Mantovani 2, A. Cappello 1

1 University of Bologna, Bologna, Italy, 2 NCS Lab, Carpi, Italy, 3 E-motion, Messina, Italy

INTRODUCTION

Over the last decade, thanks to advances in micro-electromechanical sensors and orientation estimation algorithms, the use of inertial sensors in motion capture applications is increasing. However, their diffusion in an outpatient setting requires data accuracy, which depends on the sensors’ motion characteristics [1]. The purpose of this work is to assess the errors due to the use of the MTw (Motion Tracker wireless, Xsens Technologies, NL) instead of an optoelectronic system (BTS SMART-DX 7000), in the measure of the upper limb kinematics using the protocol ISEO [2].

METHODS

To apply the ISEO protocol simultaneously with the optoelectronic system (gold standard), each MTw, positioned on thorax, scapula and humerus, was applied on a 3D-printed cluster of four markers. One subject slowly performed three tasks of six cyclical movements of humeral anteflexion or humeral abduction. The acquisition protocol was repeated six times. For each cluster, a reference system, similar to that of the paired sensor, was constructed. Any misalignment has been corrected previously with a static calibration. Using the same protocol, this study excludes any differences in the measurements of the two systems due to external factors. To characterize the overall accuracy of the MTw, we computed mean value and standard deviation (std) of the errors between the orientations estimated by the two technologies, for all the analyses performed. These two orientations have been used distinctly as input for the ISEO protocol. The data concerning the joint angles were compared by calculating the Root Mean Square Error (RMSE%), expressed as a percentage of the range of motion.

RESULTS

Regarding the pair “cluster-sensor” on thorax, scapula and humerus, the maximum recorded angular difference (represented as mean ± std) is 1.2°±0.8°, 5.5°±3.5° and 10.6°±6.1° respectively. It is evident a progressive increase of the error with the mobility of the anatomical district. The maximum linear accelerations, estimated deriving the stereophotogrammetric data, are 1.66m/s², 0.41m/s² and 0.37m/s², respectively for sensor on humerus, scapula and thorax. This preliminary result justifies the subsequent sensor error propagation analysis in the estimation of the orientation using these data in a clinical protocol. Analyzing the upper limb kinematics, higher RMSE% values correspond to the angles with a smaller range of motion. The main joint angles data from MTw are closer to the gold standard. The widest rotation of the scapula is the medio-lateral one, while in the humerus it corresponds to the angle of elevation. For example, in the humeral abduction during a task in the frontal plane (Fig.1), the maximum errors are 16%, 62% and 49% respectively for the humerus rotations with decreasing range (AB-AD, FLEX-EXT, IN-EX).

Figure 1. Humerothoracic kinematics measured by MTw (red line) and optoelectronic system (blue line)

DISCUSSION

The results confirmed that MTw performance depends on the sensor' linear acceleration and that the analyzed protocol is adequate for clinical applications because it accurately estimates the main angles. Nevertheless attention must be paid when low range angular movements are considered.

REFERENCES

The impact of turning and dual task on freezing of gait in Parkinson’s disease

M. Bertoli 1, A. Cereatti 1,2, U. Della Croce 1, M. Mancini 3

1 University of Sassari, Sassari, Italy, 2 Politecnico di Torino, Torino, Italy, 3 Oregon Health and Science University, Portland, OR

INTRODUCTION

Turning is a challenging motor task, requiring bilateral limb coordination, dynamic balance control and anticipatory postural adjustments and it is often impaired in people with Parkinson's disease (PD). In addition turning, particularly for larger angle, is a trigger for Freezing of Gait (FoG) [1]. FoG is an episodic gait disturbance that most frequently occurs during postural transitions. Also, the presence of a concurrent cognitive task while walking (DT) has been found to elicit FoG in those subjects who freeze (FoG+). While the deterioration of walking performance during DT is larger in FoG+ compared to non-freezers PD (FoG-), the effect of DT on postural transitions is still controversial [2,3]. Since turning is believed to require more cognitive control compared to walking, and since FoG+ often show impaired cognition with respect to FoG-, we hypothesize that turning performance will be poorer for larger turning angles in both groups, and this effect will be more evident in FoG+, and even worse with DT.

METHODS

Two different turning trials were performed by 19 FoG+ (70±7 y.o., MDS-UPDRS: 46±12) and 17 FoG- (71±7 y.o., MDS-UPDRS: 44±12) wearing three inertial sensors (Opal, APDM, Inc.) on feet and low back (L5). The trials were U-turns while walking and 360° turning in-place. The trials were performed first without any extra cognitive task (ST) and then in DT (serial subtraction). For both conditions, the following quantities (\( q_i \)) were computed during the turns analyzed: Peak (angular) Velocity, Turn Duration, Range of Acceleration and Step Count. To investigate the DT effect, for each quantity the DT cost (\( C_{i,DT} \)) was computed as \( C_{i,DT} = \frac{q_{i,DT} - q_{i,ST}}{q_{i,ST}} \). A repeated measures analysis of variance (two way ANOVA) between groups (FoG+/FoG-) and within trials (U-turn/360°-turn) was performed for all \( q_i \) and for their \( C_{i,DT} \).

RESULTS

In general, FoG+ were slower in completing both turn trials (Turn Duration p<0.01; Peak Velocity p<0.01) and took more steps (p<0.01) compared to FoG-. In both groups Turn Duration and Step Count worsened at 360°-turn compared to U-turn (p<0.01; p<0.01), furthermore a significant group*trial interaction was found (p=0.03; p=0.01). In both FoG+ and FoG-, the turn performance was worse (slower and more steps) in DT compared to ST. Peak Velocity was similar for U-turns and 360°-turns in ST (no trial effect), but it significantly decreased for the 360°-turn when adding the DT (\( C_{DT} \) p<0.01). Turn Duration and Step Count \( C_{DT} \) also had a significant task effect (p<0.01; p<0.01).

DISCUSSION

FoG+ showed further impairments in turning performance when increasing turn angle compared to FoG-, but surprisingly, not when adding a secondary task. The significant trial effects suggest that turning at larger angles is more demanding for FoG+ compared to FoG-, possibly due to an increased demand on bilateral coordination [1]. In accordance to previous research [3], turning seems to have a higher impact on FoG episodes with respect to DT.

REFERENCES

Inter-foot distance measurement in healthy adults during gait using a wearable prototype device: validation on straight walking and turning for different distance sensor locations

S. Bertuletti¹, A. Cerreatti¹,², U. Della Croce¹
¹ Department of Biomedical Sciences, Bioengineering unit, University of Sassari, Sassari, Italy
² Politecnico di Torino, Department of Electronics and Telecommunications, Torino, Italy

INTRODUCTION
Magneto-inertial measurement units (MIMUs) allow for the estimation of classical gait spatio-temporal parameters but do not provide any information about inter-foot distance (IFD) [1]. To overcome this limitation, we developed a wearable prototype device (SWING²DS) [2] which can integrate multiple distance sensors (DSs). The purpose of this study was to test, validate and compare IFD estimates as obtained from two different DS locations (forefoot and rearfoot) in healthy adults during gait.

METHODS
Sixteen healthy adults (38.6±10.7 y.o.) were recruited. Each participant performed a two-minute-level walking trial in a loop consisting of two straight and two curved sections at a self-selected pace in two occasions (test and retest, one week apart). The SWING²DS system, including a MIMU and two DSs, was embedded on a rigid support and attached to the medial side of the right foot. A DS was close to the forefoot (FOREDS) and the other close to the rearfoot (REARDS). Since during walking, the DSs return non-zero distance values only when the two feet face each other, a SWING²DS-based IFD estimate was performed every step by averaging the relevant DS readings. A stereo-photogrammetric system (SP) was used as gold standard. A cluster of three retro-reflective markers was placed on each foot to define a local foot coordinate system (LCS). The geometry of the SWING²DS system (DS positions, plane of the support) and the polygon identifying the medial surface of the left foot (opposite to the SWING²DS system) were calibrated with respect to the LCS during a preliminary static acquisition. The marker-based IFD was obtained as the distance between the marker on the DS and the intersection point (IP) between the medial surface of the left foot and the line orthogonal to the support passing through the DS. The comparison between the IFD estimates obtained with the SWING²DS and those provided by the SP was carried out only for those steps for which the IP fell into the polygon defining the medial foot surface. For each subject, the mean and standard deviation of the IFD obtained with the SP (IFDSp ± sd) and with the SWING²DS (IFDSWING ± sd), the mean and standard deviation of the error (e ± sd), the mean absolute error (mae) and the mean absolute percentage error (maeps) were computed. The mean of the latter indices was computed over subjects for test and retest sessions.

RESULTS
FOREDS performed better than REARDS in all conditions (straight/turn walks and test/retest sessions). The MAE (MAEps) ranged between 9.3 (13.2%) and 11.5 mm (15.3%) for straight walks and between 11.1 mm (13.0%) and 12.4 mm (13.9%) for turns.

Table I: Performance of REARDS and FOREDS for the measurement of the IFD during straight walks and turns for test and retest sessions.

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IFDSp ± SD</td>
<td>IFDSWING ± SD</td>
<td>E ± SD</td>
<td>MAE</td>
</tr>
<tr>
<td></td>
<td>[mm]</td>
<td>[mm]</td>
<td>[mm]</td>
<td>[%]</td>
</tr>
<tr>
<td>REARDS</td>
<td>Test</td>
<td>64.0 ± 11.5</td>
<td>66.9 ± 12.4</td>
<td>4.9 ± 10.3</td>
</tr>
<tr>
<td></td>
<td>Retest</td>
<td>61.1 ± 10.0</td>
<td>64.0 ± 12.8</td>
<td>2.9 ± 10.2</td>
</tr>
<tr>
<td>FOREDS</td>
<td>Test</td>
<td>80.6 ± 13.8</td>
<td>81.4 ± 15.4</td>
<td>0.8 ± 10.6</td>
</tr>
<tr>
<td></td>
<td>Retest</td>
<td>85.1 ± 14.6</td>
<td>82.0 ± 15.9</td>
<td>-3.2 ± 11.7</td>
</tr>
</tbody>
</table>

DISCUSSION
The results show that the SWING²DS system can provide satisfactory measurements of the IFD during both straight walks and turns, especially in its FOREDS configuration (MAE < 12.4 mm), which not only showed higher accuracy than the REARDS configuration, but also greater robustness to the changes of walking trajectory (similar errors for straight walking and turning). The IFD observations as provided by SWING²DS can be used in a sensor fusion framework to estimate the base during double-support phase while walking.

REFERENCES
A wearable prototype device for direct bilateral step detection by instrumenting a single foot
S. Bertuletti1, U. Della Croce1, A. Cereatti1,2
1 Department of Biomedical Sciences, Bioengineering unit, University of Sassari, Sassari, Italy
2 Politecnico di Torino, Department of Electronics and Telecommunications, Torino, Italy

INTRODUCTION
Detection of right and left steps during gait is generally obtained by instrumenting both feet with inertial measurement units (IMUs) and by identifying initial foot contacts from acceleration and/or angular velocities measurements [1]. In this work, we proposed an alternative approach based on a wearable prototype device (SWING2DS) [2] to be attached to one foot, incorporating two Time-of-Flight distance sensors (DSs), for the detection of both right and left steps. We assessed the system performance on healthy subjects for two different DSs locations on the foot.

METHODS
The SWING2DS system consisted of an IMU and two DSs embedded on a rigid base fixed to the medial side of the right foot with the DSs close to the first metatarsophalangeal joint (FOREDS) and to the heel (REARDS). Each DS was programmed to return the distance value in the range of 0-200 mm at 50 Hz. Since during walking, DSs return non-zero distance values only when feet face each other (twice for each gait cycle), step detection was performed by counting the number of distinct non-zero values intervals. A stereo-photogrammetric system (Vicon Motion Systems, Oxford, UK; 100 Hz) was used as gold standard for automatically counting the total number of steps based on the identification of the foot-strike from the vertical velocity profile of the midpoint between heel and toe markers [3]. Sixteen healthy adults (38.6±10.7 y.o.) were recorded while walking on level ground at self-selected pace for two minutes along a loop in two sessions (test and retest, one week apart). Step detection accuracy, as obtained by the two DSs locations, was computed in terms of mean absolute percentage error (MAPE).

RESULTS
A total of 5077 steps were analysed. Both DSs detected no extra steps. Considering the entire loop walk, REARDS showed 0 and 1 (0.1%) missed steps of the instrumented foot and 6 (0.5%) and 93 (7.9%) missed steps of the non-instrumented foot during test and retest sessions, respectively. FOREDS showed 1 (0.1%) missed step during test session and 9 (0.7%) missed steps during retest session for the instrumented foot, while 76 (6.4%) and 197 (18.3%) steps were missed for the non-instrumented foot during test and retest sessions, respectively.

Table I: The performance of REARDS and FOREDS for the step detection during a two minutes’ walk along a loop (divided in straight and turn paths) for test and retest sessions.

<table>
<thead>
<tr>
<th>Loop</th>
<th>Straight</th>
<th>Turn</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Instrumented Foot</td>
<td>Non-Instrumented Foot</td>
</tr>
<tr>
<td>Step</td>
<td>Missed</td>
<td>MAPE [%]</td>
</tr>
<tr>
<td>REARDS</td>
<td>Test</td>
<td>1250</td>
</tr>
<tr>
<td></td>
<td>Retest</td>
<td>1281</td>
</tr>
<tr>
<td>FOREDS</td>
<td>Test</td>
<td>1258</td>
</tr>
<tr>
<td></td>
<td>Retest</td>
<td>1273</td>
</tr>
</tbody>
</table>

DISCUSSION
The best DS location for the step detection resulted to be close to the heel (0<MAPE<12.7%). For both DS locations, step detection accuracy was always higher or equal for the instrumented foot compared to the non-instrumented foot. In fact, the step may be missed when the non-instrumented foot swings higher than the DS on the ground during the instrumented foot stance (e.g. large foot clearance). In this case, a reduction of the number of missed steps could be obtained by moving the position of the DSs on a higher location on the foot. In conclusion, the SWING2DS system applied to a single foot can detect the steps of both feet with reasonable reliability.

REFERENCES
Effect of height differences on reference values of postural sway in typically developing children: should we refer to dimensional or to non-dimensional results?

M.C. Bisi, R. Stagni

DEI, University of Bologna, Italy

INTRODUCTION

Recent literature highlighted the need of reference values for postural sway in children [1,2]. Only few studies reported numeric values for age categories and a considerable disagreement exists on the (non-)linearity of postural sway development [1]. Inertial sensors have been shown to be effective for evaluating postural sway in elderlies and pathological populations [3]. Given their portability, their use can support the definition of children postural sway reference values, facilitating the assessment and the monitoring of postural control development. Despite the topic relevance and the promising approach, some methodological aspects have to be analysed. Body height influences postural sway parameters in adults [4] and recent literature compensated this factor by analysing non-dimensional results in children [2]. On the other hand, since children’ height is strongly related to age, these two factors overlap in the developing population, requiring a specific analysis before defining eventual normalization procedure. This work aims at investigating the effect of height and age on postural sway parameters assessed using inertial sensors, with the final goal of defining new reference values for preschool and schoolchildren.

METHODS

109 typically developing children, between 3 and 8 years of age, participated in this study. Postural sway acceleration was measured for 40s in two conditions (eyes open/closed, EO/EC) by using one inertial sensor (Opal, APDM, Sampling frequency 128Hz) on the lower trunk [3]. Data of children not able to complete the task (<30s) were excluded. Descriptive sway parameters were calculated according to [3]: Jerk, Mean distance from acceleration trajectory center (DIST), Root Mean Square, Sway Path, Range, Mean Velocity, Mean Frequency and Sway Area. Data were divided in 5 different age groups (by year of birth) and correlations between sway parameters and height were assessed. Correlations between sway parameters and age/height were evaluated also on the entire dataset.

RESULTS

40 participants were selected for this preliminary evaluation. Analyzing different age groups, no significant correlation between sway parameters and height was found (p>0.5). On the entire dataset, sway parameters correlated in the same way with age and height. In EO, moderate to strong negative correlations were found (p<0.01, -0.79<ρ<-0.40) for all the parameters (except for Mean Frequency) and age/height. In EC condition, Jerk, Sway Path and Sway Area showed weak negative correlations with both age and height (p<0.05, -0.39<ρ<-0.20).

Figure 1. Exemplificative results (DIST) with respect to children’ age and children’ height.

DISCUSSION

Results showed that the effect of children’ height on sway parameters is primarily connected to the concurrent age maturation. Unlike the increase of sway parameters with adult’s height [4], no correlation was found on specific age groups in the present study. On the entire group of children, the found correlations between sway parameters and height were negative, as negative were the correlation with age. Thus, scaling postural sway parameters to obtain non-dimensional results could hide effective trend of postural development with chronological maturation. Further investigation for the correct assessment/comparison of sway parameters in children with height differences is needed.

REFERENCES

Quantitative monitoring of preterm motor development trajectory: a preliminary study.
M.C. Bisi 1, M. Fabbri 2, M. Manfredini 2, R stagni 2
1 DEI, University of Bologna, Italy, 2 UOSD, Disturbi del Neurosviluppo, AUSL Bologna, Italia

INTRODUCTION
Preterm children have an increased risk of motor difficulties, with prevalence three times greater than in the general population [1]. Mild motor deficits are difficult to timely identify and can have long-term consequences, compromising physical function, academic achievement, and other health outcomes [1]. Objective evaluation of each child's motor development progress can play a key role for the identification of deficits/delays, facilitating referral to early intervention programs. The use of wearable inertial sensors and quantitative measures for the analysis of human movement [2] can serve to this purpose, offering quantitative and interpretative methods to assess motor performance with respect to the expected maturation and potentially early highlighting deviations from typical motor development.

METHODS
Two groups of 2-year old children, matched per corrected age and months of walking experience (WE), participated in the study: 11 born preterm (PT: 27±32 weeks of gestation, age 24±1 months, 10.7±2 months of WE) and 9 born at full term (FT: >38 weeks of gestation, age 24±3 months, 10.7±3 months of WE). All children had no diagnosis of motor delays. Acceleration and angular velocities of trunk and shanks were collected using three tri-axial inertial sensors (Opals, Apdm), while children walked in a 15m long corridor. For each participant 14 strides were analyzed. Stance (ST), Double support (DS) duration, standard deviation and Poicarré plots of stride-time (stdStride, SD1 and SD2) were obtained from shank angular velocities [2]. Fundamental frequency (ff), Sample Entropy (SEN), Recurrence Quantification Analysis (RQA), short Lyapunov exponents (sLE) and Harmonic Ratio (HR) were calculated on trunk acceleration components [2]. An unpaired Student's t-test (significance level=0.1) was performed on the two groups for each parameter.

RESULTS
PT children showed higher values of sLEs and RQA results, higher cadence (ff) and longer DS and ST when compared to FT group. No significant differences were found for HR and SEN. Figure 1 shows significant results presented as polar reference bands (mean ± standard deviation) for FT (dark grey) and PT group (light grey). Bands were obtained by normalizing results with respect to minimum and maximum of data from the two groups. Sectors are related to different areas of motor control performance: A) short term stability (sLE), B) postural control ability (RQA), C) temporal parameters (ff, DS and stance) and D) timing variability (D1, D2 and stdStride).

DISCUSSION
The proposed approach allowed to quantify gait differences in gait development of FT and PT children of comparable age and WE, without diagnosis of motor delay. Considering data dispersion, despite a lower range in age and WE in the PT group, PT bands result wider than FT ones, suggesting that some PT children had a gait performance similar to FT children while others showed a decreased performance and/or a more immature gait. Further longitudinal monitoring of these PT children and comparison with reference bands of typically developing peers, will allow to relate these early biomarkers to future motor development, potentially allowing early detection of risk to develop persistent motor impairments, or to catch-up and be free from later motor impairment.

REFERENCES
Comparison of four devices for spinal immobilization: quantitative analysis of segmental mobility during immobilization procedure using wearable inertial sensors.

M.C. Bisi 1, E. Farabegoli 2, E. Magnani 3, R. Stagni 1
1 DEI, Università di Bologna, Italy, 2 U.O. Medicina d’Urgenza-118 Trauma Center M. Bufalini Cesena, Italy 3 U.O. Medicina Interna M. Bufalini Cesena, Italy

INTRODUCTION
Spinal immobilization is the safest method to prevent lesions subsequent to trauma [1]. Despite being widely used, the most consolidated methods of spinal immobilization have limits [2] and rigorous scientific evidences for supporting the choice between the different available devices are missing [3]. In clinical practice, different and innovative devices are used for ensuring spinal immobilization, on the cervical tract in particular. However, still no effective way to prove their efficacy in minimizing segmental mobility have been designed; there are only scarce studies with different results [1,3]. Human movement analysis methods and wearable inertial technologies can respond to this need. Inertial sensors allow to quantify and monitor human movement for instrumented testing, complementing the information derived from qualitative observations with that derived from quantitative biomechanical parameters. The present study aims to compare four different commercial systems for spinal immobilization during a standard immobilization procedure, analyzing quantitatively segmental mobility using inertial sensors.

METHODS
Four different spinal immobilization devices were selected (A-Stila, not requiring cervical collar; B-Spinale + cervical collar Wizlock Ferno; C-Scoop EXL65 + cervical collar Wizlock Ferno; D-Materassino + cervical collar Wizlock Ferno). Five healthy subjects (subjects, 3M/2F, 172±15cm, 69±23kg) and three volunteering emergency medical technicians participated in the study. Five wireless tri-axial inertial sensors (Opals, APDM, Sampling frequency 128 Hz) were positioned along the spinal axis of each subjects (on Head, C7, T12, L5, S2) and one sensor was fixed on each stretcher. While subjects were lying prone on the floor, technicians were asked to perform a typical immobilization procedure (log roll- and stretcher-lifting maneuvers), following the standard procedure guidelines of each disposal. The task was repeated three times per stretcher and per participant (stretcher order randomized). The mean and peak value of the differential 3D angular velocity (cut-off frequency 5Hz) was calculated for each couple of sensors attached to the subject and for each of these with respect to the stretcher, in order to quantify relative mobilization.

RESULTS
Figure 1. Mean and peak value (meanD and peakD) of 3D angular velocity difference between Head and C7 sensor for the five different subjects (triangle up, triangle down, dot, square, diamond) and four devices (A-D).

DISCUSSION
Preliminary results highlighted consistent trends over subjects per analyzed device. For Head-C7 in particular, device A (not requiring cervical collar) showed larger mean mobility, although of limited magnitude, but peaks comparable to those of the other devices (requiring cervical collar), with the exception of device D, which resulted to provide the less repeatable performance over different subjects and the highest peaks. Further ongoing analysis will address vibration transfer during the maneuver, and quantification of relative kinematics through Kalman filter modelling.

REFERENCES
AN AUGMENTED REALITY BASED PLATFORM TO MEASURE GAZE AND GAIT
T. Bonci 1,2, A. Cereatti 1,3, U. Della Croce 1
1 Department of Biomedical Sciences, University of Sassari, Italy; 2 Life and Health Sciences, Aston University, Birmingham, UK; 3 Department of Electronics and Telecommunications, Politecnico di Torino, Italy

INTRODUCTION
Understanding interactions between gait and gaze is crucial for reducing the risk of falls especially in older adults (OA). Although healthy OA adopt a more conservative motor strategy than young adults when negotiating obstacles, contacts with obstacles while walking are more frequent, increasing the risk of falls [1]. Moreover, OA seem to prioritise visual information regarding future obstacles instead of focusing on accurate execution/conclusion of the ongoing stepping actions [2]. However, it has been observed that, if properly trained, OA could implement a gaze behaviour similar to younger adults [3] and potentially reduce the risk of falls.

In this regard, a platform for tracking gaze and gait while proposing visual and audio stimuli would be beneficial both for movement evaluation and training. To maximize its benefits, the platform should be wearable, minimally obtrusive, easy to use and relatively low-cost. Some solutions have been already suggested in the literature, although they are non-portable, expensive or both [4-5].

The aim of this study is to present a platform where gaze and gait can be simultaneously tracked providing the user with a real-time feedback. An augmented reality (AR) solution has been selected that blends “real-world” with “virtual elements” (i.e., obstacles, distractors) [6], generating a safer experience for the user compared to an immersive virtual reality solution, which completely replaces the real-world scenario with a virtual one.

METHODS
A stand-alone headset (Microsoft HoloLens AR) is used to create virtual obstacles and distractors (holograms/sounds) superimposed to real-world elements. A binocular eye-tracking system (200Hz eye cameras, Pupil Labs), customized to be attached to the headset, is used to measure gaze coordinates, streamed (over a WiFi) using an Android device (Pupil Mobile Bundle) to a computer with a dedicated software (Pupil Capture). Three inertial measurement units (IMU; Shimmer, Dublin, Ireland), placed on the feet and on the trunk, are used to track the subject’s movement. Moreover, to enhance motor and visual training, real-time visual and auditory feedbacks are provided to the user.

RESULTS
The framework of the proposed AR platform is shown in Fig. 1. Blue and red boxes/connections represent sections that have been already realised and those under development, respectively. The platform allows AR events to be triggered by successful or unsuccessful obstacle negotiations and consequent gaze reactions can be recorded. Alternatively, it allows movement to be recorded when reacting to AR events triggered by gaze behaviours.

DISCUSSION
Gait and gaze can be recorded while a user is walking and stepping over virtual obstacles using a portable, wearable, and relatively low-cost platform. Further studies are planned to further develop and test the described platform with a primary intent of using it in rehabilitation contexts.

REFERENCES
Effective mobility recovery after femoral neck fractures: the necessity of gait analysis in the immediate post-operative aftercare.

I. Bortone 1,2, N. Caringella 2, G. Lelli 3, F. Rifino 2, A. Di Candia 3, P. Fiore 2,3, B. Moretti 2,3

1 Institute of Clinical Physiology, National Research Council, Pisa, Italy, 2 Department of Medical Sciences, Neuroscience and Sense Organs, University of Bari, Bari, Italy, 3 Azienda Ospedaliero-Universitaria Consorziale Policlinico di Bari, Bari, Italy

INTRODUCTION
Due to the ageing population, the worldwide incidence of hip fractures will rise from 1.66 million in 1990 to 6.26 million by 2050. Loss of function is common after a hip fracture and patients experience difficulties in their return to society or to their previous habitat. Few studies have focused on functional outcome [1,2], and have only recorded general function [3,4]. We hypothesized that femoral neck fractures results in a characteristic recovery of gait pattern based on kinematic, kinetic and electromyographic variables. The aim of the present study was to identify factors associated with poor gait ability that might help establish post-operative rehabilitation protocols that prevent such outcome.

METHODS
In this prospective, observational study, a combination of clinical, radiological and functional assessments have been proposed to patients with femoral neck fractures during the immediate post-operative aftercare. Proximal femoral nail (NF) and hemiarthroplasty (HA) had been performed to patients according to their condition. Inclusion criteria were over 65 years old, no neurological or cardiorespiratory diseases, previous walking abilities. Gait was analyzed at almost 10 weeks after intervention using the BTS GAIT LAB (BTS, Italy). All participants performed several walking trials at their natural speed. Same data were compared between operated and uninjured limbs to determine any asymmetry on kinematic and kinetic parameters. The study protocol was approved by the Local Ethics Committee and a signed consent form was obtained from each subject for all tests. Analyses were performed using Matlab (The MathWorks, Inc., USA). Results with P<0.05 (two-sided test) were regarded as statistically significant.

RESULTS
Currently, 10 patients (7 PwFN, mean age = 77±8.5; 3 PwHA, mean age = 78±3.7) have been enrolled in the study. All the clinical, radiological and functional data have been collected in a single database at Orthopedic and Trauma Clinic (AOUC Policlinico di Bari, Italy). Preliminary analysis have been carried on spatiotemporal parameters and kinematic variables through two-way ANalysis Of VAriance considering as fixed factors the treatment and the side of fracture. Significance has been observed for cadence and double support (percentage), while right and left peak hip flexion in stance, left peak hip abduction in stance and peak hip adduction in swing and double support time, stance and stride time revealed interaction effects.

DISCUSSION
Despite post-operative physical therapy training, none of the enrolled patients reached full motor recovery: only half of the patients were able to walk independently and without any support. Patients operated by proximal femoral nail showed better spatiotemporal parameters and kinematic variables, as confirmed in [1]. Following step will be the follow up at 28 weeks after intervention in order to identify significative variables and relationship among multi-parametric factors will be clarified [5].

REFERENCES
Changes in gait kinematic parameters after rehabilitation in total knee arthroplasty subjects: A prospective observational pilot study

J Pollet 1, C Arienti 2, F Bosio 2, B Piovanelli 2, Buraschi B 2, P Pedersini 2, S Negrini 1,2
1University of Brescia, Italy; 2IRCCS Don Gnocchi Foundation, Milan, Italy.

INTRODUCTION
Total knee arthroplasty (TKA), is a routine surgical intervention, with an incidence of 150-200 surgeries every 100,000 people[1]. After this surgery is common practice for every subject to undergo a period of rehabilitation to recover strength, range of motion and walking ability of the affected limb. Many evaluation scales have been developed to evaluate improvements during and after rehabilitation, but the walking ability has rarely been evaluated in the acute phase[2] (3-30 days post surgery) through an optoelectronic system. The aim is to evaluate the effect of rehabilitation on functional outcomes scales and gait kinematic parameters and verify which parameters are clinically relevant.

METHODS
After receiving ethical approval, in a postacute rehabilitation hospital, subjects were recruited after receiving TKA. International knee society score (IKSS), Barthel Index (BI), Numerical Rating Scale (NRS), Knee Flexion (KF), and gait analysis (GA) were assessed at hospitalization (T0) and discharge (T1). The GA system is a BTS DX-400 with 8 optoelectronic cameras and 2 force platforms, the markerization protocol used was Davis-Heel (22 markers). Gait was allowed with one or two crutches according to needs, and at least 3 walks were performed.

RESULTS
10 subjects (age of 68.5±10.7, 5 females, 6 left knee) met the inclusion criteria. The subjects showed a significant difference between T0 and T1 in all the functional evaluation scales (P<0.001) excluding NRS (P>0.05). GA parameters showed a Δ of improvement of 0.06 m/s, 0.08 m, 6.64%, 3.59% respectively for gait speed, step length, single support phase and swing phase on the operated limb between T0 and T1, the comparison of Δ didn’t demonstrate a significance up to now (P=0.07), while a clinical effect size has been shown by IKSS, BI and KF and many of the gait kinematic parameters (Cohen’s d>0.8) (Table1).

Table 1. Comparison between T0 and T1 for Functional Outcomes Scale and Gait Kinematic Parameters

<table>
<thead>
<tr>
<th>Functional Outcomes Scales</th>
<th>pValue</th>
<th>Cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>International knee society score (IKSS)</td>
<td>&lt;0.001</td>
<td>5.9</td>
</tr>
<tr>
<td>Barthel Index (BI)</td>
<td>&lt;0.001</td>
<td>3.0</td>
</tr>
<tr>
<td>Knee Flexion (KF)</td>
<td>&lt;0.001</td>
<td>3.7</td>
</tr>
<tr>
<td>Numerical Rating Scale (NRS)</td>
<td>0.34</td>
<td>0.3</td>
</tr>
<tr>
<td>Gait Kinematic parameters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gait Speed</td>
<td>0.05</td>
<td>1.4</td>
</tr>
<tr>
<td>Step Length</td>
<td>0.06</td>
<td>0.7</td>
</tr>
<tr>
<td>Single Support Phase on Operated Limb</td>
<td>0.07</td>
<td>1.0</td>
</tr>
<tr>
<td>Swing Phase on Operated Limb</td>
<td>0.05</td>
<td>0.5</td>
</tr>
</tbody>
</table>

DISCUSSION
According to this study, rehabilitation improved the scores collected by the functional outcome scales[3]; gait speed, step length, single support phase and swing phase on the operated limb showed an improvement but with a lack of significance, probably due to the low sample size: the study is still ongoing and we expect that a larger sample size will produce a statistical significance. Most of the parameters detected with GA and all the functional outcomes scale showed a clinically significant effect size.

REFERENCES
Correlation of neuromuscular synergies and performance indices in indoor rowing using a custom foot stretcher for ergometers: a preliminary study

T. Caporaso 1, A. Palomba 2, S. Grazioso 1, G. Di Gironimo 1, A. Lanzotti 1,
1 Fraunhofer JL IDEAS, DII – University of Naples “Federico II”, Naples, Italy, 2 University of Campania "L. Vanvitelli", DMSSD, Naples, Italy

INTRODUCTION
Indoor rowing using ergometers covers a part of the training programs of élite rowers. A major component of the machine is represented by the foot stretcher, as it influences the leg propulsion efficiency. Usually, the only variable parameter is represented by its height, and it was demonstrated how the changing of this parameter influences the rowing technique and performances [1]. In addition to the height, our previous study underlined also the role of inter-axle spacing feet on performances [2]. This influence appeared to be significant for athletes which required (according to their anthropometrical characteristics) larger inter-axle spacing feet than the standard one. In this context, the study aims to find a correlation between the changing of neuromuscular synergies and performance indices based on body pressure (BP) data analysis, using a foot stretcher which provides a custom variation of the inter-axle spacing feet.

METHODS
One Olympic rower (male, Italian) participated to the experimental session. The experiments were performed with two different inter-axle settings: (i) the standard value (d = 205 mm); (ii) a value equal to the distance between the hip joint centers (d = 216 mm) [3]. For each configuration, three tests of 15 strokes with a fixed stroke rate (30 stroke/min) and drug (125) were conducted; BP on the sliding seat and EMG data were collected. To quantify the performance (evaluated through the sink on the sliding seat), we considered the α index [2]. Non-negative matrix factorization was used to identify muscle synergies from six muscles: Biceps Femoris (BF), Rectus Femoris (RF), Tibial Anterior (TA), Medius Gluteus (MG), Gastrocnemius Medial (GM), Lumbar (L) [4]. In accordance with [4], three main synergies (s1, s2 and s3), related respectively with the three phases of the gesture (Recovery (R), Catch (C), Drive (D)), were chosen. In addition, to verify this choice the cumulative percentage of the VAF (VAFc) and the VAF for each muscle (VAFm) were carried out. The overall differences in neuromuscular synergies between the two configurations were evaluated, using: (i) Pearson's correlation for the muscles synergy vector (MSV); (ii) timing integration on rowing cycle of synergy activation coefficient (SAC), and its percentage for each rowing phases.

RESULTS
The BP shows a significant improvement of the α with the custom configuration (7%, R=4%, C%=2% and D=1%, Fig.1.a). EMG analysis confirms the appropriacy choice of the three synergies (VAFc>99.6 and VAFm>99.9 for each configuration). MSV (r >0.99, p<10^-4) and SAC show a no significant changes in neuromuscular synergies. However, MSV shows an increasing of RF and TA in s3, MG and L in s2 (Fig.1.b). The SCA shows an increase of the s3 in R and D and s2 in C (Fig 1.c).

Figure 1. Average BP (a), MSV (b) and SAC (c) for each configuration (Standard (S), Customized (Cu). Vertical dash-line divided the cycle in three phases (respectively R, C and D).

DISCUSSION
The methodological approach proposed can offer a useful tool to understand the influences of neuromuscular synergies on body pressure. Despite, in this study, the EMG analysis shows no significant changes in neuromuscular synergies, we can underline: (i) the increase of α in the R that could be related with the increased activation of s3, characterized by RF and TA muscle activation (this suggests a greater eccentric work that allows a better motor control); (ii) in the C, the increase of MG and L activation (s2) could allow a complete leg propulsion; (iii) in the last part of D, the increased activation percentage of s3 could represent the trunk muscles contribution. Further studies will be necessary to verify the reliability of this pattern.

REFERENCES
Reliability of skin-markers based measures of medial longitudinal arch angle
P. Caravaggi\(^1\), M. Ortolani\(^1\), A. Matias\(^2\), U. Taddei\(^2\), A. Leardini\(^1\) & I. Sacco\(^2\)
\(^1\) Movement Analysis Laboratory, Istituto Ortopedico Rizzoli, Bologna, Italy
\(^2\) LabIMPH, University of Sao Paulo, Sao Paulo, Brazil

INTRODUCTION
The medial longitudinal arch (MLA) is perhaps the single most important feature characterizing foot mechanics and morphology. In podiatry, shape and height of the MLA can be used to discriminate different foot types, whereas in biomechanics MLA deformation is associated to foot stiffness and foot capability to absorb and restore energy during dynamic activities. While stereophotogrammetry based on skin-markers can be used to estimate its static shape and deformation in gait, current definitions of MLA do not always appear consistent with foot anatomy, standard radiological measures (e.g. the Costa-Bertani angle) and current clinical definitions.

METHODS
Markers on the calcaneus, talo-navicular tuberosity, first metatarsal head and base, and on the two malleoli, included in the Rizzoli Foot Model [1, 2], were exploited to test seven skin-markers based definitions of MLA angle (Figure 1). Preliminary accuracy assessment of each definition was evaluated by the error with respect to standard measurements based on x-ray images. The inter-trial, inter-session and inter-examiner reliability of each MLA definition was assessed in walking and running via a validated protocol entailing the acquisition of multiple kinematic measurements on two volunteers, tested in three sessions by four examiners [3].

RESULTS
The inter-trial variability in walking was around 1 deg, the inter-session between 3.6 – 5.9 deg, and the inter-examiner between 5.1 – 8.7 deg across all MLA definitions. The Rizzoli Foot Model standard MLA definition, and its variation MLAb - using the projection of the marker on the first metatarsal head to the transverse plane of the foot (FMHp).

DISCUSSION
This study provides preliminary information on the reliability and accuracy in measuring the MLA angle via skin-markers with a number of geometrical definitions consistent with foot anatomy. Further studies should be sought to investigate which definition is more accurate with respect to the real MLA deformation in different loading conditions.

REFERENCES
Pressure insoles for the analysis of the effects of load weight and carrying mode on in-shoe plantar pressure distribution

A. Giangrande¹, A. Leardini¹, R. Bonfiglioli², F.S. Violante², P. Caravaggi¹

¹Laboratorio di Analisi del Movimento e Valutazione Funzionale-Clinica Protesi, IRCCS Istituto Ortopedico Rizzoli, Bologna, Italy ²Dipartimento Scienze Mediche e Chirurgiche Università di Bologna, Bologna, Italy

INTRODUCTION

Excessive workload can cause stress, pain, and musculoskeletal disorders in the back and lower limbs [1]. During military training, about 60% of the reported injuries while marching with heavy weights is at the foot region [2]. However, scarce is the literature on the association between weight-carrying and pressure distribution in different plantar regions [3, 4]. Aim of this study was to assess how in-shoe plantar load distribution is affected by different load weights and carrying modes.

METHODS

20 young healthy subjects (age 33 ± 6 years, BMI 23.2 ± 3.1 kg/m²) were recruited for this study. A capacitive insole system (Pedar, NovelGmbH) was used to measure plantar pressure distribution while subjects were performing the following motor tasks: walking at self-selected comfortable normal and fast speed; stair ascending, and stair descending. Subjects wore their own training shoes fitted with 3 mm latex flat insoles. Three loads (4 - 8 - 12 kg) were carried by each subject in three carrying modes: inside a box against the chest (BX); divided in two hand-held bags (HB), and inside a backpack (BP). Load weight and carrying mode were randomized for each subject. In-shoe plantar pressure distribution when subjects performed the same tasks with no weight was used as control. Maximum force (%BW), peak pressure (kPa), pressure- and force-time integral (kPa*s and %BW*s) were calculated at different plantar regions. Non-parametric paired Friedman test and Tukey-Kramer post-hoc with Bonferroni correction, were used to assess the effect of carrying modes, load weights and motor tasks on in-shoe pressure parameters.

RESULTS

During walking, the maximum force recorded at the whole foot, and in most foot regions, was correlated to load weight. When carrying 12 kg in BX mode, the maximum force significantly increased from about 20% at rearfoot to about 45% at midfoot, with respect to the unloaded condition. This was larger than what measured while carrying the same weight in HB and BP modes. In walking, peak pressure significantly increased (p < 0.05) when carrying 12 kg (Figure 1). Plantar pressure parameters were statistically different between two load weights for a minimum difference of carried load of 8 kg.

DISCUSSION

In this study we aimed at assessing the effects of load weight and carrying mode on in-shoe pressure distribution. In any motor task, the maximum force recorded by the in-shoe pressure insole system was correlated to load weight, and the system appeared suitable to detect differences in carried weights of 8 kg. In this respect, the present non-invasive analysis of in-shoe pressure has the potential to become a tool for quantitative assessment of carried loads which could be used to limit the injury risk of workers required to carry loads on a daily basis. Moreover, the study demonstrates that carrying modes affect plantar pressure and load distribution, which should be accounted for when choosing appropriate footwear and plantar orthoses in relation to specific foot ailments.

REFERENCES

Multisegmental kinematics and EMG analysis in different diabetic foot populations

P. Caravaggi, C. Giacomozzi, G. Lullini, G. Marchesini, L. Baccolini, M. Ortolani, A. Leardini and L. Berti

Movement Analysis Laboratory, Istituto Ortopedico Rizzoli, Bologna, Italy
Department of Cardiovascular, Dysmetabolic and Aging-associated Diseases, Italian National Institute of Health, Rome, Italy
Hospital Policlinico Sant’Orsola-Malpighi, Bologna, Italy

INTRODUCTION

Diabetic foot refers to a complex set of physiological and mechanical alterations characterizing feet of type 1 and type 2 patients. Due to the presence of several confounding factors, providing a comprehensive scenario of the effects of diabetes mellitus on foot biomechanics is not simple. To date, kinematic, kinetic and EMG analyses have often been performed in isolation, on a number of small-sample subgroups, and without accounting for possible confounding factors [1]. In the present study, we aimed at collecting foot motion, force and plantar pressure data from a relatively large population of patients. In this paper the effect of diabetes on foot joint kinematics and EMG activation of leg muscles is reported.

METHODS

A wide sample of patients were visited and clinically classified by an experienced diabetologist, and pooled in four groups: type 1; type 2; with or without peripheral neuropathy. 75 patients (40 M, 35 F; age 57 ± 12 years; BMI 28.7 ± 6.4 kg/m²) underwent functional evaluation via a validated foot and ankle kinematic protocol with integrated plantar pressure measurements [2, 3]. 27 subjects (11 M, 16 F; age 53 ± 9 years, BMI 24.2 ± 3.5 kg/m²) were analysed according to the same protocol and used as control. The trajectories of skin-markers on the foot and leg, according to the Rizzoli Foot Model, were recorded during walking at comfortable speed (Vicon, 100hz) and used to calculate ankle, midtarsal, tarso-metatarsal, and first MTP joint kinematics. Maximum voluntary contraction (MVC) and gait-cycle activation of the tibialis anterior and gastrocnemius medial head muscles were recorded via wireless sEMG (Cometa, 2000hz). Principal component analysis (PCA) was performed on the foot joints range of motion (ROM). Analysis of covariance (ANCOVA) and Bonferroni post-hoc test were preliminary used on joints ROM and EMG parameters, controlling for the effects of other variables such as walking speed and age.

RESULTS

The PCA first four components described 83%, 84% and 80% of the variance in foot joint kinematics for the control, type 1 and type 2 subgroups, respectively; type 2 also appeared different as for joints and planes impacting on variance. Walking speed and age were found to significantly affect ankle joint ROM in the diabetic subgroups (p < 0.05). After accounting for covariates, all diabetic subgroups showed lower mobility in several foot joints with respect to control (see e.g. figure 1). The peak of sEMG activation of the gastrocnemius during MVC tests was lower in the type 2 and neuropathic groups with respect to control (p = 0.03). Conversely, during walking, the tibialis anterior showed larger MVC-normalized EMG activation than control.

DISCUSSION

All diabetic subgroups showed restricted foot joints ROM in walking compared to healthy controls, even after adjustment for covariates. Moreover, the observed normalized larger activation of the main plantar/dorsiflexors at the ankle joint during walking might be explained as compensatory mechanism for the reduced available maximum force. A number of independent, disease-associated factors are currently under investigation to better understand possible peculiar changes due to type of diabetes and presence of neuropathy.

REFERENCES

Position estimation improvement of a lower trunk placed IMU during gait
S. Cardarelli¹, F. Verdini¹, A. Mengarelli¹, A. Strazza¹, F. Di Nardo¹ and S. Fioretti¹
¹ Università Politecnica delle Marche, Ancona, Italy.

INTRODUCTION
The estimation of lower trunk (LT) orientation and position during normal walking is a current issue in clinical settings for the assessment of walking disorders [1]. In this work we propose a filtering method based on WFLC (Weighted Fourier Linear Combiner) to increase the accuracy of the position estimation of an IMU (Inertial Measurement Unit) placed on LT.

A set of filter parameters has been estimated from a single subject walking on treadmill, minimizing the RMSE between the IMU-estimated position through double integration of gravity-free measured acceleration and the position of a passive marker placed directly on the inertial sensor acquired by a stereophotogrammetric (SP) system [2]. The aforementioned minimization has been performed by the means of a meta-heuristical optimization method called Artificial Bee Colony (ABC). The aim of this work is to prove that a single set of WFLC estimated parameters can be able to reduce the RMSE error over other trials acquired under the same experimental conditions.

METHODS
A single subject (Gender: Male, Age: 25, Weight: 80 Kg, Height: 177 cm) with no history of neurological and orthopedic disorders, was tested while walking on a treadmill at the speed of 3 km/h. The subject was instrumented with an IMU (NGIMU, x-io technologies, UK) fixed with a rubber band on the lower trunk (L5 vertebra). A single passive marker was placed directly on the IMU and recorded with a 6-cameras SP system (Elite, BTS Bioengineering, IT).

Proposed algorithm:
Phase 1 (Training - First walking trial):
I. IMU and SP data acquisition (100Hz for 30 seconds each trial)
II. Lower trunk pose estimation through a quaternion-based Unscented Kalman Filter (UKF) approach [3].
III. Double integration of gravity-free acceleration data to obtain position.
IV. High-pass filtering of position data to remove drift
V. Estimation of optimal WFLC weights and gains through Artificial Bee Colony (ABC) optimization algorithm [4], minimizing the RMSE between IMU-derived position and SP data. This is performed for each of the three axes.

Phase 2 (Test - Rest of walking trials):
In the second phase the fifth step is replaced by the following one:
VI. IMU-derived position data is passed through a WFLC filter whose weights and gains have been estimated during the previous phase.

RESULTS
In the reported bar chart, the first couple of columns for each axis shows the RMSE before and after the ABC+WFLC optimization process (training set – first walking trial).
The same WFLC parameters are then applied on the remaining acquired trials (test set).

DISCUSSION
Both in training and test set, as showed in figure, RMS errors significantly decrease after the WFLC filtering. It is noteworthy that, despite of the starting SD in the test set before the WFLC filtering, the final squared errors seem to converge to a more similar value.
Further studies will aim to prove that a single set of parameters for a determined walking speed could work on different subjects, thus removing the necessity of an SP system in the measurement setup.

REFERENCES
Lower body joints angles estimation in the sagittal plane during perturbed posturography: preliminary results
S. Cardarelli1, G. Ligorio2, A. Mengarelli1, A. Strazza1, F. Verdini1, F. Di Nardo1, P. Garofalo2, S. Fioretti1.
1 Università Politecnica delle Marche, Ancona, Italy, 2 Turingsense EU LAB, Forlì, Italy

INTRODUCTION
Failure in upright posture maintenance is a key indicator of balance impairments caused by neuro-motor system’s diseases. However, it has been observed that a normal postural control in static conditions could conceal pathological behaviors during various types of perturbations [1]. Hence Perturbed Posturography (PP) has proven to be a valuable clinical methodology to assess both impairment degrees and treatments' efficacy during subjects' follow-up. This kind of technique can involve a Stereophotogrammetric system (SP) and a Magnetic-motor controlled Moving Platform (MMP). Due to the expensiveness of an SP system and the magnetic disturbances often introduced by MMPs we proposed a novel magnetometer-free protocol based on multiple Inertial Measurement Units (IMUs) to estimate ankle, knee and hip angles during PP.

METHODS
A female subject with no history of neurological orthopedic disorders was asked to stand still on top of a MMP and maintain the balance during a backward perturbation of 5 cm at 15 cm/s speed. Three IMUs (Pivot IMUs, Turingsense Inc.) were worn by the subject on the left thigh, left shank and left foot. Moreover, infrared reflective markers were placed according to the setup reported in [2] to record ground truth data with a 6-cameras SP system (BTS bioengineering, IT). Both SP and IMU systems were sampled at 100 sample/s. The whole trial lasted approximately 2 seconds. SP data was processed with a 2nd order Butterworth low-pass filter at 5 Hz. An initial data window was used to virtually align each IMU with the vertical direction while the subject was still and standing upright. Subsequently, IMU data were processed with the Kalman filter proposed in [3] to get an optimal estimation of the gravity vector in the three body frames. Sagittal joint angles were then computed through scalar products of the estimated gravity vectors.

RESULTS
The reported figure shows the comparison among the three sagittal joint angles computed during the perturbation by the ground truth (SP) and the proposed method. The corresponding Root Mean Square Errors (RMSE) obtained over the whole trial counted up to 0.67, 0.7 and 0.45 degrees at the ankle, knee and hip, respectively.

Comparison between the joint angles estimated by the proposed method (red) and the SP system (blue).

DISCUSSION
This study represented a proof-of-concept of a novel IMU-only approach for the estimation of lower body joint angles in the sagittal plane during PP. PP is one of the ideal applications for this approach because the subject’s motion can be assumed sagittal. Moreover, it is totally immune to the large magnetic field perturbation produced by MMP because magnetometer data are not used. The results obtained by this single “probe” sample were encouraging because the angular trends and range of motions obtained were confirmed by the SP data. Also, good sensors’ response for low angular ranges confirms the suitability of IMU approach in PP. Therefore, we plan to expand this study to a larger scale of subjects and trials, in order to assess the repeatability of this whole setup under different experimental conditions.

REFERENCES
Fatigue-induced alterations of gait in Multiple Sclerosis through an instrumented 6-Minute Walk Test: a pilot study

I. Carpinella 1, E. Gervasoni 1, D. Anastasi 1, M. Ferrarin 1, D. Cattaneo 1

1 IRCCS Don Carlo Gnocchi Foundation, Milan, Italy

INTRODUCTION

Fatigue is a common symptom in people with MS (PwMS), that contributes to reduce walking capacity [1]. Motor related fatigue is usually assessed using the 6-Minute Walk Test (6MWT) and measuring the decline in distance walked from minute 1 to 6 [2]. Although widely used, this test does not provide objective information, other than speed, about fatigue-related deterioration of gait. For this purpose, optoelectronic kinematic analysis has been applied with good results [1]. However, inertial measurement units (IMUs) seem a promising alternative to obtain quantitative information directly in clinical settings, with lower costs and easier procedures. Aim of this study was a pilot analysis of fatigue-related walking decline in PwMS during the 6MWT instrumented with 3 IMUs.

METHODS

9 healthy subjects (HS, age: 35±11 years) and 15 PwMS (age: 51±13 years) performed the 6MWT wearing 3 IMUs (MTw, Xsens, NL) on ankles and posterior lower trunk (L4–L5 level). The test was conducted in a 30-meter corridor with the instruction “Walk as fast as you can”. After each minute, the examiner recorded the meters walked by the subject, who was asked to rate his perceived fatigue at lower limbs on the Borg Rating of Perceived Exertion scale (RPE _LL). After elimination of the turning portions of accelerometer and gyroscope signals (f sampling = 75Hz), the following features were computed for each minute. Heel-strike and foot-off were detected following [3] to compute stride duration and its coefficient of variation CV _Tstride = 100*(IQR _Tstride/Median _Tstride). Step symmetry [4] and harmonic ratio (HR) [5] were calculated for antero-posterior (AP) medio-lateral (ML) and vertical (V) trunk accelerations. Repeated measure ANOVA (between-group factor: HS, PwMS; within-group factor: minute 1 to 6) was used. The features showing a significant (p<0.05) TimexGroup interaction (i.e. different behavior across minutes in the 2 groups) were correlated to RPE _LL. Spearman r s was used for speed and partial r s (pr s) was used for instrumental parameters to correct for speed.

RESULTS

RPE _LL increased in both groups, with a statistically significant interaction effect (p<0.05) showing a greater increase of fatigue from minute 3 to 6 in PwMS (+27%) compared to HS (+9%). Both groups showed a similar progressive decrease of velocity from minute 1 to 6 (p<0.001) (HS: -8%, PwMS:-12%). Statistically significant interaction effect (p<0.05) was found for CV _Tstride, ML step symmetry and ML HR, indicating almost constant values across minutes in HS and a progressive alteration in PwMS from minute 1 to 6 (CV _Tstride: +38%, ML step symmetry: -23%, ML HR: -16%). Significant correlations with RPE _LL were found for walking speed (r s=-0.41, p<0.001), ML step symmetry (pr s = -0.31, p<0.01) and ML HR (pr s=-0.26, p<0.05). No correlation was found for CV _Tstride (pr s=-0.05; n.s.).

DISCUSSION

As expected, present results showed a higher level of perceived lower limb exertion in PwMS during the 6MWT. While clinical 6MWT score (i.e. speed) showed a similar decrease of velocity in both HS and PwMS, instrumental features revealed different behavior of the two groups. In particular, HS maintained an almost unaltered gait pattern during the test, while PwMS showed a progressive decrease of stride regularity (CV _Tstride), ML step symmetry and ML gait smoothness (ML HR). Importantly, the last two features significantly correlated with RPE _LL, even after correcting for gait speed. This indicated that ML step symmetry and ML HR capture distinct information compared to clinical 6MWT score. This can be used as additional objective measures of fatigue-related gait deterioration. Interestingly, the above results were found in ML parameters only, suggesting that alterations of ML movements are the most involved in lower limb fatigue. A greater sample should be analyzed in future studies to confirm present findings.

REFERENCES

A comparative accuracy analysis of five sensor fusion algorithms for orientation estimation using magnetic and inertial sensors

M. Caruso1,2, T. Bonci2, M. Knafflitz1, U. Della Croce2, A. Cereatti1,2

1 Politecnico di Torino, Torino, Italy, 2 Università degli studi di Sassari, Sassari, Italy.

INTRODUCTION
Magnetic and Inertial Measurement Units (MIMUs) are extensively used in movement analysis. The absolute orientation of the MIMU can be estimated by fusing the information recorded by a tri-axial accelerometer, gyroscope, and magnetometer. The majority of the sensor fusion algorithms proposed in the literature are either based on Kalman filter or complementary filtering approaches. Despite the number of proposed formulations, no well-established conclusions about the best performing algorithms have been reached yet. The aim of this study is to perform a direct comparison among the most common sensor fusion algorithms and to evaluate their accuracy at different speeds using as gold standard the orientation provided by a stereophotogrammetric (SP) system.

METHODS
Three Kalman filters, KF_SAB (modified version from [1]), KF_XSN (proprietary Xsens filter v1.7), KF_VAL [2] and two complementary filters, CF_MAD [3], CF_VAL [4] were selected and implemented for comparison. Two MIMUs (Xsens, MTx, f_s = 100 Hz) were aligned and attached to a wooden board. A cluster of four reflective markers was also attached to the board. Marker positions were measured using a 12-camera SP system (Vicon T20, f_s = 100 Hz). Recordings started with the board kept still and horizontal for 60 seconds for filters initialization, then an operator moved the board, first by rotating it about each axis (x, y, z) from 0° to 180° and back, five repetitions, (2D motion) and then by performing a multi-axis rotation (3D motion). Recordings were executed at slow (~120 °/s) and fast (~360 °/s) angular velocity. MIMU and SP data were synchronized using an external trigger. The orientation estimates provided by each algorithm were compared with the SP-based orientation by reporting attitude and heading error components [5]. For each algorithm, parameters values were chosen heuristically and applied to both slow and fast trials (KF_VAL does not require parameter setting).

RESULTS
For each algorithm RMS errors averaged over the 2D and 3D motions are reported separately from the one relative to the 3D rotation (Table 1).

<table>
<thead>
<tr>
<th></th>
<th>KF_SAB</th>
<th>KF_XSN</th>
<th>KF_VAL</th>
<th>CF_MAD</th>
<th>CF_VAL</th>
<th>KF_SAB</th>
<th>KF_XSN</th>
<th>KF_VAL</th>
<th>CF_MAD</th>
<th>CF_VAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMS_x (slow)</td>
<td>1.9±1.1</td>
<td>1.6±0.8</td>
<td>3.5±1.0</td>
<td>2.7±0.8</td>
<td>2.0±0.9</td>
<td>2.8</td>
<td>2.9</td>
<td>6.1</td>
<td>3.3</td>
<td>2.8</td>
</tr>
<tr>
<td>RMS_y (slow)</td>
<td>2.2±1.3</td>
<td>1.6±0.7</td>
<td>4.0±1.7</td>
<td>3.0±1.4</td>
<td>2.5±1.3</td>
<td>2.6</td>
<td>2.4</td>
<td>5.3</td>
<td>3.4</td>
<td>2.9</td>
</tr>
<tr>
<td>RMS_z (fast)</td>
<td>4.3±1.2</td>
<td>2.9±1.0</td>
<td>32.1±17.6</td>
<td>4.6±0.4</td>
<td>5.7±2.3</td>
<td>4.2</td>
<td>5.6</td>
<td>67</td>
<td>5.7</td>
<td>7.9</td>
</tr>
<tr>
<td>RMS_y (fast)</td>
<td>4.5±1.3</td>
<td>2.0±0.5</td>
<td>25.7±9.3</td>
<td>4.2±1.5</td>
<td>4.8±1.8</td>
<td>3.1</td>
<td>4.0</td>
<td>55</td>
<td>4.5</td>
<td>5.6</td>
</tr>
</tbody>
</table>

DISCUSSION
For slow 2D motions, KF_XSN showed the best performances (< 1.8 deg), followed by KF_SAB, CF_VAL, CF_MAD and KF_VAL. For 3D slow motions, KF_XSN, KF_SAB and CF_VAL had a similar accuracy (2.6-2.9 deg), followed by CF_MAD and KF_VAL. When increasing the angular velocity, a general worsening of the performances was observed for all algorithms and for both 2D and 3D motions. For 2D motion, the best performances were obtained with KF_XSN (< 2.9 deg), whereas for 3D motions with KF_SAB (< 4.5 deg). The poor performance of KF_VAL at fast velocity can be related to the fact that the procedure for fusing the orientation estimates obtained from the accelerometer/magnetometer and the gyroscope data, does not include any weighting parameter. Depending on the specific motion scenarios, parameters fine-tuning is essential for guaranteeing good filter performances. This study was partially supported by DoMoMEA grant, Sardegna Ricerche POR FESR 2014/2020.

REFERENCES
The single leg drop-landing before and after ACL surgery as biomechanical evaluation in élite athletes.

F. Cibin¹,², D. Pavan¹, A. Guiotto¹, F. Spolaor¹, M. Cesana³, E. Furlan⁴, T. Casagrande⁵, Z. Sawacha¹

¹ Department of Information Engineering, University of Padova, Padova, Italy
² BBSoF S.r.l, Startup University of Padova, Padova, Italy
³ Penta Medical Centre, Treviso, Italy
⁴ Abano Terme General Hospital, Padova, Italy
⁵ Italian Rugby Federation (FIR), Rome, Italy

INTRODUCTION
Anterior cruciate ligament (ACL) ruptures and damages occur when forces applied to the ligament are greater than the loads it can withstand [1]; in order to be effective, screening methods should be linked to ACL mechanical etiology [2], furthermore, ACL re-injury occurs in 6-13% of ACL-reconstructed knees [3]. The most likely mechanisms causing ACL injuries have been identified as: excessive knee valgus rotation, knee internal rotation moments and large anterior tibial translation [1,3]. An effective evaluation methodology should take into account these biomechanics variables as they play a crucial role in ACL injuries. To understand the biomechanics implications of ACL reconstruction, this study presents the evaluation of the differences in knee biomechanics while performing a single leg landing before surgery and prior to resume sport activity.

METHODS
Ten healthy subjects and 4 élite athletes took part in the study: mean(±SD) age and BMI respectively of 24.25±6.6 (athletes) and 21.8±3.65 (controls) years, 29.12±3.93 (athletes) and 22.41±1.39 (controls) kg/m². Two athletes were evaluated before surgery, two after surgery, before returning to trainings. After signing informed consent, subjects performed 3 repeating single leg landing tasks on the injured limb, from a 32 cm height [2]. Ground reaction forces (GRF) and kinematics were acquired by means of a force plate and a stereophotogrammetric system (6 cameras, BTS); markers were positioned as in [4]. Collected data were elaborated and hip, knee, ankle joint angles and torques were computed. Data comparisons were carried out applying a Wilcoxon Rank-Sum test between the athletes before and after ACL reconstruction, between the athletes and the controls.

RESULTS
Results (Figure 1) showed a tendency toward a reduced GRF peak at landing in post-surgery, along with a reduction in extensor moment at the knee joint. Moreover, a higher variability in the knee sagittal angle and varus/valgus moment were highlighted, while the latter one seemed to shift to the valgus after ACL reconstruction.

DISCUSSION
An increased confidence has been underlined in post-surgery subjects, along with an increased dumping ability, likely to be delivered by a more efficient use of the ankle and hip joints, and by a reduced knee stiffness, probably adopted as a knee protecting approach during pre-surgery executions. The adopted methodology has been proven to be effective in detecting knee kinematic and kinetic differences on subjects before and after ACL surgery with respect to controls.

REFERENCES
A simple method to quantify physical activity “dose” in Patients with Alzheimer Disease.
Alessandro L. Colosio, Anna Pedrinolla, Massimo Venturelli, Federico Schena, Silvia Pogliaghi.
Dipartimento di Neuroscienze, Biomedicina e Movimento, Università di Verona, Verona, Italia.

INTRODUCTION
Physical activity favourably affects symptomatology and general health in patients with Alzheimer’s disease. Accurate quantification and monitoring of exercise “dose”, as described by oxygen consumption (VO₂), is necessary to explore a possible dose-response relationship between exercise and health benefits. However, due to the elevated cost of direct, gold-standard methods, this is rarely done outside research laboratories.

A simple “field” method to estimate VO₂ in healthy adults and clinical populations was recently proposed based on the existence of a strong relationship between Metabolic equivalents (METs) and Heart rate-index (HRindex: Actual HR/resting HR)². The application of this promising tool to monitor exercise intensity in ecological conditions and specific populations requires validation. Therefore, we tested the hypothesis that exercise-related VO₂ can be accurately estimated in patients with Alzheimer disease using HRindex.

METHODS
25 patients with Alzheimer disease performed a walking test on a treadmill at increasing speed (80,100 and 120 % of the self-selected pace (SSP)). Each speed was maintained for 5 min and Heart rate (HR) and VO₂ were measured breath-by-breath throughout the 15-min test. A resting HR of 60 b/min was assumed. HRindex was calculated (actual HR/resting HR) and was used to predict VO₂ \(((\text{HRindex}-6)/3.5 \text{ body weight}))\). Measured and predicted VO₂ were compared by two-way RM-ANOVA (method, speed), correlation, and Bland-Altman analysis. Statistical significance was accepted when \(p < 0.05\).

RESULTS
All patients completed the first two steps of the protocol (80 and 100% SSP); on the contrary, only 10 patients were able to complete the test at the higher speed. Values of HR, measured and estimated VO₂ are reported in the Table. There was a strong relationship between directly measured and estimated VO₂ (\(r= 0.71\)) with no statistical difference between measured and estimated values at all the walking speeds, and a non-significant bias of (bias= 1.2 ml/kg/min z= -1.0 imprecision= 3.3 ml/kg/min).

<table>
<thead>
<tr>
<th>Patients</th>
<th>Speed</th>
<th>HR</th>
<th>VO₂</th>
<th>estVO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>#</td>
<td>km/h</td>
<td>(b/min)</td>
<td>(ml/kg/min)</td>
<td>(ml/kg/min)</td>
</tr>
<tr>
<td>80%SSP</td>
<td>25</td>
<td>1.4±0.1</td>
<td>92.3±13.6</td>
<td>10.6±3.3</td>
</tr>
<tr>
<td>100%SSP</td>
<td>25</td>
<td>2.2±0.8</td>
<td>99.0±14.0</td>
<td>13.0±3.9</td>
</tr>
<tr>
<td>120%SSP</td>
<td>10</td>
<td>3.0±1.1</td>
<td>99.4±12.7</td>
<td>15.6±4.6</td>
</tr>
</tbody>
</table>

Speed, Heart rate (HR), directly measured (VO₂) and estimated (estVO₂) oxygen consumption are displayed for each exercise intensity (percentage of self-selected speed (SSP))

DISCUSSION
Our data support the hypothesis that HRindex is a valid tool to estimate VO₂ of walking in patients with Alzheimer disease. This simple approach offers a valid alternative to the high “cost” (equipment, time, expertise) gold-standard measurement of VO₂ favouring the generalised applicability of measures of exercise “dose”. The knowledge of population-specific dose-response curves is paramount to guide personalised and evidence-based exercise prescription.

REFERENCES
HR-index, a simple way to quantify exercise “dose” in Diabetic type II patients
Giorgia Spigolon¹, Alessandro L. Colosio¹, Paolo Moghetti², Silvia Pogliaghi¹.
¹Department of Neurosciences, Biomedicine and Movement Sciences, University of Verona, Italy.
²Section of Endocrinology, Diabetes and Metabolism, Department of Medicine, University and AOUI of Verona, Italy;

INTRODUCTION
Exercise training provides health benefits and is a key element in the treatment of individuals with type 2 diabetes (T2DM) (Boulé, 2001). Current guidelines for prescription of physical exercise in T2DM recommend performing aerobic/endurance training (40-60% of maximal oxygen consumption (VO₂max)) in combination with isotonic/strength training (50 to 70% of 1RM). Accurate quantification and monitoring of exercise “dose”, as described by VO₂, is necessary for appropriate and individualised prescription of aerobic exercise and for the interpretation of exercise-induced health benefits (Gaber, 2011). However, due to the elevated cost of direct, gold-standard methods, this is rarely done outside research laboratories. HR index (HRindex) is a simple method to estimate VO₂ in healthy and clinical populations. We tested the performance of HRindex to estimate VO₂ in diabetic patients during aerobic and isotonic training sessions.

METHODS
12 male subjects (age: 64±5 years; BMI: 26±12) with uncomplicated T2DM on oral hypoglycemic drugs were recruited. VO₂ consumption and HR were continuously measured (K4, Cosmed, Italy) during one aerobic and one isotonic training session, each lasting 60 min. Individual HRindex was calculated as actual HR/resting HR and the following equation was applied to estimate average VO₂ for both training sessions²: VO₂(L/min) = \(([(HR\text{index}·6)-5] · (3.5 \text{ body weight (Kg)})\text{)}\) (Wicks, 2011). Correspondence between measured and estimated VO₂ was evaluated by two-way ANOVA (method of determination and training type) and correlation.

RESULTS
Measured VO₂ was higher for the aerobic compared to the isotonic training session (Table). Estimated values of VO₂ during the aerobic session were not significantly different from (p=0.36) and highly correlated (r=0.89) with the measured values. On the contrary, during the isotonic session, HRindex significantly overestimated VO₂ compared to the actual measure and only a moderate correlation was found between measured and estimated values (r=0.41).

<table>
<thead>
<tr>
<th>Training type</th>
<th>Measured VO₂ (ml/min)</th>
<th>Estimated VO₂ (ml/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AEROBIC</td>
<td>1368.96</td>
<td>1397.83</td>
</tr>
<tr>
<td>ISOTONIC</td>
<td>667.03*</td>
<td>910.96**</td>
</tr>
</tbody>
</table>

Directly measured and estimated oxygen consumption (VO₂) are displayed for each type of training (aerobic and isotonic). * indicates a significant difference vs measured VO₂ and ** a significant difference vs aerobic training.

DISCUSSION
We tested the performance of HRindex in predicting oxygen consumption (VO₂) in a group of diabetic patients during aerobic and isotonic training sessions, by comparison with the gold standard direct method. Our data indicate that HRindex significantly overestimates VO₂ during isotonic exercise, possibly due to the dissociation between HR and VO₂ that is inherent to this form of exercise. On the contrary, our data support the hypothesis that HRindex is a valid tool to estimate VO₂ of prolonged aerobic exercise sessions in diabetic patients. This simple approach offers a valid alternative to the high “cost” (equipment, time, expertise) gold-standard measurement of VO₂ favouring the generalised applicability of measures of exercise “dose”. The knowledge of population-specific dose-response curves is paramount to guide personalised and evidence-based exercise prescription.

REFERENCES
A Factor Analysis model of the instrumented Timed Up and Go test for physical capability assessment

A. Coni¹, S. Mellone¹, M. Colpo², S. Bandinelli², L. Chiari¹,³
¹ Department of Electrical, Electronic and Information Engineering, University of Bologna, Italy, ² Local Health Unit Tuscany Centre, Firenze, Italy, ³ Health Sciences and Technologies - Interdepartmental Centre for Industrial Research, University of Bologna, Italy

INTRODUCTION

The Timed Up and Go Test (TUG) is widely used in clinical practice as a measure of physical capability. The use of inertial sensors allows the computation of a high number of features, bringing more information than the traditional stopwatch-based measure, but there is the need of reducing the dataset dimension to a set of measures with a clear clinical meaning. The aim of this study is to define an interpretative model of the instrumented TUG (iTUG) test, through a factor analysis approach, for the assessment of physical capability in community-dwelling older adults aged 65 years and older.

METHODS

A subsample of the InCHIANTI cohort study (http://inchiantistudy.net) performed the iTUG while wearing a smartphone in a case waist belt; iTUG was segmented into sub-phases (Sit-to-Walk, Walk, and Walk-To-Sit) and a set of features were computed for each sub-phase using a system developed within the FARSEEING project [1,2]. The following variables have also been collected: age, gender, Body Mass Index (BMI), Number of Medications (NM), Mini-Mental State Examination (MMSE), Instrumental Activities of Daily Living (IADL), self-assessed physical activity level (PA), Short Physical Performance Battery score (SSPB), TUG total duration measured with the stopwatch (TUG time), gait speed, hand grip (HG), power rig (PWR), history of falls (FALL history), and prospective falls (FALL). Factors, obtained by an Exploratory Factor Analysis, have been labelled according with the meaning of the original features. Linear regression analysis was used to investigate the association between factors and between factors and the clinical variables, either removing or not the effect of age, gender, weight, height, NM, and MMSE.

RESULTS

204 community-dwelling older adults (79.47± 6.44 years old, range 65-92, 97 F) were recruited and 38 instrumented features were computed from the iTUG. Eight factors were retained, explaining the 77% of the total variance. Radar plots in Fig.1 show the performance (high or low factor score) in the physical domains defined by the factors. Only one of the three cases, Subject 1, was at risk of falling on the basis of the TUG time measured with the stopwatch. Subject 2 was considered not at risk but fell twice prospectively and exhibited abnormal values in specific domains. Subject 3 performed very well, and this is reflected in both the time measures with the stopwatch and the model domains.

Fig.1. Radar plots of the factors obtained from the iTUG test for three case studies

DISCUSSION

It is possible to define an interpretative model for the assessment of physical capability making use of a factor analysis on the features derived from the iTUG test. The resulting model provides more detailed information on specific physical domains than just the total time measured with a stopwatch. These also show added value in relation to fall risk. Such a model could enable earlier detection of functional decline and provide a tool for personalising the intervention strategy.

REFERENCES

Motor Adaptation in Response to Audio-Biofeedback in Parkinson’s disease

M. Corzani 1, A. Ferrari 1, P. Ginis 2, A. Nieuwboer 2, L. Chiari 1
1 Department of Electrical, Electronic, and Information Engineering, University of Bologna, Italy
2 Department of Rehabilitation Sciences, KU Leuven, Belgium

INTRODUCTION
Parkinson’s disease (PD) is caused by the depletion of dopamine in the basal ganglia, leading to deficiencies in movement control. Motor control relies on motor adaptation, i.e. the modification of a movement from trial-to-trial based on error feedback, and motor learning, the formation of a new motor pattern that occurs via long-term practice. Damage of the cerebellum systematically disrupts adaptation, but damage to other brain regions most often does not. Repeated adaptation can lead to a motor learning process as a long-term effect in healthy people [1]. In this study we evaluate the effects of corrective auditory biofeedback (BF), verbal in nature, in order to assess and quantify motor adaptation in response to a home-based gait training program.

METHODS
Ten persons with PD undertook gait training with the CuPiD system [2] during a period of 6 weeks (10 M, age: 65 ± 9 years, disease duration 12 ± 5 years, Hoehn & Yahr 2.3 ± 0.4, UPDRS III [0–132] 36 ± 16.2, ON L-Dopa). The CuPiD system offered praising/corrective verbal feedback, encouraging to keep the pre-set spatio-temporal gait parameters within the therapeutic window during walking in a daily environment. In this study we shall present the results obtained when stride length was the feedback variable. From the 9 steps following the BF messages, a single-term exponential decay/growth was fitted ($y = ±M \times e^{-k \cdot x}$) in response respectively to the UP (“increase stride length”) or DOWN (“decrease stride length”) BF messages. Outlying responses were removed by retaining only fitted $k$ values in the range (-0.2, 8) Step$^{-1}$ aiming to exclude absent or non-physiological responses (that can be expected given the ecological setting of the experiment). Motor Adaptation was quantified by the exponential decay/growth factor $k$ estimated during all trials and analyzing its statistical distribution.

RESULTS
An overall number of 178 trials were performed among all subjects. In particular, a total of 2562 motor adaptation responses were identified, of which 21% had absent or outlying responses. Motor adaptation following BF was well visible in 93% of the analyzed trials. Fig. 1.A shows typical motor adaptation (decay/growth factor $k$) responses to the BF messages (mean and confidence interval) obtained in a representative subject. Fig. 1.B shows the overall distribution of the two classes of responses in the whole population. The results indicate that the median value of $k$ is 0.23 Step$^{-1}$ for the UP and 0.20 Step$^{-1}$ for the DOWN messages (i.e. decay time constant $\tau$ of 4.3 and 5 Steps, respectively).

DISCUSSION
Motor adaptation is possible in a home-based training context for persons with PD using a wearable BF system. Responses to both UP and DOWN messages occurred in the desired direction: the average exponential decay/growth factor $k$ is positive, i.e. decreasing/increasing towards the reference value (0 %). Our results indicate for the patients a “refractory” period between 5 and 15 steps (3$\tau$) as the time needed to adapt gait pattern and reach 95% of the planned target value following a corrective feedback. For clinicians and BF developers this is informative to know how long to wait until providing BF again.

REFERENCES
Validation study of a protocol for upper limb kinematics: preliminary data
M. Cosma¹, G. Vallies¹, G. Ferraresi¹, M. Morelli¹, F. Baldasso², G. Paolini², A. Ravaschio³, M. Manca¹
¹ Laboratorio Analisi del Movimento-Azienda Ospedaliero Universitaria di Ferrara; ² GPEM srl, Alghero (SS); ³ GPEM srl, Alghero (SS), DINOGMI-IRCCS Ospedale Policlinico San Martino, Genova

INTRODUCTION
Motion analysis can provide us with an adequate understanding of upper limb (UL) motor control and the way functional movement is carried out. In the literature various protocols of UL kinematics have been proposed to analyze single motor tasks with different functional significance. Kim et al compared hemiplegic patients with healthy controls and observed that hemiplegic patients presented different sagittal kinematics at the shoulder and elbow during the motor task they were asked to perform [1]. For patients affected by spastic paralysis presenting different UL levels of impairment and motor control, performing a single task may not be enough to characterize the level of residual function. The present observational retrospective study compares the UL kinematics in hemiplegic patients and healthy subjects with the aim to verify the validity of the protocol used as a clinical support in the evaluation of outcomes and decision-making in the rehabilitation setting.

MATERIAL AND METHODS
In this observational retrospective study the UL joint kinematics of 14 hemiplegic patients (7 stroke, 7 traumatic brain injury) and 32 control healthy subjects aged between 20 and 75 years were compared. Their level at the Brunnstrom Motor Recovery Stage ranged from 3 to 6 and the mean time from the acute event was 4.42 years. The UL kinematics was acquired by means of an optoelectronic Vicon system (Vicon, Oxford, UK) with 14 infrared cameras using Vicon Nexus software during the following movements: reach up (RU touching the mouth with the hand), reach out (RO reaching and touching an object with the hand), reach and touch (RT reaching and touching an object with the hand and then touching the mouth with the hand), reach and grasp (RG reaching for an object, bringing it to the mouth and then replacing it on the table). Each type of movement was performed three times by all subjects. UL joint kinematics were estimated using a model [2] composed by four rigid body segments (trunk, arm, forearm and hand), and 10 degrees of freedom. The mean and standard deviation (SD) of the sagittal plane kinematics of each joint and motor task were computed. Each motor task was divided in phases and the single phase and total times as well as the range of motion (RoM) during the principal phases of the movement of the trunk, shoulder and elbow on the sagittal plane were calculated. The temporal data of each phase were also expressed in relation to the percentage of the complete cycle of the movement. A comparison of the kinematic properties between the two groups was made using t-Student and Mann-Whitney tests. A significance level of 0.05 was used for all tests.

RESULTS
Compared to the control group, all the hemiplegic patients had a significant increase in duration of the absolute and single phase times (p < 0.01); no differences were observed when the percentage of duration of single phases was calculated. 16 out of the 18 RoM of trunk, shoulder and elbow, during single phases of the different movements examined, were found to be significantly different (p < 0.01) between the hemiplegic and the control group. While the elbow RoM was consistently lower in hemiplegic patients, the trunk RoM increased in all phases examined. Shoulder RoM increased in hemiplegic patients in RU, decreased in RO and RT; in RG there was an increase but the difference between the two groups was not significant.

DISCUSSION
Increasing the complexity of the movement produces an increase in its absolute duration, but not in percentage duration of single phases: this can be explained as an apparently similar strategy of movement used by both groups of subjects. The significant increase in range of the trunk in all hemiplegic patients may be interpreted as a proximal compensation to distal impairment of movement. The quantitative kinematic results can help to provide an understanding of the movements of an affected extremity and can be useful in designing rehabilitation process decision making and outcomes.

REFERENCES
EFFECTS OF A PROTOCOL BASED ON BIOFEEDBACK ASSOCIATED TO BOTULINUM TOxin treatment in Pisa Syndrome: a single case

D. Anastasi1, A. Crippa1, A. Marzegan1, A. Montesano1, A. Castagna1

1 Don Gnocchi Foundation, Milan, Italy

INTRODUCTION

Pisa Syndrome (PS) is a postural abnormalities in persons with Parkinson Disease (PD) and it is usually characterized by a lateral flexion of the trunk at least 10°, typically more evident in standing posture but that can be relieved by lying position [1].

PS may be a disabling complication of PD because, when severe, it may cause pain, dyspnea, gait and balance problems with an increased risk of falling and a reduction of quality of life [2].

Several study experimented Botulinum toxin injection (BoNT) into hyperactive trunk muscles in people with PS and the association of a specific rehabilitation program based on motor learning can possibly improve BoNT efficacy [3]. The aim of this case report is to assess the efficacy of specific rehabilitation program using Biofeedback devices associated with BoNT on trunk control in a single patient with PS.

METHODS

We recruit D.F. aged 74 years with PS affected by PD and 5 years disease history, who underwent to 3 assessments 3 months along: before BoNT (T0), after 4 weeks (T1), after 12 weeks (T2). After kinematic assessment with a 9-camera optoelectronic system (BTS Engineering, Milan, Italy) using LAMB protocol during standing and walking, he underwent to a BoNT injection in ileocostalis and abdominal external obliquus muscles and started a tailored rehabilitation program (45 minutes, 20 sessions, 5 times a week). He was re-evaluated after rehabilitation treatment (T1) and after 12 weeks(T2). A tailored protocol was developed using specific devices (inclinometer, goniometer, laser) used as positive or negative feedback in order to control position and movements of the trunk and of the pelvis in frontal plane, giving different movement learning strategies. These devices can improve kinematic body perception and facilitate the re-learning correct movements, strategies and body schema.

We used as a measure of clinical outcome the Center of Pressure (CoP) position during standing and omolateral trunk deviation during walking.

RESULTS

Before BonT and Rehabilitation program the patient showed right shift of CoP (Figure 1a) and right trunk deviation during walking and a reduction of Hip Adduction moment. After the rehabilitation program, DF showed nearly balanced CoP position during standing and less trunk deviation even during walking, maintained at the follow up (Figure 1c). The Hip Adduction moment was positively increased after rehabilitation program (Figure 1d).

Figure 1. a. Posturography without feedback, b. Posturography after rehabilitation (T1) on the trunk movement during a right stride (0-100%) red at T0, blue at T1, green at T2. D. Hip adduction moment during a right stride (0-100%) red at T0, blue at T1, green at T2.

DISCUSSION

At the end of treatment (T1), there was an improvement trunk control during standing and walking, maintained at follow-up when the effect of BoNT was terminated. Trunk alignment and the more correct work of the pelvis determined nearly balanced CoP position during standing, allowing gaze horizontality and contributing to improve quality of life.

The study is currently in progress on a larger sample of subjects.

REFERENCES

“New model of marker placement to assess sagittal spine and lower limb during sit to stand: typical kinematic pattern in LOPD patients”

P. De Blasiis 1, Scarpetta S. 2, Sansone M. 2, M.A.B. Melone 1, Di Iorio 1, S. Sampaolo 1

1 Department of Medicine, Surgery, Neurology, Metabolic and Aging Science and Interuniversity center for Research in Neurosciences - University of Campania, L. Vanvitelli, Naples, Italy.
2 Dipartment of Electric Engineering and Information Technology, University of Naples “Federico II”, Naples, Italy.

INTRODUCTION
Late onset Pompe disease (LOPD) is a neuromuscular disorder due to a mutation of the gene codifying lysosomal enzyme GAA, whose absence or deficiency causes a progressive accumulation of glycogen within lysosome and myofibrils that determines cardiac, respiratory and skeletal muscles alteration. The disease is characterized by primary involvement of trunk and pelvic girdle musculature that results in relevant ambulatory. [1]

To the best of our knowledge only two studies assessed walking parameters in LOPD patients, finding similar spatial-temporal but heterogeneous kinematic and kinetic values [2].

Aim of our study is to assess a motor task that stressed lumbopelvic muscles in homogeneous group of LOPD patients using sit to stand test (STS), in order to find any typical clinical features.

METHODS
7 LOPD siblings, sharing the same GAA mutation compound, were assessed using clinical scales (MRC, GSCGA) and 3d movement analysis that allowed to measure kinematic and kinetic parameters during STS. Age and sex-matched healthy individuals were used as controls. A new model of marker placement was realized to analyze multi-segmental torso and the lumbopelvic rhythm (LPR) too.

Total STS duration was normalized to 100% considering the beginning of horizontal displacement of C7 as start event and the full hip extension as end event. The whole cycle was divided into two main phases: pre- and post-lift off (event corresponding to an increase of 10% in the vertical coordinate of the proximal thigh marker).[3] Moreover, the event characterized by the inversion from flexion to extension of the lumbar spine was calculated and called lumbar reverse (LR).

RESULTS
The results of 7 patients (range 50-70 years, gendered 4F-3M) showed significant abnormalities of temporal parameters consisting in an increase of task duration and a reduction of velocity. Moreover, the assessment of kinematic parameters revealed a significant increased range of motion of pelvic tilt and trunk tilt. Furthermore, time of lumbar reverse, in patients was significantly later than in healthy and it was always after lift off.

DISCUSSION
LOPD is characterized by a marked phenotypic variability among related and unrelated patients even if they share the same mutation. This study shows, in related individuals with the same genetic background, some similar alterations of temporal and kinematic parameters regardless of the severity of their phenotypes. The use of 3d movement analysis improves our understanding of specific clinical and functional features in LOPD highlighting the typical pattern alterations not detectable with the usual clinical examinations. Moreover, this instrumental examination may be used as outcome measures to monitor disease progression and response to Enzyme Replacement Therapy.

REFERENCES
CONTINUOUS 7-DAYS ACTIVITY TRACKING IN PATIENTS WITH PARKINSON DISEASE: A 1-YEAR CONTINUATIVE MULTIDISCIPLINARY REHABILITATION

E. De Giovannini 1, P. Anzolin 1, Z. Baccarin 1, F. Favaron 1, C. Lain 1, N. Locallo 1, P. Pianalto 1, C. Tomasi 1, M. Pistacchi 2, M. Rabuffetti 3

1Centro Medico Riabilita Cooperativa Sociale Mano Amica Onlus - Schio (VI) Italy
2ULSS 7 PEDEMONTANA Dip. Neurologia, Santorso (VI) Italy
3Polo Tecnologico, Fondazione Don Carlo Gnocchi Onlus IRCCS, Milano, Italy

INTRODUCTION
Parkinson Disease (PD) features a gradual evolution of clinical outcome, characterized by both motor (resting tremor, bradykinesia, rigid muscles, impaired posture), and non-motor symptoms (e.g., dysphagia, dysphonia, cognitive deficits). Multidisciplinary clinical evaluation is necessary for setting-up a rehabilitation treatment and for testing its efficacy [1]. However, some specific symptoms (e.g., tremor, circadian alteration) and global performance cannot be accurately quantified through a traditional clinical examination. The aim of this preliminary study is to test the use of actigraphs (wearable sensors for long-term motor activity tracking [2]) for the evaluation of motor symptoms progression in PD patients and the effect of an extensive rehabilitation programme (with long-term follow-up).

METHODS
Thirteen PD patients under pharmacological treatment and with preserved motor functions were recruited at Centro Medico Riabilita – Mano Amica Onlus (Schio, VI). The following exclusion criteria were adopted: camptocormia, severe articular deficits and/or dystonia, diagnosis of dementia, severe dysphagia-dystonia. Furthermore, none of the patients were undergoing infusion therapy or had been subjected to neurosurgery. Patients were enrolled in a multidisciplinary group rehabilitation programme consisting of fifty mins sessions twice a week for one year. Each session included motor and logopedic rehabilitation as well as cognitive stimulation exercises. Motor, logopedic and neuropsychological profile was assessed at baseline (T0), after 4 months (T1) and one year (T2) by means of standardized clinical scales. An actigraph with triaxial accelerometer (Geneactiv, Activinsights Ltd, Kimbolton, UK) was used to record each patient’s motor activity for 7 days at each assessment. Raw data (acquired with a 100 Hz sampling rate) were analysed as in a previous study [2]. Moreover, motor activity of 53 healthy participants was considered as control data.

RESULTS
Starting from the MA index of motor activity, the MA95 parameter (95th percentile of 24-hours level of motor activity) was calculated to measure motor activity peak. Results have shown a significant difference in MA95 between patients and controls. An average - 4% (range -27% to +8%) decrease in MA95 index emerged between T0 and T2, without reaching the threshold for statistical significance (Fig. 1). The standardized clinical scales’ scores highlighted an improvement between T0 and T1, which was maintained at T2.

DISCUSSION
The use of actigraphs has shown many advantages, such as the possibility of highlight and accurately quantify performance data (traditionally based on patient’s or caregiver’s report). Continuous recording allows to obtain an average performance profile, as well as to detect improvements in individualized performance. This information could reflect the effects of a multidisciplinary rehabilitation approach [3] and the disease progression. The absence of index variations could indicate a balance between the progression of the disease and rehabilitation-related improvements.

REFERENCES
7-DAYS ACTIVITY TRACKING IN PATIENTS WITH FIBROMYALGIA SYNDROME: PRELIMINARY DATA.

E. De Giovannini¹, G.A. Cassisi², M.R. Lagni³, P. Anzolin¹, Z. Baccarin¹, F. Favaron¹, C. Lain¹, N. Locallo¹, P. Pianalto¹, C. Tomasi¹, M. Rabuffetti⁴

¹Centro Medico Riabilita Cooperativa Sociale Mano Amica Onlus - Schio (VI) Italy
²ULSS n°1 S. A. I. Reumatologia, Belluno, Italy
³ULSS n°7 Pedemontana U.O.S. Reumatologia, Santorso (VI) Italy
⁴Polo Tecnologico, Fondazione Don Carlo Gnocchi Onlus IRCCS, Milano, Italy

INTRODUCTION
Fibromyalgia syndrome (FM) is a chronic rheumatic disease; the most common symptom is widespread musculoskeletal pain, as well as fatigue, sleep disorders and symptoms involving various apparatuses [1,3]. Some aspects of the symptomatology (level and quality of motor activity, irregular sleep-wake rhythm) cannot be measured within a traditional clinical assessment; the aim of this pilot study is the monitoring of these activities by the use of accelerometric actigraphs [2] in patients with fibromyalgia syndrome before they followed a multidisciplinary rehabilitative program.

METHODS
Nine patients were selected according to the 2010 ACR (American College of Rheumatology) guidelines. The exclusion criteria were: previous neurological diseases, significant orthopedic limitations, ongoing rehabilitative treatment. Pain, physical and emotional functions were assessed for each patient before a 10-week treatment period using standardized clinical scales. In addition, before the beginning of the treatment, the overall motor activity was recorded for 7 consecutive days using an actigraph based on a triaxial accelerometer (Geneactiv, Activinsights Ltd, Kimbolton, UK) applied to patients’ wrist. Raw data (acquired with a 100 Hz sampling rate) were analysed as in a previous study [2]. To date, post-treatment assessments has not been carried out or considered yet. Moreover, motor activity of 53 healthy participants was considered as control normal data.

RESULTS
The general motor activity and the quality of sleep turn out to be diversified between patients. However, the group-level analysis did not show significant differences in the daily average (MAav) and peak (MA95) motor activities between FM patients and controls (Figure 1). Significant differences between patients’ average week activity and peak week activity are observed in the comparison between patients’ weekly average values and their best day (characterized by a higher motor activity).

DISCUSSION
Activity tracking for several days allows to obtain a performance average profile as well as to identify the peaks in daily motor activity. In particular, 9 patients with FM showed important motor reserves that resulted in the increase of both the average activity level and the peak level in a day on the week, that are useful for the elaboration of a rehabilitation program.

REFERENCES
[1] Puttini P.S., Manuale pratico per il paziente affetto da sindrome fibromialgica, AESSEGI, Milano, 2014
An innovative microprocessor-based system for Human Activity Recognition: a fast and reliable classification algorithm

G. De Leonardis\textsuperscript{1}, D. Fortunato\textsuperscript{2}, C. M. Gianfreda\textsuperscript{1}, S. Rosati\textsuperscript{1}, G. Balestra\textsuperscript{1}, M. Knaflitz\textsuperscript{1}

\textsuperscript{1}Dipartimento di Elettronica e Telecomunicazioni (DET), Politecnico di Torino, Torino, Italy
\textsuperscript{2}Medical Technology s.r.l., Torino, Italy

INTRODUCTION
The aim of this study is to describe the implementation of a microprocessor-based system for Human Activity Recognition (HAR) able to recognize seven activities of daily life (ADLs). The system is based on a body-worn miniature inertial measurement unit (IMU) that is part of a microprocessor system based on a 32-bit CPU (ARM 4 Cortex). A Decision Tree (DT) classifier implemented on the microcontroller performs the classification of the daily activities.

METHODS
The experimental setup consisted of an IMU-based micro-processed platform (Medical Technology, Torino, Italy) for human activities recognition that is usually attached to the lateral side of the right thigh. The platform is based on a triaxial accelerometer and a triaxial gyroscope, and it acquires three axes of acceleration and of rate of turn with a sampling frequency of 80 Hz.

A group of 76 healthy subjects (36 males, 40 females) performed seven activities of daily life: sitting (A\textsubscript{1}), upright standing (A\textsubscript{2}), level walking (A\textsubscript{3}), ascending and descending stairs (A\textsubscript{4}, A\textsubscript{5}), uphill and downhill walking (A\textsubscript{6}, A\textsubscript{7}). Each activity was repeated 5 times and lasted 60s. The activities were performed in indoor and outdoor areas without restrictions in speed and style of performing. Each subject signed an informed consent form.

Signals were segmented through a 5s-sliding window, with an overlap of 3s between subsequent epochs. For each window, 221 time-domain features were extracted. In particular, for each signal we extracted information about zero crossings and number, position, and duration of positive and negative peaks (33 features x 6 signals). Moreover, we computed single and double integration of the acceleration in the anteroposterior and vertical directions, and the single integration of the rate of turn in mediolateral direction. Other 23 features were extracted from these signals.

A DT was constructed using only 20\% of the signal windows randomly selected from 50 subjects. Once the tree was obtained, it was validated by classifying all windows relative to the entire population of 76 subjects. A post-processing algorithm based on majority voting was implemented on the DT outputs, to reduce isolated classification errors: considering 5 subsequent windows, the most frequently recognized activity was assigned to the group of windows. The average performance across the 76 subjects was evaluated for each activity after post-processing.

RESULTS
Among the 221 initial features, the DT selected only 84 features. The overall recognition performance was equal to 90.5\%. Specifically, the correct classification percentages for each activity after post-processing were the following (mean ± standard deviation across the 76 subjects): 99.9\% ± 0.9\% for A\textsubscript{1}, 99.2\% ± 4.2\% for A\textsubscript{2}, 87.3\% ± 14.1\% for A\textsubscript{3}, 87.6\% ± 7.4\% for A\textsubscript{4}, 95.8\% ± 6.7\% for A\textsubscript{5}, 82.7\% ± 17.5\% for A\textsubscript{6}, 80.8\% ± 18.8\% for A\textsubscript{7}.

DISCUSSION
The purpose of this study was obtaining a classifier to be implemented on a wearable microprocessor system able to monitor a subject over a daylong period. To this purpose, the choice of a DT is favorable since it may be implemented in firmware as a set of nested “if ... then” statements. Moreover, it was sufficient using a reduced set of only 84 features instead of the initial set consisting of 221 features, since only part of the initial set was used for constructing the DT. These two facts cause a strong reduction of the computational cost, making it possible to use a microprocessor with a 32-bit architecture without floating processing unit and, consequently, reducing the power requirements of the system.

In terms of classification accuracy, the HAR system herein described was able to recognize correctly 90.5\% of ADLs. Among the entire group of activities, the lowest value of correct classification was obtained for uphill and downhill walking (83\% and 81\%), that sometimes were erroneously classified either as level walking or as ascending/descending stairs. This is probably due to the slight slope of the ramp used in our protocol, which ranged between 10\% and 15\% (wheelchair ramp).

In conclusion, we believe that results so far obtained are accurate enough for most applications of interest in clinics and rehabilitation. Battery life of the system is over 20 hours, making it suitable for a daylong analysis session.
A new wearable low-cost method to detect Virtual Reality sickness: a preliminary study

G. Gentile 1, G. Ferriero 2, R. De Miti 1, R. Di Marco 3, S. Masiero 3,4, P. Sale 3,4

1 San Camillo Hospital IRCCS, Venice, Italia, 2 IRCCS Istituti clinici scientifici Maugeri, Lissone, Italia, 3 University-Hospital of Padova, Padova, Italia, 4 Neuroscience Dept-University of Padova, Padova, Italia

INTRODUCTION

Virtual reality (VR) settings was proved to be a useful complementary therapy for neurologic and orthopaedical rehabilitation. Patients attending VR rehab sessions can improve their motor function and autonomy in every-day life activities [1]. However, due to the virtual environment exposure, virtual reality sickness (VRS) can be observed: e.g. postural instability, fainting, sweating, disorientation and retching [2]. Mobility self-efficacy, balance confidence, and fear of falling can be evaluated by monitoring task-related biofeedback, which are linked to the sympathetic nervous system (SNS) activity [3]. The aim of this study is to validate a wearable not-intrusive system for multimodal monitoring of SNS in subject performing a VR rehabilitative task.

METHODS

Six healthy subjects (5M; 34 ± 9 yo; no medical treatment) underwent to a custom VR session (Hybrid Reality srl, Padova) in a dimly illuminated and air-conditioned room (20°C) [4]. Subjects wore a “MS Microsoft Band 2” on the non-dominant side wrist, measuring skin conductance (SCL - μS, 5 Hz). The basal values were registered asking the subjects to comfortably seat on a chair with eyes open and closed for 1 min each. They were then invited to wear a commercial VR headset (HTC VIVE) and to perform 3 different tasks: t1) observe and explore the environment; t2) find design errors in a scaffolding (t2a) and react to a collapse (t2b); t3) watch down from a third-floor terrace (t3a) and jump from there (t3b). Raw data were filtered (1-order Butterworth, 5 Hz [4]), and labeled by using a video recording to link the signal portion to the relevant performed task. Windows of 15 s of the signal after stimulus onset were selected and retained for the analysis [4]. An event-related Continuous Decomposition Analysis was then performed to isolate the phasic component, which is a fast response related to the underlying sudomotor nerve activity (Ledalab 3.2.2) [6]. Moreover, to assess the VRS, subjects self-evaluated their valence and arousal using a 9-points Likert scale at each task completion [5], and correlation with the maximum value of phasic activity (PhasicMax) and SCL was tested via the Pearson’s correlation index (r). Finally, a non-parametric repeated measures Friedman-Test was used to statistically test differences among subject responses to the tasks (p=0.05, IBM SPSS Statistics).

RESULTS

The statistical analysis of the different electrodermal activity components showed a significant difference among the VR tasks for both SCL (p<0.001), and PhasicMax (p<0.05), reporting the highest mean rank for t3b (M=4.33 μS). Variables significantly correlated with self-reported arousal (PhasicMax: r = -0.339; p<0.05; SCL: r = -0.548; p<0.001) and valence (PhasicMax: r = 0.553; p<0.001; SCL: r = 0.564; p<0.001).

DISCUSSION

Results lead to conclude that sympathetic responses during cognitive, motor and emotional (CME) tasks in a VR environment can be differentiated by detecting specific features on the biosignals related to different stress levels, and collected in an ecologic, and non-intrusive way. For future scenarios, these methods could serve as: a) monitoring system that allows a more detailed control of the patient’s engagement and effort during CME therapy; b) biofeedback system to tune the emotional state of subjects, and the overall CME performance; and c) to monitor and predict the effects of VRS.

REFERENCES

Stabilometry in patients with Dravet Syndrome to quantitatively assess ataxia: a preliminary study
R. Di Marco 1, M. Duso 1,2, R. Cesaletti 2, L. Nieves 1,2, C. Boniver 1, F. Darra 3, F. Ragona 4, S. Masiero 1,2, A. Del Felice 1,2

1 University Hospital of Padova, Padova, Italy, 2 University of Padova, Padova, Italy, 3 University Hospital of Verona, Verona, Italy, 4 IRCCS Istituto Neurologico C. Besta, Milano, Italy

INTRODUCTION
Dravet Syndrome (DS) is a rare disease characterised by recurrent seizures, intellectual and behavioural disability, myoclonus, pyramidal or extrapyramidal signs, and ataxia. However, ataxia has only been clinically observed [1]. The aim of this study was to test the possibility of using the stabilometry as a tool to quantitatively monitor ataxia in subjects with DS at different time-points, and to help the differential diagnosis from other diseases featuring similar signs [2].

METHODS
Eight subjects with DS (2M; median 22.5 yo, range 17-32 yo; 161.5 cm, 124.0-194.5 cm; 54.5 kg, 44.5-80 kg), and seven controls (CS: 5M; 29 yo, 25-41 yo; 175.0 cm, 161.3-188.6 cm; 73.8 kg, 55.0-95.0 kg) were asked to stand on a force plate (BERTEC, 6 components, 800 Hz), staring at an eye-level point for 60 s on the 3 m far front wall. Feet at hips distance and arms close to their trunk. Center of Pressure (CoP) trajectory was filtered (4-order Butterworth, 8 Hz) and down-sampled at 20 Hz [3]. CoP parameters in both time and frequency domain were calculated: 95% confidence ellipse area (CEA, mm²), total length (SP, mm) and displacement (Δ, mm) of CoP trajectory, its mean velocity (MV, mm/s), total spectral power (TP, mm²), and frequency below which the 50% of TP is present (f50, Hz) [3]. All parameters but CEA were also calculated for the antero-posterior (AP) and medio-lateral (ML) directions and were normalized as in [4] with respect to subjects’ height and body mass. Eventually, a Wilcoxon test was used to test differences between DS and CS values (p=0.05).

RESULTS
Figure 1. Median, 25th and 75th percentiles of the parameters for CS and DS (outliers are marked with a red +). Statistical differences are highlighted with a red star (p<0.05).

DISCUSSION
The increased Sway Path in AP and ML and the increased Mean Velocity in the ML direction are both robust indices of ataxia, which is a common clinical finding in DS. The differences in CEA, TP and f50 results, even though not statistically significant, are in line with this finding. Indeed, the higher TPs coupled with lower f50 values in DS rather than in CS, are the correlate of the gross adjustments needed to maintain the static posture, which are often observed in ataxias.

In conclusion, despite the objective limits of stabilometric test data interpretation [4], these preliminary results show that postural parameters could be used in clinical practice to quantify and follow-up neurological signs in DS.

ACKNOWLEDGEMENTS
The presentation of this study is supported by the Association Dravet Italia Onlus.

REFERENCES
Interaction between EMG activity of intrinsic and extrinsic foot muscles during child walking
F. Di Nardo¹, M.S. Palmieri², A. Strazza³, S. Cardarelli¹  O. Orsini¹, A. Mengarelli¹, F. Verdi¹, A. Bortone², and S. Fioretti¹
¹ Department of Information Engineering, Università Politecnica delle Marche, Ancona, Italy.
² Centro Ambulatoriale di Riabilitazione Santo Stefano, Porto Potenza Picena (MC), Italy.

INTRODUCTION
A relationship between intrinsic and extrinsic foot muscles is acknowledged during adult walking [1]. However, literature on foot-muscle recruitment in children is not very extensive. Purpose of the study was the surface-EMG-based evaluation of possible interaction between intrinsic and extrinsic foot muscles during healthy-children walking.

METHODS
Surface-EMG and basographic signals during 4-minute walking were acquired in 8 healthy children (mean±SD: age 8.3±1.7 years; height 136±8 cm; mass 30.9±6.2 kg). Lower limbs were instrumented with 3 foot-switches, below the heel and the first and fifth metatarsal heads, to characterize 4 different gait phases: Heel contact (H), Flat foot contact (F), Push-off (P), Swing (S). Single differential surface-EMG probes were applied over muscles according to Winter’s guidelines [2]. Gastrocnemius lateralis (GL) and Tibialis Anterior (TA) were analyzed as representative for extrinsic foot muscles. Extensor digitorum brevis (EDB) was considered as representative for intrinsic foot muscles. Large stride-to-stride variability of surface EMG signals was handled by Statistical Gait Analysis [3], processing separately distinctly muscle activation modalities, averaging only across gait cycles with the same number of activations, and achieving mean activation intervals for each activation modality.

RESULTS
265±30 (mean±SD) strides were analyzed for each child, nearly 2500 in total. EDB activity was localized in two separate regions of gait cycle (GC): mid-stance (from 8.2±7.0 to 50.3±15.0% of GC) and swing phase, from 73.8±13.8 to 95.1±4.7%. Main GL activity occurred in the same regions: mid-stance (from 5.7±2.5 to 49.7±4.6% of GC) and swing phase, from 69.2±18.7 to 95.4±5.4%. Differently, TA activity was detected from the beginning of GC to 18.2±16.9% of GC and from 56.4±9.2% to the end of GC. Summarizing pattern for sEMG activity of each muscle was reported in Fig. 1.

![Fig. 1: Activation intervals in the whole population summarized in terms of number of children where muscular activity was acknowledged. Horizontal bars are grey-level coded, according to the number of children where a certain condition is observed; black: condition observed for all subjects in considered activation modalities, white: condition never met. Dashed lines delimited H, F, P, and S phases.](image)

DISCUSSION
Regions of EDB and GL activity were practically overlapped, suggesting that EDB and GL worked synergistically for foot and ankle-joint control in able-bodied-children walking, in a large percentage of strides. Otherwise, EDB and TA muscles are recruited in antagonistic way in controlling foot movement. Short and sporadic superimpositions between muscles may be interpreted as actions exercised by neuromotor system to control ankle-joint movement. Present study produced novel data on the variability of the reciprocal role of intrinsic and extrinsic foot muscles during children walking, providing insights in mechanisms regulating ankle-foot stability.

REFERENCES
Is it possible to identify an optimal bipolar system positioning to discriminate the activation of scapular stabilizers between correct and poor posture during upper limb exercises?

F. Dos Anjos¹, G. Boccia², PR. Brustio², M. Gazzoni¹, A. Rainoldi²

¹ Politecnico di Torino, Torino, Italy, ² Università di Torino, Torino, Italy

INTRODUCTION

Poor postures during exercises for strengthening training may affect the selective muscle activation. Biofeedback based on electromyograms (EMGs) can be used to provide real-time indication on the correct muscle activation during an exercise to a subject [1]. In this study we investigated if it is possible to identify an optimal positioning of an EMG bipolar system in order to provide information about the correct activation of stabilizer muscles during upper limb exercises.

METHODS

Seven male volunteers expert in the execution of pull down at latmachine and dumbbell row were recruited. They were instructed to perform five repetitions for each exercise, both in a correct (scapular stabilizer activated) and incorrect (no activation of scapular stabilizers) way. Monopolar surface EMGs from the scapular stabilizers (medial and lower portions of trapezius muscle) were sampled with a grid of 32 surface electrodes (8x4 electrodes, inter-electrode distance: 10 mm). From the 32 monopolar signals we simulated the 15 (5x3) possible positioning of a conventional bipolar detection system with 2 cm inter-electrode distance and electrode surface of approximately 1 cm² [2]. The Root Mean Square (RMS) maps of simulated, bipolar EMGs were computed on epochs of 0.125 s centred in the time instants corresponding to 0%, 25%, 50% and 75% of the range of movement of the bar or dumbbell during the concentric phase of the exercises. In order to identify the optimal positioning providing information about the correct activation of stabilizer muscles, for each exercise we calculated the map resulting from the difference between the RMS maps obtained during correct and incorrect execution. The x and y coordinates of the highest RMS amplitude in the RMS differential map was computed for each movement phase and exercise repetition.

RESULTS

Figure shows the positioning (mean±std) of the highest RMS in the differential map. For the pull down exercise at latmachine, although the location of highest RMS coincided for some subjects on average, it was variable between subjects for both medial and lower trapezius. For the dumbbell row exercise, the coordinates of highest RMS difference were less variable between subjects for medial trapezius. For lower trapezius, however, there was a variability between subjects.

![Figure 1. Mean and standard deviation of the coordinates of highest RMS amplitude in the map obtained as the difference between the RMS maps during correct and incorrect exercise execution for pull down at latmachine (on the left) and dumbbell row (on the right).](image)

DISCUSSION

The between-subjects variability for the position of the highest RMS difference between correct and incorrect exercise execution seems to be exercise and muscle dependent. Our results revealed the position of the highest RMS difference was less variable for medial trapezius during dumbbell row. This finding suggests an optimal positioning of a bipolar detection system could not be identified for all muscles and exercises. The extension of the study to a higher number of subjects and exercises is ongoing.

REFERENCES

EMG comparison between medial pivot and posterior stabilized knee prosthesis designs

F. Esposito\textsuperscript{1,2}, M. Freddolini\textsuperscript{1}, L. Latella\textsuperscript{1,3}, M. Marcucci\textsuperscript{1,2,3}, A. Corvi\textsuperscript{1,2}

\textsuperscript{1}Fondazione ONLUS: In cammino...”, Fucecchio, Italy, \textsuperscript{2}University of Florence, Firenze, Italy, \textsuperscript{3}Institute “Centro di Eccellenza Sostituzioni Articolari Toscana (C.E.S.A.T.), Fucecchio, Italy

INTRODUCTION
Total Knee Replacement (TKR) is extremely effective in improving function and reducing pain in patients with osteoarthritis. There are different prosthesis designs available, and in the present work we evaluate the posterior stabilized (PS) and medial pivot (MP) knee prostheses in terms of muscular activation during gait.

METHODS
Forty patients following TKR were recruited from C.E.S.A.T. database and separated in two groups according to the implanted prosthesis design: MP and PS. Furthermore, twenty Healthy Control (HC) subjects were collected. EMG signal of Rectus Femoris (RF), Vastus Medialis (VM) and Biceps Femoris (BF) were recorded with six wireless probes (BTS FREEEMG 100 RT), three for each limb, at sampling frequency of 1000 Hz. Probes were positioned according to SENIAM protocol. We acquired at least five gait trials for each participant. After the acquisitions, EMG signals were band-pass filtered with 30-300 Hz cut-off frequencies. A low pass filter with cut-off frequency of 50 Hz were used to obtain linear envelope of signals. Teager-Kaiser energy operator (TKEO) was applied to improve onset-offset detection \cite{1} and an activation threshold was calculated as a sum of the mean plus fifteen times the standard deviation of the baseline signal \cite{1}. An Analysis of Variance was performed on each of variables between groups.

RESULTS
No significant differences were found for age, BMI, walking speed and healthy limb muscles activation between patient’s groups (p>0.05). Significant differences (p<0.05) were found between HC and patients groups in terms of prolonged muscular activity during gait (Figure 1). Only on RF activation there were significant differences between MP and PS groups (p<0.05).

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure1.png}
\caption{Onset and Offset of the EMG activity for the RF, VM, BF muscles during gait for MP, PS and HC groups. Onset are indicated by the left edge of the horizontal bar, while offset by the right edge of the horizontal bar. Error bars indicate standard deviation. * indicates significant differences between MP and PS group, + indicates significant differences between MP and HC groups, ^ indicates significant differences between PS and HC groups. Vertical purple line denotes heel strike.}
\end{figure}

DISCUSSION
Despite there is a significant difference only for RF activation, it seems that MP group increases activity of investigated muscles to stabilize the knee during stance phase. The maintenance of stiff knee consists in a functional adaptation of the patient to a sense of instability \cite{2}. In addition, a prolonged muscular activity could cause an increased energy request and a muscle fatigue during gait. Further investigations are needed to confirm this hypothesis.

REFERENCES
\begin{enumerate}
\end{enumerate}
Gait events estimation using inertial wearable sensors while walking in water
G. Pacini Panebianco1, M.C. Bisi1, A.L. Mangia2, R. Stagni1,2, S. Fantozzi1,2
1University of Bologna, Bologna, Italy; 2CIRI SDV-TS, Ozzano dell’Emilia, Italy

INTRODUCTION
Recently, the water environment has gained an important role in the rehabilitation world [1]. More specifically, walking in water represents an exercise useful for people with specific gait deviation and can be practiced by individuals without swimming skill [1,2]. In order to characterize gait alteration, gait timing is considered of primary importance and required the correct identification of gait events (GEs) [3]. With the widespread use of inertial measurement units (IMUs), a large number of algorithms was proposed and applied for the purpose during walking out of the water [4]. Nevertheless, to authors’ knowledge, none analysed the influence of the water on the identification of GEs. Thus, the purpose of the present study is to assess the performance of different algorithms in the identification of GEs in the water environment using IMUs.

METHODS
Ten healthy subjects (5F,5M; 26.2±3.3y.o.; 171.5±7.2m; 65.4±8.6Kg) were recruited for the study. Participants were asked to walk in the water at self-selected speed back and forth along a 10m straight path wearing water shoes. Measures of acceleration and angular velocities were collected using 5 tri-axial waterproof IMUs (Cometa, Italy, fc285Hz) located on the lower trunk, the shanks and the feet. For each participant, 32 steps were analysed. Steps were also visually counted during each trial. Seventeen algorithms previously implemented to identify GEs from IMU measures out of the water [3] were adopted for the analysis in the water environment. Then, the identified approaches were classified based on: 1) IMU position, 2) target variable, 3) computational approach (Table 1). Intraclass correlation coefficients (ICC) and standard error of measurement (SEM) were calculated for intra-class and inter-classes reliability statistics using Matlab (MathWorks, USA, 2017). Then, the influence of each class in GEs detection was analysed by means of a linear mixed model using R software (R-CoreTeam, Austria, 2017).

RESULTS
All trunk- and one shank-based (exploiting acceleration signal with peak identification) algorithms showed more than 50% of missed event, thus were discarded from the analysis. GEs detection was highly reproducible among algorithms within each class (ICC=0.99–1.00; SEM,0.09–0.24s) and among classes (ICC=0.99–1.00; SEM,0.09–0.18s). Comparing Shank- and foot-based algorithms, no difference was found for HS estimation (p=0.832), while difference (p<0.01) was highlighted for TO identification. Significant differences (p<0.05) were shown in GEs detection between acceleration and angular velocity for target variable and between peaks identification and zero crossing for computational approach.

DISCUSSION
Preliminary results suggested that trunk-based algorithms are not suitable for GEs detection in the water environment. Conversely, GEs detection was highly reproducible within and among shank- and foot-based algorithms. Moreover, no difference was found between these positioning in HS detection, suggesting that both can equally be adopted for HS definition. This result is in line with Pacini et al. [4] that showed similar performance in GEs detection between algorithms adopting signals from shank and foot. Significant differences were found for all the other comparisons: further analyses will allow to investigate the accuracy in GEs definition among different classes comparing these results with those obtained from a gold standard (e.g. camera waterproof).

REFERENCES
Quantitative characterization of walking in marine environment: a pilot study.
G. Pacini Panebianco¹, M. C. Bisi¹, P. Tamburini¹, A. L. Mangia², S. Fantozzi ¹ ², R. Stagni¹ ²
¹DEI, University of Bologna, Bologna, Italy; ²CIRI SDV-TS, Ozzano dell’Emilia, Italy

INTRODUCTION
The beach environment offers an easily accessible, inexpensive and unique opportunity for training. Walking on sand increases lower limb strength and improves balance [1], while walking in water provides beneficial effects in terms of biomechanics and cardiorespiratory response [2]. Although the literature reported many physiological and biomechanical modifications related to walking on sand and in the water [1,2], to authors’ knowledge, no study analyzed the modifications of gait in terms of motor control. In recent years, novel non-linear metrics have demonstrated their potential in quantifying motor control characteristics [3], such as rhythmicity, regularity, complexity and variability [3]. The purpose of the present study was to characterize motor control changes as resulting from walking on sand and in sea-water.

METHODS
Five healthy subjects (3F, 2M; 35.2±7.3y.o.; 171.5±11.5m; 60.8±7.5Kg) were asked to walk at self-selected speed in 6 different conditions: out of the water (OW) 1) on hard surface (even concrete blocks), 2) on wet sand, 3) on dry sand, and in sea-water (IW) at 4) knee, 5) pelvis- and 6) xiphoid process-level. Acceleration and angular velocities of lower-trunk and shanks were collected using three tri-axial inertial sensors (Cometa, Italy, fc 142 Hz). For each participant 50 strides were analyzed. For each condition, stride-time was estimated from shank angular velocities [3]; standard deviation and Poicarré plots of stride-time were calculated to quantify timing variability; fundamental frequency (ff) of trunk acceleration was calculated as estimate of cadence. Multiscale Entropy (SE τ=1-6), Recurrence Quantification Analysis (RQA: AvgL, RR, DET), and Harmonic Ratio (HR) were calculated on trunk acceleration in each coordinate direction (V, AP, ML) [3]. The influence of the different (a-f) walking conditions on motor control as quantified by different indexes was analyzed adopting a mixed linear model using R software (R-Core Team., Austria,2017).

RESULTS
No significant difference among conditions was found for ff and for RR and AvgL in AP direction, and for DET in all directions. Timing variability resulted significantly lower and HR higher in all directions for gait OW (i.e. 1, 2, 3) than IW (i.e. 4, 5, 6). SE increased for all τ in V and AP directions from condition 1 to6, while RQA, RR and AvgL decreased in V and increased in ML direction.

DISCUSSION
Statistical results, visually represented on the polar plots, suggested that water environment substantially changes gait performance, independently from the level of immersion, while motor control did not seem to be affected by surfaces. Results highlight that IW gait is less rhythmic, more variable, and more complex (less automatic) than OW. IW is more recurrent on the ML direction and less in V direction, than OW. Future research will focus on including a higher number of participants and testing different population to obtain more significant and interpretative results related to the motor control characterization in the marine environment.

REFERENCES
How foot pressure distribution change between standing upright and walking in subjects affected by small foot and spine deformities

V.Farinelli 1, L.Flaviani2, G. Meloni 2, M.Mutti3, C.Frigo1
1 Politecnico di Milano, DEIB, Milano, Italy,
2 Orthesys Srl, Milano, Italy
3 Istituto Ortopedico Galeazzi, Milano, Italy

INTRODUCTION

Computerized baropodometry is increasingly used in gait analysis laboratories to analyze the alterations of foot-ground contact. Information obtained by this method however are not only limited to the local problem of the foot but include the effects of several anatomical districts above the foot, that are the knees, the hips, the spine, and probably the high level control systems affecting posture and movement. Our purpose, in the present study, was to ascertain what kind of parameters extracted from the maps of foot pressure distribution could globally represent the postural attitudes deriving from small deformities of spine and foot.

METHODS

In the gait analysis laboratory of Orthesys Srl (Milano) fourteen subjects (mean age:15 years, range:10-22 years) affected by mild foot deformities and scoliosis were analyzed by a baropodometric system (DiaSu Health Technologies, Rome). Subjects were asked to walk at their natural cadence, barefoot, on a straight line and measures were taken also during standing upright in orthostatic posture. The following parameters were extracted from the baropodometric maps: average load on the rear- and fore-foot bilaterally as percentage of the body weight, ratio between left and right support load. Based on these measurements a global index of load distribution was defined as: LD=sum(ΔALR+ΔALR+ΔALL+ΔALL), where ΔL represent the deviations of loads on forefoot, rearfoot from an ideal load distribution (pedices AR, PR, AL, PL, indicate anterior right, posterior right, anterior left, posterior left). The ideal load distribution was considered for static conditions 20% forefoot, 30% rearfoot, while for walking conditions 30% forefoot, 20% rearfoot, symmetrical for left and right. The static and dynamic indexes were compared with Spearman correlation test (JMP13). In order to quantify alteration occurring in the frontal plane and in the sagittal plane, two subset indexes were computed: LD L in which the deviation of left-right loads in relation to the ideal 50% load distribution was computed; LD A-P in which the deviations of anterior-posterior loads were computed. In this plane the ideal load distribution was considered 40% forefoot 60% rearfoot for standing upright, and 60% forefoot 40% rearfoot for walking.

RESULTS

The Load Distribution index provided us a global evaluation of load imbalance during standing and walking. After calculating the median of the sub indexes LDML and LDAR, which was respectively 9.25% (range:1.6-31.2) and 11.35% (range:1.6-36.7) the only subjects with values higher than the median were considered and they revealed interesting correlations with posture alterations occurring in the mediolateral side or in the anterior-posterior side respectively (Table1). Interestingly, the load distribution obtained in standing posture did not usually correspond to load distribution in walking as shown by the Spearman’s coefficient ρ=-0.22 identifying an inverse correlation not statistically significant (p value>0.05).

<table>
<thead>
<tr>
<th>Patients</th>
<th>Load Distribution Index</th>
<th>Pathological condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td>LDA-P &gt;11.35%</td>
<td>Morphological alterations of the foot, pain at the foot, knee and spine, scoliosis</td>
</tr>
<tr>
<td>Group B</td>
<td>LDML &gt;9.25%</td>
<td>Leg length discrepancy, frontal pelvic tilt, scoliosis</td>
</tr>
</tbody>
</table>

DISCUSSION

Most musculoskeletal diseases affecting the locomotion apparatus have an effect on posture and force distribution at the foot-ground interface. Measuring these forces can help understanding the causes and the compensation mechanisms adopted by the subjects. A synthetic quantification of these alterations can be obtained by proper load indexes. Load distribution between left and right, and between forefoot and rearfoot can be different in standing upright and in walking, so that static measurements are not predictive of loading in dynamic conditions.
Balance assessment in young with Friedreich’s ataxia: Longitudinal study
M. Favetta1, M. Petrarca1, S. Summa1, A. Romano1 S. Minosse1, E. Castelli1
1MARlab, Neuroscience and Neurorehabilitation Department, Bambino Gesù Children’s Hospital – IRCCS, Rome, Italy

INTRODUCTION
Currently, there are no standardised measures to evaluate the effectiveness of balance rehabilitation for children with Friedreich’s ataxia (FRDA) [1]. FRDA is an autosomal recessive, degenerative and rare disease [2]. Clinical features are progressive gait ataxia, dysmetria, dysdiadochokinesia, muscular weakness, sensory loss, areflexia. The balance disorder is the major cause of disability for these patients [3]. Aim of this study is to assess the balance ability of children with FRDA and the progression in their natural history looking at Center of Mass and Pressure (CoM, CoP).

METHODS
Three FRDA patients were enrolled (3 females, mean age 11.5±3). Two evaluations were carried out with three months apart (T0-T1). We acquired the full body model by an optoelectronic system (Vicon MX) to assess CoM. The stabilometric assessment was run using force plate (AMTI,Or-6,US). Patients were instructed to look straight ahead and to maintain balance for 30 seconds with arms and feet in their natural position. CoM and CoP displacement was recorded in two conditions: with open eyes and closed eyes. The average values of three trials for each condition were analyzed.

RESULTS
The CoM and CoP’s areas are represented in Figure 1. The average area increases, in both eyes open (CoM\textsubscript{T0}=2336.33±1548.45 mm\textsuperscript{2} - CoM\textsubscript{T1}=3171.77±2329.93 mm\textsuperscript{2} and CoP\textsubscript{T0}=389.05±183.23 mm\textsuperscript{2} - COP\textsubscript{T1}=545.51±278.46 mm\textsuperscript{2}) and eyes closed (CoM\textsubscript{T0}=6605.33±4300.43 mm\textsuperscript{2} - CoM\textsubscript{T1}=8478±8354.02 mm\textsuperscript{2} and CoP\textsubscript{T0}=1117.17±431.14 mm\textsuperscript{2} - COP\textsubscript{T1}=1683.27±969.06 mm\textsuperscript{2}) conditions. Moreover CoM and CoP’s average length of the path in both eyes open (CoM\textsubscript{T0}=377.40±162.18 mm - CoM\textsubscript{T1}=411.18±161.25 mm and CoP\textsubscript{T0}=1117.17±431.14 mm - COP\textsubscript{T1}=1683.27±969.06 mm) and eyes closed (CoM\textsubscript{T0}=723.67±289.10 mm - CoM\textsubscript{T1}=821.87±271.38 mm and CoP\textsubscript{T0}=1261.77±336.42 mm - COP\textsubscript{T1}=1814.8±751.03 mm) conditions increases.

DISCUSSION
Our results show an increase of the CoM and CoP’s area and total length path at T1 compared to T0 and in closed eyes condition compared to open eyes condition. This represents the FRDA natural history and the progression drop of balance ability. The differences in closed eyes condition data is greater than open eyes condition data. This suggests the involvement of proprioceptive deterioration. This knowledge is essential for the definition of reliable indicator useful during clinical trial.

REFERENCES
On the use of the instrumented Timed Up and Go test to objectify the screening validity of the CSF tap test
A. Ferrari 1, D. Milletti 2, S. Magnoni 2, L. Chiari 1
1 HST-ICIR University of Bologna, Bologna, Italy, 2 DIBINEM University of Bologna, Bologna, Italy

INTRODUCTION
Idiopathic normal pressure hydrocephalus (iNPH) is a neurodegenerative, yet reversible, disease of the senile age, characterized by the clinical triad: dementia, urinary disturbance and gait apraxia. Described by Hakim in 1965 [1], the etiology and pathophysiology of the iNPH are not clarified yet; though the pathology is treatable via a cerebral shunt. CSF tap test (CSFtt) is the test commonly used to give indication to surgery. To date, however, CSFtt outcome is assessed without the use of objective data. By means of inertial sensors, is nowadays possible to accurately measure and analyze the modification of gait performances over screening tests or interventions in the clinical routine. In the present study, 57 persons suspected of iNPH performed an instrumented Timed-Up and Go test (TUG) and a 10m walking test extended to a distance of 18m (18mWT) pre and post CSFtt.

METHODS
The diagnosis of iNPH was assessed according to [1] via a clinical and neuroradiological evaluation by a team of experts (neurologist, neurosurgeon, neuroradiologist, physiatrist and psychologist). Patients were stratified in three groups: non-iNPH; iNPH; iNPH with comorbidities (iNPHwC). The TUG and 18mWT were instrumented by means of three inertial sensors, two wore on the shoes and one on the trunk. Similarly to [2], a smartphone app was used to obtain accurate gait spatio-temporal and trunk posture parameters. Three repetitions per test were recorded on pre- and post-24 and -72 hours the CSFtt. Test-retest reliability of parameters was evaluated by computing the ICC type 1,1.

RESULTS
57 patients were enrolled (40% women; mean age 75 yo), clinically divided in 10 non-iNPH; 22 iNPH and 25 iNPHwC. ICC values on three repetitions are all above 0.89, proving excellent test-retest reliability. In Figure 1 the pre vs post-24 and -72 hours CSFtt mean values for gait speed, stride length and number of steps to perform the 180° turning of the TUG, are reported.

DISCUSSION
In this study, coherently with literature [3], non-iNPH don’t show an improvement in gait performances post-CSFtt, as instead both iNPH and iNPHwC patients do. In particular, via an instrumented TUG is possible to evaluate different factors concurring in performance modification, revealing for example how iNPHwC present a pre- vs post-CSFtt improvement for gait speed but not for stride length per se. In conclusion the use of instrumented motor test such as TUG or 18mWT are able to objectively perform modification due to CSFtt therefore strengthening its validity as indicator to surgery in iNPH.

REFERENCES
A small horizontal component of the barbell trajectory is a simple index of technical efficiency in squat.

Ferrari L, Bochicchio G, Pogliaghi S
Dipartimento di Neuroscienze, Biomedicina e Movimento, Università di Verona, Italy

INTRODUCTION

During a deep squat, the lateral kinematic trajectory of the barbell in the eccentric and concentric phases describes a near V-shaped curve. Because of the vertical nature of the squat, the horizontal displacement of the barbell is not useful for the force expression. Based on this assumption, the present study proposed and aimed at validating a new index of technical efficiency (TE), derived from the two-dimensional motion analysis of the lateral barbell trajectory.

We tested the hypothesis that more experienced power lifters would display higher TE compared to low-skilled novice athletes.

METHODS

In 12 young males (22.7±1.8 yrs) 6 Intermediate skilled (>2 yrs experience) and 6 low skilled novice powerlifters (< 2 yrs experience) we measured: maximum squat strength (1RM) and recorded the lateral trajectory of the barbell (sagittal two-dimensional motion analysis, Sony’s video camera, 250 Hz) during sets to failure performed at 60%, 75% and 90% of 1RM. For the determination of the TE at each intensity, the integral of the instant by instant horizontal (x) components of each movement, expressed as % of the ideal vertical (y) displacement, was subtracted by 100 as follows:

\[ TE = 100 - \left( \frac{\sum X \text{ component of the eccentric and concentric}}{\text{Ideal Y component}} \right) \times 100 \]

An average TE was calculated for each intensity. 1RM data were compared by t-test and TE data by two-way ANOVA (experience group and exercise intensity).

RESULTS

Intermediate skilled subjects had a significantly higher 1RM than novice (146.9±24.6 vs 99.7±21.0 Kg). There was a significant main effect of experience (p<0.001) yet no main effect of intensity (p=0.364) on TE. Intermediate skilled subjects had significantly higher TE at 60 (92.2±1.2 vs 88.8±1.1%), 75 (92.1±1.4 vs 87.4±2.2%) and 90% of 1RM (91.1±1.5 vs 87.5±4.0%), all intensities not significantly different from each other.

DISCUSSION

The study proposed a new index, that quantifies the not useful, horizontal component of the barbell displacement in squat. In agreement with our hypothesis, the TE index is significantly different in athletes with distinct technical ability and performance. Other studies are needed to confirm the possible role of the barbell trajectory kinematics as a synthetic index of the athlete’s technical ability in a deep squat.

REFERENCES

Validation of the “single 3-min submaximal test” for the prediction of the Critical Power in young women.
Ferrari L, Colosio A, Pogliaghi S
Dipartimento di Neuroscienze, Biomedicina e Movimento, Università di Verona, Italy

INTRODUCTION
Critical power (CP) demarcates heavy/sustainable from severe/unsustainable exercise intensity and is used for evaluation/monitoring of exercise capacity and for training design and exercise prescription[1]. The standard measuring technique requires either a physically demanding and time-consuming protocol (3-5 constant-load trials to exhaustion) or a maximal all out test, neither of which are applicable in all contexts and populations. A recent study from our group demonstrated that CP is accurately and precisely predicted based on blood lactate (LA) accumulation at the third minute of a single submaximal non-exhausting cycle ergometer trial in adult males[2]. The application of the above simple, submaximal and time-efficient approach for CP estimation in adult women requires validation. Therefore, we tested the hypothesis that CP can be accurately determined from a single delta blood lactate measurement in the third minute of a submaximal cycle ergometer trial in women.

METHODS
Nine healthy young women (24±4 years, BMI 24±3, VO$_2$max 42±7 ml$^{-1}$·kg$^{-1}$·min$^{-1}$) performed two to four constant-power-output trials on a cycle ergometer to the limit of tolerance. CP was calculated based on the individual watt–time to fatigue relationship and successively validated ($val$CP) through 1-2 30-min constant power output trials. During each trial, LA accumulation ($LA_{3\text{min}}$) was calculated as the difference between 3-min and resting values. The following multiple linear regression was applied to estimate $val$CP from subjects’ sex and $LA_{3\text{min}}$:

$$\%CP = 94.7 - (4.18 \times \text{sex}) + (6.9 \times LA_{3\text{min}})$$

sex: 1=male, 2=female

The estimated CP ($est$CP) was compared to $val$CP by paired t-test, correlation and Bland-Altman analysis.

RESULTS
The group mean value of $val$CP was 163 ± 30 watt, not significantly different from ($p=0.43$) and highly correlated with ($r^2=0.81$) $est$CP (165 ± 36 watt). The average difference (bias) between $val$CP and $est$CP was -1.5 watt (not different from zero) with a precision of 16 watts.

DISCUSSION
In agreement with previous work in a healthy male population and with our hypothesis, the simple, submaximal, time- and cost-efficient 3-minute submaximal test proposed in our study accurately and precisely predicts CP in women. This newly developed method offers a practical and valid alternative to traditional, time consuming and physically demanding CP determination.

REFERENCES
Spatiotemporal parameters and shoulder joint loadings in post total hip replacement surgery patients during aided gait are influenced by crutch set-up?

M. Freddolini1, F. Esposito1,2, L. Latella1,3, M. Marcucci1,2,3, A. Corvi1,2

1Fondazione ONLUS: “In cammino...”, Fucecchio, Italy. 2University of Florence, Firenze, Italy, 3Institute “Centro di Eccellenza Sostituzioni Articolari Toscana (C.E.S.A.T.), Fucecchio, Italy

INTRODUCTION
Crutch is prescribed to permit patients to walk independently immediately after surgery, increasing both tolerance to exercise, independence, and in turn accelerating recovery [1]. During crutch-assisted gait, part of the body mass is borne by the upper limbs, which improves stability and reducing load on the pathologic limb. On the other hand, crutch-assisted gait results in higher energy cost than normal gait [2] and induces load on the upper limbs, which in some cases may be higher than body weight [3]. Crutch users showed prevalence of shoulder pain and other upper limbs pathological conditions [4]. Regarding crutch length, two setups have been proposed as a general guideline, one consisted in setting the crutch length with the elbow semi flexed (EF = elbow flexed setup) which was defined by setting the crutch handle level with the greater trochanter. The elbow completely extended configuration (EE = elbow extended setup), was achieved by setting the crutch handle at the distance between the ground and wrist crease [5]. Purpose of this study is to evaluate the influence of the crutch setup on upper limbs biomechanics and walking performance to detect possible differences related to the crutch length.

METHODS
Thirty patients were randomly assigned to EF or EE forearm crutch setup. Optoelectronic motion tracking system together with two force platforms, were used to evaluate crutch and upper limbs motion, spatiotemporal gait parameters, crutch and limbs ground reaction force (GRF). Reflective markers were placed on subjects following a model used previously to get 3-D shoulder kinematics in thorax coordinate system [6]. Shoulder kinetics were derived through inverse dynamic approach. After a familiarization protocol, subjects walked straight at their comfortable pace on the laboratory path. Shoulder angles were FE=flexion/extension, AA=abduction/adduction and IE=internal/external rotation. Anterior (Fan), posterior (Fpo), medial (Fme), lateral (Fla), superior (Fsu) and inferior (Fin) shoulder force peaks and peak-to-peak values for adduction/abduction (Maa P-P), flexion/extension (Mfe P-P) and internal/external rotation (Mie P-P) moments were taken during crutch stance. In addition, limb symmetry was evaluated for both gait and force parameters using the symmetry index. Variability was quantified for base of support width, stride time and length as the coefficient of variation. An Analysis of Variance was performed on each of variables between groups.

RESULTS
Results showed that cadence and walking speed were not significantly different (p>0.05), but stride length significantly decreased, and base of support width increased for the EF group when compared to the EE group (p<0.05). AA angle ROM, Fla and Fdo force peaks, Mfe, Maa and Mie P-P moments (p<0.05) increased significantly in the EF group when compared to EE group (p<0.05). No significant differences were found for the other shoulder parameters (p>0.05). Operated limb GRF parameters were significantly decreased for the EF group, while crutch force parameters decreased for the EE group (p<0.05). Furthermore, the EF group showed greater stride length variability and asymmetry of force and spatiotemporal parameters than EE group did (p<0.05).

DISCUSSION
The present study showed that crutch setup influenced performance and upper limb loading during walking, with EE setup allowing a more stable and symmetric gait and reducing stress on the shoulder joint when compared to the EF setup. Results may help therapists in rationalizing crutch length adjustments for patients after THR surgery.

REFERENCES
INTRODUCTION
There is growing interest in the therapeutic potential of cannabinoid-based chemicals for neurological conditions to understand their effects specifically as it relates to movement disorders [1]. Dystonic tremor is considered a tremor in a body part affected by dystonia [2]. This involves: tremor in an extremity or body part that is affected by dystonia, focal tremors, usually with irregular amplitudes and variable frequency (mainly less than 7 Hz), and mainly postural/kinetic tremors usually not seen during complete rest [3]. The aim of this research was to analyze the possible effect of cannabinoid-base medicines in subject with DYT1 dystonia associated to dystonic tremor during different upper limb motor task.

METHODS
A 21-years old woman affected by upper limb dystonia associated to dystonic tremor at the right hand performed, sat comfortably on a chair, four tasks: rest - with arms relaxed and hands hanging freely from the arm rest; posture - with arms/wrists outstretched at shoulder level: subject should bring her arms forward, slightly lateral to the midline and parallel to the ground, the wrist should also be straight and the fingers maximally abducted; finger-to-nose task: subject extended only their index finger, she then touched a target located to the full extent of her reach, which was located to the same height (parallel to the ground) and slightly lateral to the midline, subject then touched her own nose and repeated this back and forth motion; spiral - while holding a pen vertically the patient drew a spiral by following the printed model, without lifting the pen, once using the right hand and once using the left hand. The hand and the arm holding the pen should not touch the table. Electromyography of flexor and extensor carpi radialis, spatiotemporal and kinematic parameters of both arms were recorded in a laboratory with integrated optoelectronic system (SMART-DX, BTS bioengineering, Italy) of a rehabilitation clinic during two sessions, in the OFF and ON medication state condition (30 mg die 5-8% THC / 7,5-12% CBD). The parameters defined to identify any significant differences in the kinematic of the movement of the upper limb were: duration, average and peak velocity of the movement, Jerk index, hand sway path, index of curvature, frequency of the movement, number of movement unit (NMU) [4].

RESULTS
Compared to normal value, data of patient in OFF revealed: EMG activation at 5Hz during posture, finger-to-nose task and spiral; during finger-to-nose task: increased duration, jerk index, length of hand sway path, index of curvature and NMU. Data of patient in ON revealed, compared to OFF, absence of activation at 5 Hz; during finger-to-nose task: decreased length of hand sway path, frequency of direction change and number of movement unit (NMU).

DISCUSSION
EMG data and NMU value in ON showed the absence of dystonic tremor in all the task performed. Higher values of NMU and hand sway path indicated lower precision and fluidity in the movement, which explains the difficulty that patient had in conducting specific tasks in OFF condition. Lower values of registered average velocity in combination with higher value of change of direction frequency was a clear sign of the motor disability that characterizes subject with dystonia. Dystonic tremor has shown a positive response to treatment. This result suggests a possible benefit of cannabinoids for dystonic tremor.

REFERENCES
Effect of bilateral globus pallidus internus deep brain stimulation on gait in isolated generalized dystonia: A case report

S. Frittoli 1,2, V. Libera 2, F. Cosignani 1,2, B. Conti 1,2, L. Romito 3, L. Santillio 1

1 Department of Neuro-Rehabilitation, MultiMedica IRCCS, Limbiate, Monza Brianza, Italy, 2 Gait & Motion Analysis Laboratory, Department of Neuro-Rehabilitation, MultiMedica IRCCS, Castellanza, Varese, Italy, 3 Department of Neurology, Movement Disorders, IRCCS Fondazione Carlo Besta, Milano

INTRODUCTION

Bilateral globus pallidus internus deep brain stimulation (GPiDBS) has been established as an effective treatment for generalized dystonia [1]. Dystonia is a movement disorder characterized by sustained or intermittent muscle contractions causing abnormal, often repetitive, movements, postures, or both. Dystonic movements are typically patterned, twisting, and may be tremulous. Dystonia is often initiated or worsened by voluntary action and associated with overflow muscle activation [2]. Three-dimensional motion analysis system is utilized to quantify specific pattern of movement abnormalities in the several dystonic phenomenology [3]. The aim of this study was to assess gait changes in subject with isolated generalized dystonia induced by bilateral globus pallidus internus deep brain stimulation (GPiDBS).

METHODS

A 31-years old man affected by isolated generalized dystonia with impairment of trunk, left lower limb and right upper limb performed gait analysis in a laboratory with integrated optoelectronic system (SMART-DX, BTSbioengineering, Italy) of a neuro-rehabilitation clinic. Kinematic, kinetic and electromyographic data of gait at a self selected speed were recorded during two sessions, before implantation (OFF) and six months after initiation of pallidal stimulation (ON) according to Helen Hayes protocol.

RESULTS

Spatiotemporal variables of the gait in the OFF condition showed that patient had reduced walking velocity, stride length (right < left) and percentage of right swing during gait cycle compared with normal data. In the ON condition, patient had significant increased walking velocity and right stride length compared with OFF condition. Kinematic and electromyographic data of gait in OFF revealed several differences with respect to healthy controls during the gait cycle: increased left lateral trunk bending and anterior pelvic tilt; left knee extension in stance; increased left ankle dorsal flexion in pre and initial swing; increased left ankle external rotation; increased sagittal jerk index of left ankle; co-contraction of Tibialis anterior and Triceps surae muscle at initial contact and in the loading response; decreased ankle power generation (left < right) in stance and maximum knee power absorption in stance. Gait parameters of patient in ON revealed significant differences compared with OFF: absence of lateral trunk bending; presence of correct left ankle dorsi-plantiflesion and intra-extrarotation; decreased sagittal jerk index of left ankle; proper timing activation of Tibialis Anterior and Triceps Surae muscle during all the gait cycle; increased ankle power generation in stance.

DISCUSSION

These results may indicate GPiDBS facilitated the neuromuscolar function during gait increasing smoothness of joint flexion-extension movement and reducing the dystonic movement. Gait analysis may provide a non invasive and useful tool to measure and to monitor the functional improvement following the GPi stimulation in generalized dystonia.

REFERENCES

INTRODUCTION
In the last years, the use of robotic devices for upper limb rehabilitation has grown rapidly, especially for patients with brain injury [1]. However, there is insufficient evidence for the use of these devices to recover upper limb motor function in patients with peripheral damage.

METHODS
We present a case of a 28 years old man with a traumatic lesion of the right brachial plexus, occurred after a road trauma. One month later he came to our observation. Physical examination revealed hypotonia of the deltoid, biceps and triceps of the right arm, with a decrease of muscle strength of deltoid, biceps and triceps. The patient was not able to perform movements as shoulder flexion and abduction or elbow flexion against gravity. The patient was treated with a set of 4 robotic devices, six times a week, each session lasting 45 minutes. To investigate the effects of the robot-assisted therapy, we analyzed the evolution of his motor ability by means of an optoelectronic system (Smart D500, BTS, Italy). Specifically, we analyzed a reaching task toward 5 targets, placed on a table and equally spaced on a semicircle (with radius of 40 cm). For each direction, the following parameters were computed (as means of 5 repetitions): travelled distance, mean speed, smoothness (with the Normalized Jerk, NJ [2]), and elbow, shoulder elevation and trunk inclination range of motion (ROM). The evaluation protocol was performed at the beginning of the treatment (T0) and after one (T1), two (T2) and three (T3) months of treatment.

RESULTS
All the investigated parameters, for each target and each evaluation, separately, are reported in Figure 1. During the robotic treatment, the patient progressively increased the travelled distance toward the fifth target (the ipsilateral target). In addition, the patient increased his quality of movement, as showed by the increase of the mean velocity and the decrease of the NJ, for all the investigated directions. Finally, we observed an evolution of his strategies, as showed by the changes in the analyzed range of movements, toward an increase of elbow and shoulder ROM, and a reduction of compensatory trunk movements.

Figure 1. – Polar plots showing the results of the motion analysis test, for the 5 targets, separately.

DISCUSSION
Our results show that a treatment with a set of robotic devices can improve the upper limb motor functions of a young patient with a traumatic lesion of the right brachial plexus, as highlighted by the motor changes in a reaching task measured by means of an optoelectronic system. Therefore, they support the hypothesis that a robotic treatment could be effective in patients with peripheral damage.

REFERENCES
Propagation of foot anatomical landmark identification variability on foot regional plantar pressure assessment

C. Giacomozzi ¹, E. Bergamini ², V. Camomilla ²
¹ Istituto Superiore di Sanità, Rome, Italy, ² IUC-BOHNES, Foro Italico University, Rome, Italy

INTRODUCTION

Clinical assessment of foot joint kinematics and plantar loading can be performed using multisegmental models [1] and a pressure-kinematics integrated approach [2]. While the impact of inter- and intra-operator precision in identifying foot anatomical landmarks has been investigated on joint kinematics [3], the propagation of this variability to the assessment of foot regional pressure has been scarcely described. The present study addresses this issue with respect to the Oxford Foot Model (OFM).

METHODS

A seven-cameras 3D tracking system (MTx, Vicon, UK, 100Hz) was used to track OFM markers on anatomical landmarks (AL) and 9 technical markers (Fig.1.B) placed on the right limb of 10 healthy participants (7 M; 27±6 y; 73±14 kg; 1.7±0.1 m; 4 normal, 4 cavus and 2 flat feet). Synchronous plantar pressure was acquired (Emed q-100, novel Gmbh, DE; 4 sensors/cm²). For each participant, 5 operators (Fig. 1.A) identified the OFM ALs position after anatomical palpation [1]. The 3D position of markers placed on these ALs was then represented in ad hoc defined technical marker-clusters during a single stance orthostatic posture trial. Each participant performed 5 gait trials and the AL trajectories corresponding to all anatomical calibrations (4 op * 1 trial + 1 op * 5 trials) were obtained through a rigid transformation based on the technical marker-clusters. Anatomical Masking (AM) was applied [2] based on each calibration to extract pressure-related parameters of 5 foot regions (ROIs) i.e. medial and lateral hindfoot and forefoot, and midfoot. The most similar geometrical masking (GM) was applied as a reference, to estimate gait intra-subject variability. Coefficients of variation (CV) were calculated for the three conditions (GM, intra-AM, inter-AM) and focusing on Contact Area (CA), Peak Pressure (PP), Contact Time (CT) and Force-Time Integral (FTI).

RESULTS

Intra-operator variability of anatomical landmarks identification was 2.5±0.6 mm and 3.1±0.6 mm along the medio-lateral and anterior-posterior axes. Corresponding inter-operator variability was 4.1±1.8 mm and 6.5±1.7 mm. CVs of intra- and inter-AM were comparable with the expected gait variability (GM) for CA, CT and FTI in all ROIs (overall ranges: 0.4-4.7% for GM; 0.0-2.2% for intra-AM; 0.1-3.1% for inter-AM) and much lower for PP (1.9-10.7% for GM; 0.0-2.2% for intra-AM; 0.0-2.0% for inter-AM). Intra-AM was more variable for cavus feet, inter-AM for normal and flat feet. Highest variability was found at the forefoot for all parameters except for CT, which was more variable at midfoot.

DISCUSSION

Anatomical masking based on OFM seems robust enough to variability in anatomical calibration, and error propagation entails a variability in main parameters comparable with intra-subject gait variability. For less experienced operators, the identification of the forefoot anatomical landmarks can be critical.

REFERENCES

Impact of urban life scenarios on balance and falls: a pilot experiment

C. Giacomozzi 1, F. Martelli 1

1 Istituto Superiore di Sanità, Rome, Italy

INTRODUCTION

Consolidated, in-lab tools and methods for movement analysis do allow accurately investigating alterations of balance and risk of falling, under reference conditions and also including standardized visual, proprioceptive, and vestibular perturbations. However, the need is emerging to bring functional assessment outside the lab, based on the preliminary evidence that motion in daily living context is indeed different from motion during in-lab assessment [1]. The present study aimed at contributing to understand whether and how much the typical environmental disturbances of a chaotic and noisy city may represent an additional risk factor for those who, due to aging or to single or concurrent diseases, have difficult moving and interacting safely with the real-life scenario.

METHODS

Safe and repeatable experiments were designed based on: measuring instruments and supports (capacitive pressure measurement platform (EMED q-100, novelGmbH, DE, 4 sensors/cm²), reflective markers, high-speed video cameras); viscoelastic, styrene gel destabilizing pad; sounds and noises recorded from the street (sirens, dogs, motorbikes, mobile phone rings, buses); visual and vestibular disorders (flicker, strobe lights, in-subjective video projections); VAS-based questionnaire for self-assessment of perceived instability. 6 single stance balance tests were then performed by 5 healthy subjects (3M; 25±14y; 1.7±0.1m; 65±12kg) on the platform (20 samples/s), 30 seconds each, stance on dominant limb, with: open eyes (OE) (T0, reference); closed eyes (CE) (T1); CE and styrene pad (SP) (T2); CE+SP+acoustic disturbances (AD) (T3); OE+SP+visual disturbances (VD) (T4); OE+SP+video projection (VP) (T5). Preliminary data analysis on the central 20 seconds of each test concerned: center of pressure (COP) sway path and confidence ellipse; a modified Romberg index to compare tests T1-T5 with T0; 1-way ANOVA (p<0.05) with Bonferroni-Holm correction on Romberg indices. COP parameters were finally correlated with the perceived difficulty.

RESULTS

In general, disturbances reduced the ability to maintain balance, but for all volunteers unexpected urban sounds or noises had a smaller impact than proprioceptive disturbances and the lack of visual information. The visual stimuli, on the contrary, significantly reduced COP oscillations (Table 1). Overall correlation between the perceived instability and COP sway path was moderate-to-good (R² in the range 0.49-0.73).

<table>
<thead>
<tr>
<th>Test</th>
<th>COP sway path</th>
<th>COP confidence ellipse</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1 (CE)</td>
<td>2.20 (0.54)</td>
<td>3.03 (1.04)</td>
</tr>
<tr>
<td>T2 (CE+SP)</td>
<td>2.33 (0.44)</td>
<td>3.63 (1.01)</td>
</tr>
<tr>
<td>T3 (CE+SP+AD)</td>
<td>2.19 (0.59)</td>
<td>3.12 (1.88)</td>
</tr>
<tr>
<td>T4 (OE+SP+VD)</td>
<td>1.07 (0.14)*</td>
<td>0.81 (0.21)**</td>
</tr>
<tr>
<td>T5 (OE+SP+VP)</td>
<td>1.63 (0.28)</td>
<td>1.92 (0.66)</td>
</tr>
</tbody>
</table>

*different from T1 (p<0.001), T2 (p=0.0013) and T3 (p=0.0015); **different from T2 (p=0.0017)

DISCUSSION

Despite normalization issues and possible learning effects have not been accounted for in this pilot experiment, it provided encouraging results and good ideas for the development of repeatable, informative functional tests, close to real life scenarios, which will be soon validated on wider urban populations.

ACKNOWLEDGMENTS

This pilot study was partly developed during the 2018 “Alternanza scuola-lavoro” ISS path PS.9

REFERENCES

The text neck: How the smartphone can protect us from the smartphone?
D. Giansanti¹, G. Maccioni¹, L. Colombaretti², S. Raffaele², R. Simeoni²

¹ Centro Nazionale Tecnologie Innovative in Sanità Pubblica, ISS, Roma, Italia
² Univ. Cattolica del S.C., CDL Fisioterapia, Villa Immacolata, S Martino del Cimino (VT), Italia

INTRODUCTION
The text neck syndrome was introduced for the first time in 2008 by Dean L. Fishman, a scientist in the treatment of technology injuries. This definition was proposed to explain the consequences of repeated solicitations to the human body, caused by the excessive use of smartphones [1]. In detail the text neck can cause: frequent headache; cervical pains; stiffness of the scapulo-humeral girdle and dorsal rigidity; tingling and numbness in the upper limbs. From a biomechanical point of view it is evident that this problem is due to an excessive tension on the part of the cervical spine due to incorrect motor/postural tasks exercised during the use of the smartphone; in particular it has been shown that this tension increases with the neck inclination [1-2]. Scientists suggest simple lifestyle changes to alleviate stress due to the ‘text-neck’ [1-2]. For example, it is advisable to keep the smartphone vertically, this enforces to raise up it in front of the face, or at eye level, while looking at the display and to perform some indicated physical exercises.

METHODS
The smartphones are equipped with a very complex and heterogeneous sensor system, among the different types of sensors we highlight those of motion such as accelerometers and gyroscopes used by applications for the analysis of movement (walking, running, step count) and the two cameras (front and back). By means of the accelerometer, sensitive to gravity acceleration, for example, it is possible to have a measurement of the angle of the smartphone with respect to the terrestrial vertical; it is this sensor that in fact is used for the "display rotation" function. The general idea is to use the smartphone itself, as "a tutor who protects us from the text neck, stinging us in holding the device in front of the face and advising us, for example, to perform physical exercises after a programmed time. Some examples of these types of applications available on Google Play (the store for Android and one of the most used stores) are: Text Neck indicator; HeadUp-Protect your neck!; Text Neck. A group of experts of several fields has been defined to investigate the usefulness of Apps as an aid to prevent the text neck. A study has been arranged into four polarities: (a) the design of an App for the prevention of the text neck; (b) the technology assessment investigation of the acceptance and subjective perception of the App usefulness; (c) the validation of the performance by means of wearable devices [3]; (d) the enlargement of the study to psychological and cognitive implications.

RESULTS
An App has been proposed for the prevention of the text neck and a technology assessment study was carried. This App, among the various functions allows:- A biofeedback on correct/incorrect posture.- A time accumulation function that indicates with a programmed time how long the device is being used; if, for example, the programmed time is 15 m, every 15 minutes will send a notification.- A suggestion of postural exercises.

The technology assessment was conducted by means of a questionnaire submitted to 50 subjects who used the App. The analysis of the data showed a high desirability of text neck prevention solutions, on the average a high acceptability of the functioning of the App and a high acceptance of the functions proposed in the App.

DISCUSSION
The design and construction of the App for the prevention of the text neck has been performed. Its acceptance and subjective usefulness perception has been successfully assessed on a first sample of subjects. The next steps of the study will be dedicated to the enlargement to the third and fourth aspects of the study. At the moment: (1) we have designed an accelerometric system for the assessment of the head inclination during the use of the smartphone with and without the proposed App; (2) we are enlarging the questionnaires to address the psychological implications.

REFERENCES
The Powered Exoskeletons: towards an investigation on the health professionals
D. Giansanti¹, R. De Chicchis², G. Maccioni¹, S. Raffaele², R. Simeoni²

¹ Centro Nazionale Tecnologie Innovative in Sanità Pubblica, ISS, Roma, Italia
² Univ. Cattolica del S.C., CDL Fisioterapia, Villa Immacolata, S Martino del Cimino (VT), Italia

INTRODUCTION
It is widely demonstrated that solutions for rehabilitation and for the aids which allow the “upright position” are very useful to improve the functionality of the internal organs and avoid the bedsores. The Mechanical (not motorized) Exoskeleton, such as the Reciprocating Gait Orthosis, even if, allows a rehabilitation with a “upright position” needs a high energy consumption during the use, for this reason subjects under a rehabilitation process, prefer to use the wheelchair at home, a useful aid but an incomplete rehabilitation-tool which does not allow the “upright position” and the assisted deambulation. The introduction of the mechatronics is allowing new opportunities to the exoskeletons in rehabilitation with the so called powered exoskeleton (PE) [1-2]. The introduction of a new technology should face several basic issues. The first step is the acceptance and the opinion of the citizen [3] and the professionals who will use it. We have planned a wide ranging study based on the data collection on this issue in two directions. The first direction is the collection and analysis of information from the citizen [3-4]. The second direction, and purpose of this specific work is the collection and analysis of information from the professionals using and not using the PE.

METHODS
The study focused to these systems and faced the design of a tool to investigate the opinion and the acceptance of the health care professionals on the introduction of these systems. The tool was based on a dedicated questionnaire that generally addressed the following points: • Categorization of the professional, • Basic knowledge of technology, • Opinion on the introduction of technology in the rehabilitation processes, • Collection of useful comments, • methods of use of PEs, • Observed outcomes, • Collection of opinions and wishes. The questionnaire was designed with the support of various professionals in the healthcare system such as biomedical engineers working in the field of the Health Technology Assessment, physicians and psychologists working in the field of the physical rehabilitation. The questions were organized in sections and were proposed using the graded evaluation methodology with four levels of appreciation. The test-givers also gave an essential description on the PEs during the questionnaire compilation.

RESULTS
This questionnaire involved 35 rehabilitation professionals in Italy. From a general point of view the work elucidates a high interest on the new technology, in the use in several scenarios of life (home, all environments, clinics) and in the relevant investments. Furthermore the interviewed professionals gave useful information on the inclusion criteria and on the methods of administration of the therapy. According to the questionnaires, the interviewed professionals found improved the following assessed outcomes: - the muscle recruitment, - the sensibility, - the intestinal function, - the functions of the vascular system, - the range of motion, - the reduction of spasticity, - the resistance to the stress.

DISCUSSION
The proposed study elucidated the usefulness of the PE introduction and of the proposed questionnaire as a tool of investigation to collect information for the Health Care System for further data-mining and analysis. The next step will be directed to (a) the procedure automatization by means of electronic forms; (b) the enlargement of the tool to comprehend the patient’s opinions; (c) to collect also psychological aspects as outcomes to be assessed also to investigate the improvement in the perception of quality of life [5]. The final tool based on the questionnaire for the investigation of the acceptance and introduction of the PEs on professionals, patients and citizen could represent a basic methodology useful for the stake-holders in the health care system.

REFERENCES
Adaptation to predictable postural perturbations induced by a mobile platform in patients with Parkinson's disease.

M. Giardini1, M. Godi1, I. Arcolin1, M. Schieppati2, A. Nardone1,3
1Istituti Clinici Scientifici Maugeri IRCCS, Italy; 2LUNEX International University of Health, Exercise and Sports, Differdange, Luxembourg; 3University of Pavia, Italy.

INTRODUCTION
When healthy subjects (HS) stand on a platform continuously and predictably moving in an anterior-posterior direction, balance control relies on a progressive adaptation of the activity of the lower limb muscles [1]. At variance with HS, patients with Parkinson's disease (PwPD) show instability when standing on a predictably moving platform [2]. We hypothesized that, under this condition, instability of PwPD is related to impaired adaptation process.

METHODS
We recruited 32 PwPD (age 68.7 years ± 6.9; Hoehn-Yahr range 2-2.5) and 14 HS (69.9 years ± 4.5). The participants had to stand blindfolded on a platform continuously moving 100mm back and forth at 0.4Hz in the horizontal plan for 45 cycles. Area of electromyographic (EMG) responses (as % of maximal voluntary contraction) of Tibialis Anterior (TA) and Soleus (Sol) muscle of both legs was measured during the whole duration of each successive cycle. An index of adaptation (IA) was calculated for each leg muscle as the ratio of the EMG area averaged across the last six cycles to that across the first six cycles. Kinematics was evaluated through reflecting markers, positioned on lateral malleolus, greater trochanter and head, detected by a stereophotogrammetric system. We then evaluated the standard deviation (SD) of the antero-posterior displacement of the marker on the head and greater trochanter. For each marker, we calculated an index of stability (IS) as the ratio of the SD averaged across the last six cycles to that across the first six cycles.

RESULTS
Area of EMG activity of both TA and Sol muscles was similar in PwPD and HS in the first cycle of the series of platform displacement cycles. In HS, TA and Sol EMG activity showed a rapid decrease of area in the first few cycles, more evident in TA. Area of electromyographic (EMG) responses (as % of maximal voluntary contraction) of Tibialis Anterior (TA) and Soleus (Sol) muscle of both legs was measured during the whole duration of each successive cycle. An index of adaptation (IA) was calculated for each leg muscle as the ratio of the EMG area averaged across the last six cycles to that across the first six cycles. Kinematics was evaluated through reflecting markers, positioned on lateral malleolus, greater trochanter and head, detected by a stereophotogrammetric system. We then evaluated the standard deviation (SD) of the antero-posterior displacement of the marker on the head and greater trochanter. For each marker, we calculated an index of stability (IS) as the ratio of the SD averaged across the last six cycles to that across the first six cycles.

DISCUSSION
EMG activity of TA muscle adapts during subsequent cycles of platform displacement in HS [3]. This phenomenon is accompanied by reduction of body oscillations [1]. TA muscle appears to play a balance control role: reduction of TA activity in HS decreases ankle muscle co-contraction leading to a reduction of the postural destabilization produced by the platform displacements [1]. On the contrary, the patients' difficulties in adapting to the predictable movements of the platform are shown by both the impaired reduction of EMG activity of the TA muscle and the consequent inability of reducing the destabilization of body segments. In both groups, Sol activity remains constant or even increases in PwPD, in keeping with the notion of a postural role of Sol not only during quiet stance but also during postural perturbations. The impaired adaptation of TA EMG activity to predictable postural perturbations might be related to the known abnormalities in anticipatory postural adjustments in PwPD [4] and can partly explain their postural instability in everyday life.

REFERENCES
Musculoskeletal modeling and gait analysis can improve diabetic foot preventive management
Guiotto A.¹, Spolaor F.¹, Bellè F.¹, Guarneri G.², Avogaro A.², Sawacha Z.¹
¹Dept of Information Engineering, ²Dept of Medicine - University of Padua, Italy

INTRODUCTION
Complications of diabetes that affect the lower extremities are common, among them foot ulceration is the most frequently recognized one, and unfortunately also ulcers recurrence is common [1]. Preventive programs aiming at reducing both plantar ulcers occurrence and recurrence is one of the most important topics in the current approach to diabetic foot disease [1]. By considering the wide number of amputations per year due to diabetic foot pathology, early detection of subjects at risk through a good understanding of the factors that predict ulcers and its recurrence is becoming mandatory [1]. Repetitive stresses both on the plantar aspect of the foot and at the level of internal tissues can be detected through musculoskeletal modelling techniques, in particular finite element modeling (FEM) is the most commonly used. Such measurements can also be adopted to plan therapeutic footwear for preventive management. Recently the authors demonstrated that the development of foot FEM can be enhanced on diabetic subjects by adopting both subject specific geometries (MRI based) and boundary conditions acquired during gait [2]. Furthermore by including lower limb muscle forces as further boundary conditions, the foot FEM simulation results were improved even more on a healthy subject [3]. The aim of the present study was to evaluate the impact of combining subjects specific gait analysis data, lower limb muscle forces computed in Opensim on the estimation of internal stresses on a cohort of neuropathic subjects.

METHODS
Eight neuropathic foot FEMs and 10 healthy subjects were developed as in [2] by applying subject specific boundary conditions acquired during gait to two, previously developed, foot FEMs respectively of a healthy and of a neuropathic subject [2]. Three gait trials per subjects were acquired through 2 force plates (Bertec FP4060), a motion capture system (BTS S.r.l), 2 plantar pressure plates (Imago Ortesi), an 8 channels electromyographic system (BTS) [2, 4]. Hence subjects specific muscle forces were determined as in [4] in Opensim for both healthy and diabetic subjects and compared through T-Test (p<0.05). FEM simulations were run by considering only the kinematics and the ground reaction forces as boundary conditions [2] or by including the muscles forces generated with the Gait 2392 model in Opensim. Plantar pressure data obtained through the FEMs were compared with the experimentally measured ones in both conditions for validation purposes.

RESULTS
Better results were obtained when adopting the FEM driven with the muscle forces as boundary conditions together with the ground reaction forces and the kinematics (Figure 1). Furthermore these models leaded to lower Von Mises stresses, thus confirming that the important role of muscle forces.

Figure 1: Top: OpenSim Static Optimization results: comparison between mean muscles forces (dashed lines) plus and minus 1 standard deviation of both CS (in blue) and of DPNS (in red). Results of T-Test have been reported in term of the instants of the gait cycle where significant differences were found (blue asterisk means p < 0.05). Bottom left: Von Mises stresses on plantar soft tissues for one Neuropathic subject: simulations with the GRF FEM model and the one with GRF and muscle forces. Bottom right: comparison between simulated and experimental plantar pressures on the 8 neuropathic subjects.

DISCUSSION
This methodology can be adopted to optimize the preventive management by providing a early detection of subjects at risk and in order to develop specific insoles that can improve gait biomechanics and foot function aiming to reduce foot internal and external stresses.

REFERENCES
Efficacy of Robotic-Assisted Gait Training in sub-acute stroke patients: an Italian bi-centre study
C. Iacovelli 1, M. Franceschini 2,3, A. Cruciani 1, C. Simbolotti 1, M. Goffredo 2, C. Pecchioli 1, L. Padua 1,4, D. Galafate 2, S. Pournajaf 2, I. Aprile 1

1 IRCSS Don Carlo Gnocchi Onlus Foundation, Milan – Italy
2 Department of Neurorehabilitation, IRCCS San Raffaele Pisana, Rome – Italy
3 San Raffaele University, Rome – Italy
4 Department of Geriatrics, Neurosciences and Orthopedics, Catholic University of the Sacred Heart, Rome – Italy

INTRODUCTION
Over the last years, the introduction of robotic technologies in gait rehabilitation of stroke patients has had a greatest interest. Some studies have been conducted to assess the effects of robot-assisted training compared to gait conventional rehabilitation in sub-acute stroke patients. The main results were obtained in studies that used robotic exoskeletons or treadmill training with partial body weight support and only few papers used end-effector device [1]. To date, there are very few studies that have used gait analysis to show improvements in gait parameters after gait rehabilitation in sub-acute stroke patients [2]. The aim of this study was to evaluate the effects of Robotic Gait Training (RGT) in Sub-Acute Stroke Patients using clinical scales and gait analysis.

METHODS
We enrolled 27 sub-acute stroke patients (within six months from onset). They were divided into 2 groups: robotic group (RG) and conventional group (CG). 15 patients received RGT using an end-effector system machines (G-EO system device); 12 patients received a program of conventional gait rehabilitation. The rehabilitation program of both groups was combined with traditional physiotherapy. The clinical evaluation included: Motricity Index, Ashworth Scale, MRC Scale, Timed Up and Go Test (TUG), 6 Minute Walking Test (6MWT), 10 Meter Walking Test (10MWT), Functional Ambulation Categories (FAC), Walking Handicap Scale (W.H.S), Tinetti Scale, Fugl-Meyer Assessment (FMA) for lower limb and Trunk Control Test. Gait analysis was performed by the SMART-D500 optoelectronic system using Davis protocol. All spatio-temporal parameters were calculated and five of these (step length, swing time, stance time, double support time and an intra-limb ratio of swing:stance time) were used to calculate the following symmetry index: Symmetry Ratio (ratio), Symmetry Index (SI), Gait Asymmetry (GA) and Symmetry Angle (SA) [3]. To assess the lower limb joint kinematics we also calculated hip, knee, and ankle range of motion (ROM) in the sagittal plane. The assessments were performed at the beginning (T0) and at the end of the treatment (20 sessions) (T1).

RESULTS
The within-group analysis revealed a statistically improvement in most of the clinical scales in both groups. Regarding to the gait analysis RG showed statistically differences in the following parameters (related to the affected side): Stride Time (p=0.01), Cadence (p=0.018), Step Length (p=0.011), Velocity (p=0.017), Swing Velocity (p=0.041), Stride Length (p=0.008), Mean Velocity (p=0.028), knee ROM (p=0.026), ratio swing time (p=0.019), GA swing time (p=0.030), SA swing time (p=0.013). While CG showed statistically differences only in: ratio swing time (p=0.041), SA swing time (p=0.041), ratio and SA step length (p=0.016 and p=0.016, respectively). With regard to the between-group analysis, the change from baseline were higher in the RG than in the CG in: Hip and Knee Ashworth Scale (p<0.001 and p=0.016, respectively), Total Ashworth Scale (p<0.000), MRC Hip extension and MRC Ankle flexion (p=0.035 and p=0.045, respectively), 10MWT (p=0.032), TUG (p=0.002), 6MWT (p<0.000), ratio and SA step length (p=0.027 and p=0.023, respectively).

DISCUSSION
Both rehabilitation treatments produced promising effects on functional and motor outcomes in sub-acute stroke patients but in RG there was more significant improvement in the walking strategies. Comparing the two groups a greater clinical improvement with a more symmetric gait was observed in RG than CG after therapy. These results are obtained probably because the end-effector device offers a more intensive and controlled gait training, so a more physiological gait can be obtained.

REFERENCES.
Long-lasting actigraphic monitoring of the upper and lower limbs movements in acute stroke patients: a COMMAS spin-off study

C. Iacovelli 1, M. Rabuffetti 1, G. Reale 2, M. Ferrarin 1, C. Simbolotti 3, L. Padua 1,2, P.M. Rossini 2, P. Caliandro 3

1 IRCCS Don Carlo Gnocchi Onlus Foundation, Milan – Italy
2 Institute of Neurology, Catholic University, IRCCS Policlinic A. Gemelli Foundation, Rome – Italy
3 Complex Operative Unit of Neurology, IRCCS Policlinic A. Gemelli Foundation, Rome – Italy

INTRODUCTION

In acute stroke patients detecting modifications of motor deficits could be crucial both for a prompt medical assistance and for a better definition of patient’s prognosis. The stroke unit represents the gold standard in the management of the acute stroke with a multiparametric monitoring of vital functions, while no instruments are actually implemented in stroke unit for a continuous monitoring of patients motor performance. In a pilot study [1] we found that a 24 hours actigraphic recording is informative of the overall neurological clinical picture as measured by NIH Stroke Scale (NIHSS). Given these results, we propose a long-lasting recording during the stroke unit stay to provide a continuous evaluation of motor symptoms during the unstable period of the acute stroke.

METHODS

We enrolled 29 stroke patients (16M, 13F; mean age, 72.7 ± 11.1 years) during their Stroke Unit stay for an averaged period of 6 days. Motor activity of both arms and both legs were recorded using a programmable actigraphic system (GENEActiv Original, Kimbolton, UK) integrated inside a watch-like case. For each patient the actigraphs were bilaterally positioned on wrists and ankles. During the acquisition (about 6 days) the single device recorded the three acceleration components, sampled at a frequency of 100Hz. We calculated the Motor Activity index 2 [1] for the upper (MA2_wrist) and lower (MA2_ankle) limbs. Then we obtained the Asymmetry Indices [2] between the paretic limb and the contralateral limb: AR_wrist and AR_ankle. The patients were also clinically evaluated by NIHSS at the beginning (NIHSST0) and at the end (NIHSST1) of the recruitment. We used the Wilcoxon test to compare the values of MA2_wrist and MA2_ankle indices between the paretic and unaffected limbs. In order to evaluate the agreement between the deficit laterality measured by AR_wrist and AR_ankle and the clinically defined laterality, we used the Phi Coefficient. The Pearson’s test was used to correlate AR_wrist and AR_ankle with NIHSS total scores and subscores.

RESULTS

Comparing the NIHSS scores we found statistically significant differences between T0 and T1 being the clinical picture at T1 less severe (respectively for NIHSSupper limb subscores p=0.001, NIHSSlower limb subscores p=0.002 and NIHSStotal p<0.001). MA2_wrist and MA2_ankle indices were smaller in the paretic than in unaffected limbs (respectively p = 0.002 and p =0.030). Table 1 shows the correlation between AR and NIHSS scores, briefly we have found a good correlation between the NIHSS scores and the AR of upper limbs while the correlation was less significant for the lower limbs. AR_wrist and AR_ankle showed a good capability (Phi Coefficient respectively: 0.673 and 0.654) to discriminate the laterality of the clinical deficit.

Table 1. Correlation between Asimmetry Indices (AR_wrist and AR_ankle) with NIHSS total scores and subscores. Pearson correlation coefficient are reported. * indicates statistical significance, with p ≤ 0.05; ** with p < 0.01; *** with p ≤ 0.001.

<table>
<thead>
<tr>
<th>NIHSS score</th>
<th>AR_wrist</th>
<th>NIHSS score</th>
<th>AR_ankle</th>
</tr>
</thead>
<tbody>
<tr>
<td>NIHSST0 total score</td>
<td>0.415*</td>
<td>NIHSST0 total score</td>
<td>0.382*</td>
</tr>
<tr>
<td>NIHSST0 upper limb subscore</td>
<td>0.505**</td>
<td>NIHSST0 lower limb subscore</td>
<td>0.364</td>
</tr>
<tr>
<td>NIHSST1 total score</td>
<td>0.445*</td>
<td>NIHSST1 total score</td>
<td>0.373*</td>
</tr>
<tr>
<td>NIHSST1 upper limb subscore</td>
<td>0.600***</td>
<td>NIHSST1 lower limb subscore</td>
<td>0.395*</td>
</tr>
</tbody>
</table>

DISCUSSION

The presented data represent an ad interim evaluation of a more extensive data set collected in the frame of the COMMAS multicenter project, aimed to evaluate the motor performance in acute stroke patients in relation to changes in cortical connectivity. The findings demonstrate that actigraphic monitoring of spontaneous movements of upper and lower limbs is informative of the clinical severity, with the arms movement showing a stronger correlation to the clinical picture. Given these results, we will proceed in evaluating the asymmetry index in epochs of 1h in the entire sample of the COMMAS study to describe the trend of motor performance changes during the acute phase of stroke.

REFERENCES

Title. Non-immersive virtual reality for gait and balance, after stroke

P. Kiper1, C. Luque-Moreno 1,2, M. Agostini1, M. Ugazzi1, S. Pernice1, A. Turolla1
1 Laboratory of Neurorehabilitation Technologies, Fondazione Ospedale San Camillo IRCCS, Venezia, Italy, 2 Departamento de Enfermería y Fisioterapia. Universidad de Cádiz, Spain.

INTRODUCTION

The loss of balance and ability to walk is one of the most devastating consequences within common symptoms of stroke. Therefore, gait recovery is considered one of the primary aim of stroke rehabilitation. In the last decade, the therapeutic modalities based on virtual reality (VR) technologies for rehabilitation have shown positive results for recovery of gait and balance after stroke [1,2]. Innovative technologies have provided the opportunity to enrich training environments for motor rehabilitation. The aims of this study were to examine the effect of VR lower limb therapy on balance, gait and motor impairment after stroke and to analyse whether subacute (< 6 months) or chronic (> 6 months) phases might influence motor recovery of the lower limb.

METHODS

A longitudinal pilot study was conducted among inpatients accepted at the IRCCS San Camillo Hospital Foundation (Venice). Patients were affected by a first stroke (i.e. ischemic, hemorrhagic) and stratified into two groups according to the time since stroke (i.e. subacute, chronic). Clinical scales (i.e. Berg Balance Scale, BBS; 10-meters walking test, 10MWT; Functional Ambulation Category, FAC; Functional Independence Measure, FIM; Fugl-Meyer lower extremity scale, FM LE; modified Ashworth scale, mA) and kinematic parameters of standardized movements (speed, mm/s; time, s; peak –mean number of submovements, No; spatial error, mm²; length, mm) were assessed before and after treatment. Treatment consisted of a real-time simulation of three-dimensional exercises, in sitting and standing positions, with each task enhanced by feedbacks (i.e. visual, auditory, sensory) in Ashworth scale, mA) and kinematic parameters of standardized movements.

RESULTS

A group of 59 consecutive patents were enrolled in this study (mean age was 60.29±14.76 years with 13.96±25.68 months since stroke). Results observed at clinical outcomes are reported in table 1.

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>Overall (59 patients)</th>
<th>Subacute phase (32 patients)</th>
<th>Chronic phase (27 patients)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td>Before</td>
</tr>
<tr>
<td>FM LE</td>
<td>21.83 (15.48)</td>
<td>23.73 (1.16)*</td>
<td>24.65 (5.72)</td>
</tr>
<tr>
<td>FIM</td>
<td>103.70 (19.07)</td>
<td>106.40 (17.64)*</td>
<td>101.8 (18.67)</td>
</tr>
<tr>
<td>BBS</td>
<td>44.27 (9.64)</td>
<td>47.85 (7.76)*</td>
<td>45.39 (8.62)</td>
</tr>
<tr>
<td>FAC</td>
<td>3.36 (1.35)</td>
<td>3.64 (1.24)*</td>
<td>3.07 (1.30)</td>
</tr>
<tr>
<td>mA</td>
<td>1.47 (1.86)</td>
<td>2.72 (1.55)*</td>
<td>2.84 (1.13)</td>
</tr>
<tr>
<td>10MWT</td>
<td>33.70 (52.79)</td>
<td>24.49 (24.18)*</td>
<td>24.38 (28.84)</td>
</tr>
</tbody>
</table>

Kinematics

| Speed | 140.7 (90.75) | 175.0 (84.7)* | 155.2 (90.07) | 193.9 (86.35)* | 104.9 (86.97) | 128.5 (62.54) |
| Time   | 7.52 (5.24) | 4.79 (3.69)* | 6.68 (5.18) | 3.99 (2.61)* | 9.59 (5.08) | 6.75 (5.22) |
| Peak   | 30.97 (21.53) | 19.54 (15.27)* | 27.34 (21.13) | 16.22 (10.87)* | 39.83 (21.02) | 27.65 (21.45) |
| Spatial error | 33541 (15593) | 28460 (11802)* | 31650 (14536) | 26041 (11938)* | 37985 (18259) | 27484 (12105) |
| Length | 517 (147) | 466 (117)* | 505 (198) | 468 (122) | 547 (172) | 461 (110) |

DISCUSSION

Results showed that using virtual environments similar to the real one to provide task-oriented exercises with augmented feedback fosters recovery of the lower limb. Moreover, was observed that the VR training provided to the patients in this trial was beneficial in both chronic and subacute phase, however this improvement did not differ significantly between the two groups.

REFERENCES

On the estimation of knee angle joint with a biomechanical model during indoor rowing: implications for FES applications

M. Lalli1, C. Stocchi1, GL. Cerone1, M. Gazzoni1, T. Vieira1
1 Laboratorio di Ingegneria del Sistema Neuromuscolare, Politecnico di Torino, Torino, Italia

INTRODUCTION

Functional electrical stimulation (FES) rowing has been shown to lead to several health benefits in paraplegic subjects. Although the quantification of knee joint angle is crucial for the determination of stimulation in FES Rowing, previous studies computed knee angle (KA) from either inertial sensors or motion capture systems [1, 2] limiting the application of FES Rowing because those systems are bulky and expensive. Here we develop and test a biomechanical, subject-specific model to estimate KA during indoor rowing, from anthropometric data and the rowing machine seat position.

METHODS

Eighteen elite rowers (range: 14-30 years, 163-195 cm) have been instructed to row for 3 sessions, 2 minutes long each. We instrumented a commercially available rowing machine (Model E, Concept II, Morrisville, USA) to measure seat position with a custom-made incremental linear encoder. The linear encoder consists of: i) an adhesive strip, placed along the surface of the rowing machine rail, with a pattern of black and white marks allowing to obtain position and movement direction; ii) two couples of infrared emitter and receiver mounted at the bottom rear of the seat, 2mm distant from the rail (resolution: 10mm; Figure A). Encoder data were acquired wirelessly (DueBio; OT Bioelettronica and LISIN, Torino, Italy) and offline synchronized, to validate model, with angle data measured with an electrogoniometer (D.E.M. Italia, Torino, Italy). Anthropometric data were acquired according to [3]. The biomechanical model to calculate KA was implemented through the law of cosines, considering the rowing machine seat position and length measurements of the leg and thigh [3].

RESULTS

Results from a representative participant are shown in Figure B. While KA estimates were accurate during the rowing drive phase, differences between estimated and measured KA reached 12 deg during recovery phase. Statistical analysis revealed the average error in the cycle is 4.7±5.1 deg.

DISCUSSION

Our results suggest KA may be estimated from the rowing machine seat position with 5 deg accuracy on average. This value roughly corresponds to 4% of the knee range of motion during rowing and results smaller than the between-subjects’ variability in the onset of leg muscles’ activation previously reported during rowing [4]. It seems therefore the model presented here estimates sufficiently well KA during rowing, finding potentially relevant application in FES rowing [1,2].

REFERENCES

The use of kinematic robotic indices to predict motor outcome in upper limb treatment of stroke patients

G. Lamola 1, M. Barsotti 2, E. Sotgiu 2, C. Procopio 1, A. Frisoli 2, C. Chisari 1
1. U.O. Neuroriabilitazione - Azienda Ospedaliero-Universitaria Pisana, Pisa, Italy.
2. PERCRO Lab - TeCIP Scuola Superiore Sant'Anna, Pisa, Italy.

INTRODUCTION

Upper limb rehabilitation in stroke patients is currently open to debate. Robotic therapy proved to be effective in ensuring intensive and highly repetitive treatment, but also in providing quantitative assessments that are useful from a clinical point of view. The advantage of robotic measurements consists in recording objectively the characteristics of the movement and using them as indices of progress in motor recovery [1]. Our study aims to verify the predictability of motor outcome using robotic kinesiological indices of upper limb in patients with chronic phase stroke, in order to customize rehabilitation treatment based on the expected functional improvement.

METHODS

Twelve patients with mild to moderate right hemiparesis after chronic ischemic stroke were selected. All subjects underwent robotic treatment of 18 sessions (3 sessions/week), performed using a robotic exoskeleton for the proximal portion of the upper limb (shoulder and elbow), consisting of a series of rehabilitative tasks and an evaluation exercise in virtual reality. Clinical and robotic evaluations were performed at the beginning (T0) and at the end of treatment (T1). The following clinical evaluations were used: the Fugl-Meyer scale (FM) for the upper limb and the Bimanual Activity Test (BAT) for bimanual integration activities. At each rehabilitation session, two instrumental performance evaluation indices were extracted from the robotic device during the execution of a specific evaluation exercise: the execution time (T) and the smoothness of the movement (S). A correlation analysis was then conducted between these performance indices. A regression analysis was used to study the correlation between the robotic indices at T0 and the change in the FM score (ΔT1-T0). Multilinear regression analysis was performed using

\[ \Delta FM = c + \sum_{i=ipsi,contra} a \sigma_i + b \tau_i. \]

The regression model F-test was used to evaluate the significance of the linear regression relationship between the response variable and the predictive variables.

RESULTS

At the end of the treatment there was a significant improvement in FM (p <0.05) and BAT execution time (p<0.01). From a separate analysis of proximal and distal motor functions, an improvement was observed in the shoulder/elbow (FM, p <0.01) and in the distal joints (p <0.01) and in the execution time of the grasping tasks (p <0.05) and in fine motility (p <0.01). The results obtained from the instrumental indices showed a marked decrease in the task execution time (p <0.05) and a significant improvement in smoothness (p <0.05). The results of the multilinear regression analysis showed a significant correlation between the robotic performances obtained at the baseline and the change in FM score (R² = 0.91). Further analysis have been conducted focusing separately on the proximal and distal portion of the FM. We found out that robot outcomes at baseline can significantly predict the change in the proximal portion of the FM (R² = 0.92) but not the improvement in the distal portion of the FM (R² = 0.45).

DISCUSSION

In our study, changes in the clinical data obtained at the end of a specific rehabilitative treatment were related to kinesiological indices extracted from the robotic device before treatment. Regression analysis suggests that instrumental indices can be significantly predictive of clinical change at the proximal segment of the upper limb; this issue can be justified because the robotic exoskeleton used in the present study is mainly aimed at treating the proximal district of the upper limb. Improvements of performance time and smoothness of movement can therefore represent predictive indices of functional recovery of the upper limb in subjects with hemiparesis after stroke. The predictability of the motor outcome thus calculated can also provide the basis for the rehabilitation treatment customization.

REFERENCES

Gait in stroke patients is influenced by upper limb functioning: a quantitative analysis correlating QuickDASH with Instrumented TUG and 10MWT

R. Buraschi¹, J Pollet ², B. Alghisi⁰, S. Beltrami⁰, P.Pedersini⁰, B Piovanelli⁰, S. Lazzarini, S. Negrini ¹,²
¹IRCCS Don Carlo Gnocchi Foundation, Milan, Italy; ²University of Brescia, Brescia, Italy

INTRODUCTION
Loss of mobility after stroke is one of the main target of intervention in PRM and physiotherapy as motor impairment affects gait efficacy and upper limb function[1,2]: it is possible to observe a consensual improvement of these latter aspect throughout rehabilitation. Neural connections between upper and lower limb in gait are known[3,4] as well as the fact that modifications of upper limb movement during gait can affect gait parameters[5]. A recent review supports the inclusion of arm activity in addition to leg activity as a component of gait retraining after neurotrauma[6]. To the best of our knowledge, the association has not been quantitatively studied: analysis of correlation between Instrumented TUG/10MWT tests and QuickDASH questionnaire can be a preliminary, easy to perform, and clinically suitable way to assess it.

METHODS
A cross sectional study was performed in a tertiary referral sub-acute rehabilitation centre in Northern Italy. 20 stroke inpatients aged 66.53 (±7.60) were enrolled. Inclusion criteria were stable clinical conditions and no other neurological or musculoskeletal pathologies. Subjects evaluation consisted of motor and gait skills assessment by performing TUG and 10 MWT, and upper limb disability evaluation by QuickDASH. A wearable BTS G-Sensor IMU (Inertial Measurement Unit) was utilized to obtain a kinematic and temporal analysis of tests[7]. Spearman Correlation was carried out to assess the association between tests parameters and QuickDASH score (p<0.05).

RESULTS
Correlation between QuickDASH score and TUG sub-phases was found as well as for 10MWT parameters (see Tab.1).

<table>
<thead>
<tr>
<th>TUG</th>
<th>r&lt;sub&gt;s&lt;/sub&gt;</th>
<th>p-value</th>
<th>10MWT</th>
<th>r&lt;sub&gt;s&lt;/sub&gt;</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time to completion</td>
<td>r = 0.64</td>
<td>p=0.003</td>
<td>Time to completion</td>
<td>r = 0.71</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Forward gait</td>
<td>r = 0.60</td>
<td>p=0.007</td>
<td>Cadence</td>
<td>r = -0.55</td>
<td>p=0.015</td>
</tr>
<tr>
<td>Mid turning</td>
<td>r = 0.65</td>
<td>p=0.003</td>
<td>Speed</td>
<td>r = -0.78</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Return gait</td>
<td>r = 0.66</td>
<td>p=0.002</td>
<td>Gait cycle (both sides)</td>
<td>r = 0.60</td>
<td>p=0.007</td>
</tr>
<tr>
<td>Max rotation speed in end turning</td>
<td>r=-0.58</td>
<td>p=0.009</td>
<td>Stride length</td>
<td>r=-0.64</td>
<td>p=0.003</td>
</tr>
</tbody>
</table>

DISCUSSION
The application of IMU wearable sensors to field tests has proven to be a useful, valid and user-friendly mode for assessing motor skills in stroke patients within clinical practice. Valuable correlations were demonstrated between the disability of upper limb and residual motor skills in stroke subjects: the higher the motor disability of the upper limb, the lower the performance in movement tests, and vice versa. These findings may open an alternative way to assess and thinking of the rehabilitation intervention in stroke patients, suggesting the possibility to enforce upper limb rehabilitation not just per-se, but in a wider and comprehensive program of motor skills recovery.

REFERENCES
Dynamic Balance during level walking in patients affected by Multiple Sclerosis, Stroke and Parkinson’s disease
T. Lencioni 1, D. Anastasi 1, I. Carpinella 1, A. Castagna 1, A. Crippa 1, E. Gervasoni 1, A. Marzegan 1, M. Rabuffetti 1, D. Cattaneo 1, M. Ferrarin 1
1 IRCCS Fondazione Don Carlo Gnocchi, Milan, Italy

INTRODUCTION
Balance disorders are a common feature in patients affected by Multiple Sclerosis (MS), Stroke (ST) and Parkinson’s disease (PD) generally conditioning their walking ability. These persons adopt a gait strategy that help them preventing falls. Maintaining of this stable gait require balance control, where sensory feedback is integrated to sense the position and the velocity of Center of Mass (CoM) [1]. On the basis of this information a dynamic balance is reached and maintained with appropriated foot placement to stabilize and redirect the CoM. Understanding the strategy of CoM positioning adopted by MS, ST and PD patients during walking is an important step to program an effective rehabilitation treatment to improve gait control and prevent falls. The aim of this work was to evaluate the dynamic balance during level walking in MS, ST and PD patients with respect to healthy subjects (HS).

METHODS
Twenty MS, 14 ST and 10 PD (age, mean±SD: 54.9±11.4, 53.5±16.2, 67.6±6.6 yrs) underwent a clinical examination and a complete gait analysis. The LAMB total body marker set was used to capture kinematic data. The margin of stability MoSTerry [1], at mid stance was calculated as the distance between the extrapolated Center of Pressure and the extrapolated CoM. Given the dependency of MoS by the spatio-temporal gait parameters [2], 10 HS (51.4±11.5 yrs) walking at matched speed and step width were considered as control group. Statistical analysis of the dynamic balance measure was done through an ANOVA for repeated measures using Group as the between factor (MS, ST, PD and HS) and Legs as the repeated measure factor (Most Affected/Non-Dominant and Less Affected/Dominant Side). Bonferroni-Holm difference test was used for post hoc analysis.

RESULTS
In the medio-lateral (ML) direction, ANOVA disclosed significant effect of the main factors Group (p=0.002, mean(95%CI) [mm]: PD 72.5(60.7-84.3), MS 67.7(59.9-75.7), ST 63.4(54.0-72.9), HS 43.1(31.9-54.3)) and Legs (p<0.001) on MoSTerry. In addition, a significant interaction effect (p<0.001) between Group and Legs emerged on MoSTerry in the medio-lateral direction (Figure 1).

DISCUSSION
Increased MoS values suggest that patients adopted a cautious strategy, keeping CoM far from stability limit. In addition, MoS was able to reveal the strong asymmetry in ST and also in MS. Objective assessment revealed pathology-specific strategy showing differential impact of MS, ST and PD on the ability to control CoM information for balance control during gait. It is expected that the analysis of dynamic balance here presented might provide useful information to address a tailored rehabilitation for patients affected by different neurological disorders.

REFERENCES
A full-body 3D reconstruction of yoga poses through inertial sensing
G. Ligorio1, E. Bergamini2, M. Guaitolini3, A. Mannini3, P. Garofalo1, A.M. Sabatini3, G. Vannozzi2
1 Turingsense EU LAB, Forlì, Italy, 2 BOHNES, Università degli Studi di Roma “Foro Italico”, Roma, Italy, 3 Scuola Superiore Sant’Anna, Pisa, Italy

INTRODUCTION
Yoga has recently gained popularity as a way of promoting physical and mental well-being, mainly associated with physical poses, breathing techniques, and meditation [1]. The correct execution of yoga exercises is crucial for both their effectiveness and safety [1]. In this respect, the development of tools, such as exergames, that can guide practitioners in learning correct yoga postures, and possibly provide real-time feedback about performance in daily life environments, would be of great benefit for all practitioners and, particularly, for beginners [2]. To develop this kind of tools, the accurate estimation of each body segment 3D orientation is needed. Low-cost and wearable technology, such as Magneto-Inertial Measurement Units, represents the ideal candidate for this kind of applications. However, when indoor scenarios are considered, ferromagnetic disturbances still represent a significant hindrance [3]. In this work, the feasibility of using a pure inertial system (IMUs) for estimating the 3D orientation of fourteen body segments was evaluated during sun salutation yoga poses.

METHODS
Eight yoga practitioners (age: 42±22 years, mass: 66±9 kg, stature: 1.71±0.09 m, years of practice > 3) participated in the study after signing written informed consent. Each participant was equipped with 14 IMUs (Turingsense, US) on the following body segments: right and left feet, shanks, thighs, arms, forearms, and hands, as well as pelvis and trunk. To validate IMU-based estimates, three retroreflective markers were placed on a 3D-printed plate rigidly attached to each IMU, and their trajectories measured with a stereophotogrammetric system (Vicon MX, UK). A sun salutation exercise, a paradigmatic pose sequence commonly practiced in yoga and lasting about 90 s, was performed by each participant while linear accelerations, angular velocities, and the 42 marker trajectories were simultaneously collected at 100 samples/s. The 3D orientation of each IMU was obtained extending the tilt estimation algorithm presented in [4] with gyroscope integration for heading computation. Heading and tilt Root Mean Square Errors (RMSE) between IMU- and marker-based 3D orientation were computed for each body segment. A two-way ANOVA was conducted that examined the effect of “error component” and “body segment” on orientation accuracy, i.e. RMSE values (α=0.05).

RESULTS
Heading and tilt average RMSE values were 4.7±3.1° and 3.2±2.3°, respectively (Fig.1). Only the “error component” main effect resulted statistically significant (F(1,196) = 16.41; p < 0.001), with heading errors greater than tilt ones. Both the “body segment” main effect and the interaction effect were not statistically significant (p > 0.05).

DISCUSSION
In the time window considered, pure inertial systems proved to be accurate enough for obtaining the 3D orientation of body segments during yoga practice in indoor environments. Although the accuracy evaluation presented in this study does not include full-body joint angle estimation, the work is a necessary preliminary analysis toward the development of exergames that could help yoga practitioners for a safe and effective learning. Future studies will include the assessment of joint angles estimation accuracy, thus considering anatomical calibration procedures.

REFERENCES
Correlation study among 3D-Gait Analysis, Magnetic Resonance Imaging and cognitive parameters in unrestricted people with relapsing-remitting Multiple Sclerosis

M. Liparoti1, M. Della Corte2,3, R. Rucco1, M. Sparaco2,3, R. Minino1, R. Capuano2, P. Sorrentino4, G. Sorrentino1,3 and S. Bonavita2
1 Department of Motor Sciences and Wellness - University of Naples “Parthenope”, via Medina 40, 80133, Naples;
2 Department of Medical, Surgical, Neurological, Metabolic and Aging Sciences - MRI Research Center SUN-FISM, University of Campania "Luigi Vanvitelli", Piazza Miraiglia 2, 80138, Naples;
3 Hermitage Capodimonte Hospital, via Cupa delle Tozzole 2, 80131, Naples;
4 Department of Engineering - University of Naples “Parthenope”, Centro Direzionale Isola C4, 80133, Naples;

INTRODUCTION
The subclinical gait disorders may affect people with Relapsing-Remitting Multiple Sclerosis (pwRR-MS). The Expanded Disability Status Scale (EDSS) is the most used scale to evaluate gait impairment in pwRR-MS, however it may be insensitive to subclinical disability at the lower end of the scale [1]. The three Dimensional-Gait Analysis (3D-GA), might detect the slight gait abnormalities in pwRR-MS. The aims of study were: 1) To detect, by 3D-GA, changes of gait pattern during usual walking (single task, SinT), motor and cognitive dual tasks (MotDT, CogDT) in pwRR-MS as compared to healthy controls (HCs); 2) To analyze the correlations among cognitive status scores, brain atrophy measures and gait parameters.

METHODS
Twenty-eight pwRR-MS and twenty-one HCs underwent: 1) Neuropsychological assessment, through Rao brief repeatable battery (Rao-BRB) [2]; 2) Magnetic Resonance Imagine scanning; 3) 3D-GA evaluations by a Stereophotogrammetric System (Qualysis® 120 Hz), after placing forty-one passive markers. Gait parameters were analyzed in three categories: range of motion, velocity and stability, for the latter the coefficient of variability (CV) was calculated. The range of motion of Thigh, Knee and Ankle, was normalized for the 100% of gait cycle [3]. The means and standard deviations of outcome measures were calculated, after correcting the value of each parameter for the body mass index (BMI).

RESULTS
During SinT, pwRR-MS as compared to HCs, showed an impairment of velocity (cycle time (p<0.05)), stability (stance time (p<0.05), stance time-CV (p<0.05), stride length-CV and swing time-CV (p<0.01) and kinematic (increase of ankle dorsiflexion (p<0.05) during mid and terminal stance phases) parameters. The CogDT and MotDT failed to produce a further impairment of gait parameters as compared to SinT, indeed only a slight increase of swing time (p<0.05) for both DT and double limb support-CV (p<0.05) for MotDT were recorded. In both DT, it was observed an increase of thigh flexion (p<0.05) during initial contact and loading response phases and an increase of ankle dorsiflexion (p<0.05) during mid and terminal stance phases. Finally, MotDT caused a reduction of knee flexion (p<0.05) in initial contact and loading response. We also found an inverse correlation between the verbal fluency and both stride length-CV (p<0.01) and stance time-CV (p<0.05), and a direct correlation between the normalized deep gray matter volume (ndGMV) and stance time-CV (p<0.05) during SinT.

DISCUSSION
In unrestricted pwRR-MS as compared to HCs, 3D-GA shows impairment of velocity, stability and kinematic gait parameters. The correlation between cognitive status and gait outcomes suggests a role of cognition in the slight motor impairment observed in pwRR-MS. The association between impaired motor function and ndGMV is consistent with the physiological role of these structures. The study shows that 3D-Gait Analysis is a useful tool to verify slight motor impairment in pwRR-MS.

REFERENCES
Wearable-enabled digital application for the self-management of shoulder muscular skeletal disorders.  
I. Lucchesi 1, F. Lorussi 1, N. Carbonaro 1,2, A. Tognetti 1,2  
1Center “E.Piaggio” University of Pisa, Pisa, Italy, 2Information Engineering Department, University of Pisa, Pisa, Italy.

INTRODUCTION  
We present SHOULPHY, a digital application which includes a rehabilitation protocol for the treatment of Shoulder Impingement Syndrome (SIS). SHOULPHY is conceived to lead and assess the patient, wearing a minimal set of wearable sensors, through personalized physical rehabilitation programs, under the remote supervision of the physician/therapist.

METHODS  
The SHOULPHY platform employs wearable sensors and our bi-articular shoulder model [1] to reconstruct the upper limb movement. The sensing system, similar to the configuration reported in [1], consists into two IMUs (MTw by Xsens [2]) placed on the sternum and the wrist and a textile deformation sensor (made of knitted piezo-resistive fabrics [3]) placed from the spine to the scapula, to detect the scapular sliding. The patient can choose an exercise from a library created ad hoc by physicians. The real-time visualization of the exercise performance is available for the user, through a virtual environment in which a 3D humanoid – driven by the wearable sensors – reproduces the actual shoulder motion. A local unit transfers data to the cloud to make them available for clinicians in order to remotely improve or correct the treatment (Fig.1a). Completed the exercise, the application provides a simple and intuitive score display both on the patient and physician interfaces. The physicians are provided with an additional interface, as shown in Fig.1b, where the yellow band represents the zone correct execution, and the black graph the behaviour of the users.

RESULTS  
We tested SHOULPHY both on healthy subjects and clinicians, to provide a technical and preliminary clinical evaluations on its efficacy. In particular, we performed a blind test in which a clinician team was asked to give an evaluation of the exercises. The evaluation of the trials given by physicians and by the system agrees in the 95% of the experiments.

DISCUSSION  
We have shown that SHOULPHY can provide reliable results in terms of reconstruction of the arm position. Moreover we were able to remotely evaluate the quality of the exercise performed, thanks to a smart and user-friendly assessment tool, capable of aid both patients and physicians in the treatment of SIS.

REFERENCES  
A system for motor and cognitive activities for people with mild or moderate cognitive impairment

M. Magrini 1, S. Coscetti 1, U. Barcaro 1, C. Dolciotti 2

1 Istituto di Scienza e Tecnologie dell’Informazione, C.N.R., Pisa, Italy
2 Istituto di Fisiologia Clinica, C.N.R., Pisa, Italy

INTRODUCTION

A hardware-software system is described for the administration of motor and cognitive exercises to people affected by mild or moderate cognitive impairment. This system was built in the framework of the “Intesa” project, funded by the region of Tuscany. The objective of this project has been the implementation of services based on non-invasive ICT technologies aimed at the improvement of the life quality of elderly non-disabled people in a condition of “fragility”.

METHODS

The hardware part of the system included: 1) The portable Interaxon “Muse” EEG headset for the acquisition of four EEG traces; 2) the Microsoft “Kinect” V2 infrared-based sensor for the characterization of gestures and movements; 3) a PC connected to the integrated database of the “Intesa” project. Three categories of software applications were implemented: 1) applications providing cognitive and motor exercises, aiming to improve the conditions of the subjects; 2) applications providing tests, aiming to measure this conditions; 3) application allowing quantitative measures to be performed. Motor exercises generally consisted in asking the subject to mimic the movements proposed by means of an avatar projected on a large screen. A number of simple tasks, such as connect-the-dots and select-the-tile, were simultaneously motor and cognitive. A simplified version of the classic “ANT” (Attention Network Task) [1] was implemented: the subject was asked to lift the right or left arm according to the direction of the central arrow of a pattern projected on a computer screen: in the pattern the central arrow was surrounded by flanking either neutral or congruent or opposite directions. The procedures for quantitative measures concerned the reaction times, the number of errors, and the basic features of the recorded EEG traces. As regards the EEG traces, signal powers were calculated for five band activities (delta, theta, alpha, beta, and gamma); the power values were compared between the test epochs (or the exercise epochs) and the resting-state epochs, thus measuring the subject’s capability to pay attention during the tests or exercises (among the vast relevant literature in the last two decades, see, e.g., [2] and [3]).

RESULTS

Initial application of the system to eight elderly people (ages in the range 65 – 75 years) affected by mild or moderate cognitive impairment did not require particular efforts on the part of the subjects. Reaction times and number of errors during the ANT test and the other tests and exercises were measured: these measures provided an easy and effective way of assessing the impairment degree of the subjects. All of the subjects presented a decrease in theta and alpha power during the tests and exercises with respect to the resting-state epochs. Specifically for the ANT test, comparisons were also made between the band powers before, during, and after the visualization of the pattern: so far, perhaps because of the small number of subjects, we have not observed statistically significant general trends or variations connected to the impairment degree. From the point of view of the general purposes of the “Intesa” project, aiming at improving the subjects’ conditions, it has been interesting to observe that the administration of the Attentive matrices Test [4] both before and after the ANT test generally implied better results for the Attentive matrices Test administered after the ANT test.

DISCUSSION

The system is characterized by simplicity: it consists of portable, light (and low-cost) devices; the exercises and tests are easy and friendly and appropriate for people affected by mild or moderate cognitive impairment. A property of most of the tests and exercises is that they combine cognitive and motor aspects: we feel that this combination can be fruitful for an actual improvement of the subjects’ condition. The implemented measures allow to subjects’ condition to be quickly assessed and comparisons to be made among different sessions of a subject and among the various subjects.

REFERENCES

Age-Related Changes In Mobility Evaluated By The Instrumented Timed Up And Go Test

G.R.A.Mangano, M.S. Valle, A. Casabona, A. Vagnini, M. Cioni

Neuro-Biomechanics Lab., Dpt. of Biomedical and Biotechnological Sciences, University of Catania, Catania, Italy; Physical Medicine and Rehabilitation Residency Program, University of Catania, Catania, Italy; BTS Bioengineering, Garbagnate Milanese (Milano), Italy

INTRODUCTION

Originally, the Timed Up and Go test (TUG) was settled as a simple and quick clinical tool to assess mobility in elderly people. It was used to evaluate the risk of falls and the effects of different neurological pathologies, such as the influences of sensory cues on mobility of persons with Parkinson’s disease. Recently, normative data for children and adolescents typically developed were reported. The common outcome of the TUG test was the total time (TT) to cover a distance of 3mt. The introduction of instrumented TUG (iTUG) based on inertial measurements units improved the accuracy and reliability of the test, allowing an objective evaluation of the TT and the subcomponents of the test. The aim of this study was to evaluate the age-related mobility comparing the results of the TUG test performed on children, adults and older adults. We tried to take advantage from iTUG to identify specific changes in mobility associated with the process of development and ageing.

METHODS

We enrolled 16 children (C, 7-12 y), 16 adults (A, 31-42 y) and 14 older adults (OA, 61-75) with no neurological, orthopedics and cognitive disorders. A wearable inertial sensor (G-sensor, BTS, Italy) was applied over the back at the L2 level and the data were elaborated by the G-Studio software (BTS, Italy). Subjects performed the TUG test over 3 and 7 mt, following the standard steps: stand up from a chair, walk along a straight path, turn, walk back to the chair, and sit down again. The test was repeated 3 times for each distance and the median value was used for the analysis. We collected the TUG TT and the duration of the following subcomponents: Stand to Up (SU), Forward Gait (FG), Mid Turning (MT), Return Gait (RG), Final Rotation (FR), Stand to Seat (SS). Moreover, the following velocity parameters were measured: Average Mid Turning Velocity (AMTV), Peak Mid Turning Velocity (PMTV), Average Final Turning Velocity (AFTV) and Peak Final Turning Velocity (PFTV).

RESULTS

Performing 1-way ANOVA with each distance as factor, significant differences were exhibited between children and each of the two adults groups for all the subcomponents requiring turning or body rotations (SU, MT, FR, SS, AMTV, PMTV, AFTV and PFTV, Table 1), while no differences were detected for linear walking components (FG and RG). Adults and older adults showed no significant differences for all the parameters. Using a 2-way ANOVA with group and distance as factors, no significant effects there was for distance (except for the TT, FG and RG) and for the interaction between group and distance.

Table 1. Groups comparison using 1-way ANOVA with Bonferroni correction.

<table>
<thead>
<tr>
<th></th>
<th>SUD</th>
<th>MTD</th>
<th>FRD</th>
<th>SSD</th>
<th>AMTV</th>
<th>PMTV</th>
<th>AFTV</th>
<th>PFTV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3mt</td>
<td>7mt</td>
<td>3mt</td>
<td>7mt</td>
<td>3mt</td>
<td>7mt</td>
<td>3mt</td>
<td>3mt</td>
</tr>
<tr>
<td>F(2,43)</td>
<td>5.45</td>
<td>3.41</td>
<td>7.20</td>
<td>10.09</td>
<td>4.02</td>
<td>7.82</td>
<td>6.48</td>
<td>10.98</td>
</tr>
<tr>
<td>P</td>
<td>&lt;0.01</td>
<td>0.04</td>
<td>&lt;0.01</td>
<td>0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>CvsA</td>
<td>0.06</td>
<td>0.15</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>0.08</td>
<td>0.05</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>CvsOA</td>
<td>0.01</td>
<td>0.04</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>0.04</td>
<td>0.01</td>
<td>0.18</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>AvsOA</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.42</td>
<td>0.4</td>
<td>1</td>
<td>0.59</td>
</tr>
</tbody>
</table>

DISCUSSION

The instrumented TUG test adopted in this study revealed that children stand up, sit down and rotate more rapidly than adults and older adults. This behavior may be associated with the process of motor control optimization during the more challenging components of the TUG test.

REFERENCES

Thermography as a tool for evaluation and prevention of injuries in athletes
S. Matteoli 1, S. Fulceri 1, G. Pasquini 2, A. Corvi 1
1 Department of Industrial Engineering, University of Florence, Florence, Italy  2 IRCCS Rehabilitation Centre “Don C. Gnocchi”, Florence, Italy

INTRODUCTION
Skeletal muscles constitute approximately 40% of the human body weight. About 75% of the metabolic energy is not employed as mechanical work but it is lost in heat, released as infrared radiation. In the biomedical field, the idea of using infrared thermography (IT) for evaluating muscles health condition and preventing potential injuries has developed more and more [1-2]. The aim of this work is to evaluate muscle conditions (pre and post training) of volleyball players’ legs by means of IT for identifying subjects who could be at risk of injury.

METHODS
A team of male volleyball players (27±6 years) were subjected to thermographic acquisitions (FLIR 320A, FLIR Systems, Oregon, USA) once a month, for 4 months. None of the athletes had any injuries within the last two months before the test. Athletes were required not to: use body lotions, smoke, drink coffee, have massages and train in the 24 hours before thermographic test [2]. They had to fulfil a questionnaire in order to achieve personal information such as: weight, height, age, health condition, dominant leg, habitual training (with focus on the week before the test), and past injuries (if any). Thermographic acquisitions were performed in a climate controlled-room, illuminated with neon lights and with subject placed at 2m from the camera. The temperature of both lower limbs (front and back) was recorded in two different conditions: 1) at rest (after 20 minutes of acclimatization, t0); 2) after training (t1). Furthermore, each athlete was subjected to plicometry (4-Site Skinfold, Jackson & Pollock). During the 4 weeks following the thermographic test a follow-up was carried out to monitor the physical condition of the athletes and to check for possible signs of painful symptoms or injuries. Post-image processing was carried out applying a custom semi-automatic procedure developed in Matlab (MathWorks Inc., USA) which allows normalizing a subject’s thermographic profile [3] and calculating the mean and maximum temperature of each muscle/joint located in the thighs, knees and lower legs (front and back). In order to use thermography as a preventive tool, it was necessary to establish the healthy muscular thermal behaviour of an athlete that can be described by two parameters: 1) symmetry of the thermal distribution between the two limbs; 2) thermal gradient of the two symmetrical limbs recorded at t0 and t1. When the temperature difference between right and left ROIs exceeded 0.8 °C [3] and/or the thermal gradient exceeded 0.8°C [3], then the district(s) involved needs to carefully monitored during the follow-up as it might be subjected to injuries.

RESULTS
The study pointed out a negative correlation between the percentage of fat measured on the tight and the maximum temperature of the rectus femoris, showing that adipose tissue, interposing between muscle and skin attenuates the emission of infrared radiation since it acts as a thermal insulation. The temperature analysis showed that two athletes had their right knee at risk of injuries, as the temperature difference between the right and left ROI was up to 3°C. Both athletes confirmed pain and discomfort at their right knee during the follow up. No injuries happened thanks to prevention techniques followed by both athletes.

DISCUSSION
Infrared thermography is a non-invasive technique that allows monitoring the superficial temperature of athletes. This study points out that thermography paves the way to be a tool for injury prevention.

REFERENCES
A subject-specific musculoskeletal model to estimate joint loading at different walking speeds
E. Montefiori, B.M. Kalkman, A. Clarke, M. Paggiosi, E.V. McCloskey, C. Mazza
Insigneo institute for in silico medicine, University of Sheffield, Sheffield, UK.

INTRODUCTION
Physical activity, i.e. walking and jogging, are nowadays highly recommended by physicians for reducing the occurrence of fall and injury in elderly [1]. Little is known about whether these tasks might increase joint loading and represent a risk for articular integrity. Previous studies, in fact, have only investigated the link between walking speed (WS) and hip joint loading in young healthy adults [1]. This study aimed at investigating the effect of WS on the lower limb joint contact forces (JCFs) estimated using a patient-specific musculoskeletal model in a group of women with osteoporosis.

METHODS
Seven women (69.6±4.0y, 67±8kg, 160±3cm) underwent 3D gait analysis (Vicon and Kistler, UK) and lower limb MRI (T1-weighted VIBE). Bones and muscles (21 from each limb) were segmented using Mimics 20.0 (Materialise, Belgium) and used to build personalised anatomical models (NMS Builder, [2]) using a previously established modelling technique [3]. Values of muscular maximal isometric force $F_{max}$ were calculated based on segmented muscle volumes according to: 
$$F_{\text{max}} = k \times \frac{\text{Volume}}{l_{\text{opt}}} \times \cos(\alpha),$$
where $k$ is the specific tension (61 N/cm²), $l_{\text{opt}}$ is the optimum fibre length and $\alpha$ is the pennation angle at $l_{\text{opt}}$. MRI-visible markers were included in the model and used for the registration with gait data. Simulations of walking tasks at slow, self-selected, and fast speed were run in OpenSim [4] and the estimated JCFs were compared through 1-way ANOVA ($\alpha=0.05$) using 1d Statistical parametric Mapping (SPM) package [5].

RESULTS
JCFs, scaled to bodyweight (BW), varied significantly with WS in the first peak of hip and knee stance phase (0.9 BW and 1.1 BW average group increase, respectively). Ankle JCF peak decreased by 0.7 BW on average, but this was not significant at group level due to three subjects presenting slightly increased JCFs.

DISCUSSION
The values of hip JCFs estimated for our group of osteoporotic women were in line with those reported for young adults (4.2 BW at 0.8 m/s vs 5.7 BW at 1.7 m/s) [1]. Peak JCFs increased by 45% and 65% at hip and knee joints, respectively, however loading remained always well below the values previously observed for possible spontaneous fracture in osteoporosis [6]. The ankle JCF showed inconclusive evidences, suggesting variable loading strategies between individuals. Current investigation is focusing on possible relation between ankle JCF and $F_{\text{max}}$ of muscles acting on the ankle joint.

This study was funded by the UK EPSRC, MultiSim project (EP/K03877X/1). We thank Angela Green for her help with patient recruitment and data collection.

REFERENCES
Impact of gait analysis (GA) on treatment appropriateness in stroke patients with stiff knee gait
A. Merlo, S. Scaltriti, R. Iotti, B. Damiano, I. Campanini
LAM – Motion Analysis Laboratory, AUSL-IRCCS di Reggio Emilia, Correggio (RE), Italy

INTRODUCTION
Stiff Knee Gait (SKG) is the second most frequent lower limb deformity in stroke survivors. It is typically treated by means of inhibition of quadriceps femoris (QF) muscles by botulinum toxin, because of the presence of QF spasticity at the clinical evaluation [1]. Gait analysis (GA)-based studies showed that the inadequate ankle push-off (APO) can result in SKG, too [2]. We recently presented an algorithm, based on GA data, that differentiates the individual's main cause of SKG between SKG consequent to QF spasticity (SKG_{QF}) and SKG consequent to the lack of APO (SKG_{APO}) [3].
In this study, we assessed the occurrence of these two causes of SKG to estimate the potential contribution of GA to treatment appropriateness and cost reduction.

METHODS
We retrospectively analyzed GA data (BTS Smart-DX system, Conventional Davis Protocol, 5 trials per subject) from chronic patients with hemiparesis following ischemic or hemorrhagic stroke referred to our laboratory in 2017 because of SKG and clinically evaluated spasticity. Subsects were excluded in the case of any recent (<6 months) treatment or concurrent pathologies. SKG was classified as SKG_{QF} when knee flexion velocity KFV fell without the 95% confidence interval of the regression model between APO and KFV [3], and as SKG_{APO} otherwise. Briefly, when QF spasticity brakes knee flexion, KFV is much lower than the one expected based on APO. The percentage occurrences of SKG_{QF} and SKG_{APO} were computed. SKG_{APO} provides an estimate of inappropriate treatments by QF muscles inhibition that could be avoided by adding an instrumental evaluation at the beginning of the rehabilitation path.

RESULTS
A sample of 56 chronic patients 55(13) years, 24/32 M/F, 24/29 L/R affected side was included in the study. Walking speed was 0.4(0.2) m/s, and ranged between 0.1 and 1.0 m/s, thus providing external validity to results. The peak of knee flexion peak during swing was, on average, 26(12) degrees and ranged between -5 and 44 degrees.
34 patients (61%) were classified as SKG_{APO}, 10 (18%) as SKG_{QF} and 12 (21%) showed a mixed pattern.

DISCUSSION
SKG_{APO} is the main cause of SKG in stroke patients. Based on our results, about 60% of QF inhibition treatments, planned after clinical assessment, could be avoided. The availability of a tool for identifying the patient-specific cause of SKG could greatly increase the appropriateness of the treatment selection, support the design of tailored clinical pathways and decrease the related costs.

REFERENCES
Is there a role for functional surgery in the management of quadriceps spasticity in adults with upper motor neuron lesion?

D. Mazzoli, A. Merlo, P. Zerbinati, M. Galletti, E. Giannotti, F. Mascioli, L. Del Casale, P. Prati
Gait & Motion Analysis Laboratory, Sol et Salus Hospital, Rimini, Italy

INTRODUCTION
Quadriceps femoris (QF) spasticity is frequent in patients with upper motor neuron lesion (UMN) and stiff knee gait (SKG). When SKG is due to QF spasticity, this is frequently treated by means of focal inhibition of QF muscles by botulinum toxin [1,2], followed by physiotherapy, and repeated many times over years. Despite of its cost, the efficacy of this approach on SKG reduction is far from being satisfactory, with an average increase in knee flexion lower than 10 degrees [2]. Later, typically at years from the UMN, functional surgery is considered, as a last-chance treatment, to correct the individual's acquired deformities, including equinus foot and SKG. Amongst surgical procedures, QF aponeurectomy is a low-cost and easy to deliver surgical procedure, which lasts about 15 minutes. Aim of this work is to assess the effect of QF lengthening by aponeurectomy on both knee flexion and QF spasticity in a sample of adults with UMN following stroke or traumatic brain injury (TBI) and SKG.

METHODS
A sample of 19 chronic patients with UMN, 52(12) years, 11/8 L/R, 6(5) years after lesion and walking speed 20(7) %height/s who underwent functional surgery including QF lengthening by aponeurectomy was included in the study. The same surgeon always performed the surgeries. Patients were assessed by complete gait analysis before and 1 month after surgery. QF spasticity was assessed through the Tardieu Scale (TS), which is not affected by passive muscle characteristics. Median TS was 3 (range 2-4) before surgery. Walking speed, peak of knee flexion and TS scores were analyzed. Paired values were compared using the non-parametric Wilcoxon test. Percentages of patients with worsened, unchanged and improved MTS scores were also computed and reported.

RESULTS
At 1 month after surgery, walking speed was unchanged in the sample, as expected [3]. PKF significantly improved from 18±11 degrees to 27±11 degrees (p<0.001). In 6 cases PKF improvement was >15 degrees.

Noteworthy, median TS score significantly decreased from 3 to 0 (p<0.001) at the 1-month mark. Spasticity was stable in 7 subjects (37%), improved in 12 subjects (63%) and never worsened. Ten subjects (53%) were completely relieved from QF spasticity, with MTS decreasing from 3 to 0 and from 2 to 0. No adverse events arose in the sample during the first month following surgery.

DISCUSSION
QF aponeurectomy can be effective in reducing QF spasticity in adult stroke and TBI survivors. This is reasonably due to the reduction in spindle activation during the stretching maneuver consequent to the decrease in muscle shortening, passive tension and stiffness. Data collection is ongoing to obtain long term results on a wider sample. If confirmed, these results would promote a change in the current management of SKG, where aponeurectomy could be considered within the first year after stroke or TBI. This would 1) limit/prevent the development of fixed deformities that dramatically affect patients’ autonomy, 2) contain muscle overactivity, 3) relieve the national health systems from the huge costs currently deriving from the repeated treatment by focal blockages.

REFERENCES
Feasibility study of relationships between joints using cyclograms in different walking patterns.
S. Minosse\textsuperscript{1}, S. Summa\textsuperscript{1}, A. Pisano\textsuperscript{1}, M. Favetta\textsuperscript{1}, A. Romano\textsuperscript{1}, E. Castelli\textsuperscript{1}, M. Petrarca\textsuperscript{1}
\textsuperscript{1}MARlab, Neurorehabilitation Division, Bambino Gesù Children’s Hospital – IRCCS, Rome, Italy

INTRODUCTION

Usually, joints gait patterns are evaluated independently. Cyclograms \cite{1} allow appreciating the relationship between joints. Gait analysis can be used for highlighting the differences between normal gait (healthy, H) and pathological conditions. Cerebral Palsy (CP), Charcot Marie Tooth (CMT) and Duchenne Muscular Dystrophy (DMD) that exhibit different walking patterns involving the 1\textsuperscript{st}, the 2\textsuperscript{nd} motor neuron and muscles, respectively. The objective of this study is to understand if cyclograms can describe the clinically relevant differences in the gait patterns.

METHODS

Forty-two children (12 H, 10 CP, 10 DMD, 10 CP) were included in this study and underwent a gait analysis with eight-camera motion capture system (Vicon MX, UK). Three gait cycles were acquired for each patient. We constructed sagittal plane joint-joint angle cyclograms \cite{2, 3}. Angle-angle plot across the two joint pair shows six relationships between pelvis, hip, knee and ankle joints. From this cyclograms, we assessed the perimeter in the whole cycle (total) and in the stance and swing phases (deg). Moreover, we computed the total area (deg\(^2\)). Later the differences (\(\Delta\)) in the perimeter and area between pathological and healthy participants were calculated.

RESULTS

The difference of the variables between pathological and healthy participants across the six relationships among pelvis, hip, knee and ankle joints was summarized in Table 1. The major difference in the total perimeter is found in \(\Delta\)(CP-H) for hip-ankle angle cyclograms. However, the contribution of differences between stance and swing phases are dissimilar, but are always more accentuated in the case of \(\Delta\)(CP-H). While the major area is discovered in \(\Delta\)(DMD-H) for hip-knee angle cyclograms.

Table 1. Comparison between CMT, DMD, CP and control subjects (H) for joint-joint variables: perimeter (deg) and area (deg\(^2\)) in the stance, swing and total phases.

<table>
<thead>
<tr>
<th>Joint1</th>
<th>Joint2</th>
<th>(\Delta)(CMT-H) Perimeter (deg)</th>
<th>(\Delta)(CMT-H) Area (deg(^2))</th>
<th>(\Delta)(DMD-H) Perimeter (deg)</th>
<th>(\Delta)(DMD-H) Area (deg(^2))</th>
<th>(\Delta)(CP-H) Perimeter (deg)</th>
<th>(\Delta)(CP-H) Area (deg(^2))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pelvis</td>
<td>Hip</td>
<td>Perimeter (deg)</td>
<td>Area (deg(^2))</td>
<td>Total</td>
<td>Stance</td>
<td>Swing</td>
<td>Total</td>
</tr>
<tr>
<td>Pelvis</td>
<td>Knee</td>
<td>2.29</td>
<td>0.41</td>
<td>1.89</td>
<td>3.58</td>
<td>11.31</td>
<td>3.55</td>
</tr>
<tr>
<td>Pelvis</td>
<td>Ankle</td>
<td>-2,19</td>
<td>-4.93</td>
<td>-16.28</td>
<td>3.10</td>
<td>-5.11</td>
<td>-2.18</td>
</tr>
<tr>
<td>Hip</td>
<td>Knee</td>
<td>1.85</td>
<td>4.64</td>
<td>-2.79</td>
<td>38.08</td>
<td>6.29</td>
<td>-0.32</td>
</tr>
<tr>
<td>Hip</td>
<td>Ankle</td>
<td>-0.94</td>
<td>-2.67</td>
<td>-6.27</td>
<td>-100.84</td>
<td>5.62</td>
<td>1.84</td>
</tr>
<tr>
<td>Knee</td>
<td>Ankle</td>
<td>-9.53</td>
<td>1.04</td>
<td>-10.57</td>
<td>-216.47</td>
<td>-2.21</td>
<td>-4.09</td>
</tr>
</tbody>
</table>

DISCUSSION

The study of the perimeter gives information about the amount of reciprocal joints excursion, while the area gives us the information about the level of homogeneity in the studied joints couple with respect to the perimeter variation. This analysis allows identifying easily the variation in the coordination, as shown in the Table 1, in a synoptic exposition without the loss of the major clinical relevant information. This investigation will be extended for deepening the role of biomechanical constraints in the determination of pathological gait patterns through their comparison.

REFERENCES

\cite{1} Goswami A. Gait and Posture 1998; 8(1):15-36.
INTRA- AND INTER-OPERATOR RELIABILITY OF A NOVEL HAND PROTOCOL DURING GRIP MOVEMENT

P. Pedersini¹, J.H. Villafañe¹, B. Piovanelli¹, V. Cappellini¹, R. Buraschi¹, J. Pollet², S. Moschin¹, S. Negrini¹²

¹IRCCS Don Carlo Gnocchi Foundation, Milan, Italy, ²University of Brescia, Italy.

INTRODUCTION

Quantitative and qualitative measures of human movement can be two important features for discriminating healthy and pathological conditions, for expressing the outcomes and clinically changes in subjects' functional state and for helping in the decision making within clinical setting. Clinical scales are the most frequently used instruments for the upper extremity functional assessment [1]. Currently there are no methods sufficiently accurate that analyze the hand mobility in clinical practice. The purpose of the study was to evaluate the Intra-and inter-operator reliability of a novel hand protocol during grip movement.

METHODS

5 healthy subjects were scheduled for analysis. The experimental protocol required the positioning of 8 optoelectronic cameras and 24 markers. Three reference markers are located on the Head of Radius, on the Styloid processes of Radius and Ulna to determinate the wrist coordinate frame and global position and orientation of the model. Then, a marker is placed on the hand dorsum, corresponding to the position of scaphoid, capitate and lunate bones to determinate the dorsum coordinate frame and the direction during the movement. A marker is placed on each hand joint (metacarpal, proximal and distal) and on the top of the finger to determine the position of the segment hand. The subjects perform a grip movement in order to grasp a cylinder at a non-imposed speed, and return to starting position (Figure.1). Each subject received 2 markerizations by two different operators (A and B) and they carried out 3 tests at a time T0 and at a time T1 (a week after) for each markerization [2]. The following distances were considered in the analysis, between SCAL and 5 points: HR, CMJT, Met3, Dist3, Dist1.

RESULTS

Intraclass correlation coefficients were calculated to assess inter- and intra-operator reliability. Operators did not obtain significantly different values. Test-retest reliability of the markers positions measurements was good (test: 0.893, p<0.001; retest: 0.773, p<0.01) and intra-operator reliability was excellent (A: 0.983, p<0.001; B: 0.993 p<0.001).

DISCUSSION

This system provides information on quality and amplitude of the movement. Hand movement analysis by 3D kinematics has the potential to become an important clinical evaluation method and no standardized protocol for clinical application has yet been developed [3]. A good intra- and inter-operator reliability provides a reliable protocol in order to apply it in clinical practice to study possible patterns in pathological conditions. The study is still ongoing and we expect that a larger sample size will produce a statistical significance.

REFERENCES

Effects of short pulse-width stimulation on gait ataxia of Essential Tremor patients implanted with thalamic Deep Brain Stimulation
C. Palmisano 1,2, M. Reich 1, J. Volkmann 1, C. A. Frigo 2, I. U. Isaias 1

1University Hospital and JMU Wuerzburg, Wuerzburg, Germany
2Politecnico di Milano, Milan, Italy

INTRODUCTION
Deep Brain Stimulation (DBS) of the Subththalamic nucleus (STN) is a well-established and effective treatment for disabling and drug-refractory essential tremor (ET), but it can lead in some cases to a delayed onset cerebellar syndrome (e.g. ataxia), possibly caused by a maladaptive response to the neurostimulation of the thalamic area. In this study we investigated the effect of stimulation pulse-width on gait ataxia of ET patients. We envisioned that short pulse-width (30μs) could prevent gait disturbances in ET patients by selective neurostimulation only of fast conducting dentate-thalamic myelinated fibers, thus ensuring tremor suppression but without ataxia symptoms.

METHODS
We enrolled 7 patients (2M; age: 73(65±86) years) with pharmacologically intractable ET and gait progressive ataxia with bilateral DBS implant of the STN area. Patients were studied under two stimulation conditions: at the baseline, with their usual stimulation parameters, and at 2-week follow-up after reducing the pulse-width to 30μs. The protocol included a clinical evaluation with the Fahn-Tolosa-Marin tremor rating scale (TRS) and the SARA scale for ataxia (items 1-3) and a kinematic assessment of locomotion. Subjects were instructed to perform at least 5 walking trials (6 m each) in a gait laboratory environment walking barefoot at their preferred speed. Kinematics was recorded with an optoelectronic system (SMART DX, BTS) and gait spatio-temporal parameters were calculated with ad hoc Matlab algorithms. We averaged the parameters across trials and calculated the coefficient of variation (CV, the ratio between the standard deviation and the average value) as an index of parameter variability. The baseline and ataxic conditions were compared with a Wilcoxon matched pairs test (JMP13).

RESULTS
Short pulse-width (30μs) remarkably improved gait ataxia, as shown by the clinical scale (SARA1-3 baseline score: 6.8±2.8; follow-up score: 3.0±2.0; p<0.01) and the kinematic parameters (Table 1). Of note, tremor was always well controlled by DBS (TRS baseline score: 10.2±9.5; follow-up score: 4.8±4.2; p=n.s.).

Table 1

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Baseline</th>
<th>Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stride duration (s)</td>
<td>1.21 (1.04 – 1.52)</td>
<td>1.17 (1.01 – 1.24)</td>
</tr>
<tr>
<td>Stride length (%BH)</td>
<td>50.73 (36.28 – 62.31)</td>
<td>58.39 (41.11 – 70.48)</td>
</tr>
<tr>
<td>Stride velocity (%BH/s)</td>
<td>36.89 (31.90 – 59.32)</td>
<td>48.71 (33.86 – 65.65)</td>
</tr>
<tr>
<td>Double support duration (%stride)</td>
<td>34.15 (24.35 – 39.79)</td>
<td>30.30 (18.77 – 35.57)</td>
</tr>
</tbody>
</table>

Median (range) of CVs

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Baseline</th>
<th>Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stride duration (s)</td>
<td>0.06 (0.04 – 0.10)</td>
<td>0.04 (0.03 – 0.07)</td>
</tr>
<tr>
<td>Stride length (%BH)</td>
<td>0.07 (0.04 – 0.15)</td>
<td>0.05 (0.03 – 0.06)</td>
</tr>
<tr>
<td>Stride velocity (%BH/s)</td>
<td>0.09 (0.05 – 0.17)</td>
<td>0.07 (0.05 – 0.11)</td>
</tr>
<tr>
<td>Double support duration (%stride)</td>
<td>0.14 (0.11 – 0.17)</td>
<td>0.11 (0.09 – 0.16)</td>
</tr>
</tbody>
</table>

Gait parameters. All comparisons are statistically significant (p<0.05) except for the CV of stride velocity. BH: body height.

DISCUSSION
DBS-induced gait ataxia in ET patients can be well managed by reducing the stimulation pulse-width to 30μs. Such a short pulse-width might allow the stimulation of the only fast conducting dentate-thalamic myelinated fibers, the proper target for tremor control, preventing current spread responsible for the cerebellar side effects. Of note, the reduction of the pulse-width does not alter the tremor suppression, which was well controlled also in this stimulation condition.
Can be a subjective qualitative evaluation reliable to assess the perceived physical status and the level of the performance in élite sprinters with Intellectual Impairments?

A. Palomba 1, T. Caporaso 2, S. Grazioso 2, G. Di Gironimo 2, A. Lanzotti 2, G. Iolascon 1, R. Gimigliano 1, F. Gimigliano 3

1 University of Campania “L. Vanvitelli”, DMSSD, Naples, Italy 2 Fraunhofer JL IDEAS, DII – University of Naples “Federico II”, Naples, Italy, 3 University of Campania “L. Vanvitelli”, DMPHPM, Naples, Italy

INTRODUCTION

Training programs for athletes are usually based on quantitative objective performance measures and qualitative subjective feedback coming from the athletes. However, it is difficult to have reliable qualitative feedback when the athletes are affected by Intellectual Impairments (II). The current practice is to perform a functional evaluation to assess quantitative performance measures. Previous studies suggested the use of wearable devices to evaluate and correlate physical and mental functions in II subjects [1]. The aim of this study is to clarify whether a simplified version of the Smiley Face Likert Scale (SMLS) [2] might be adequate to self-assess the perception of the II subjects of their physical status after the test and of the level of their performance when compared to objective measures such as the metabolic and kinematic analyses.

METHODS

Three male sprinters, members of the national team of the Italian Federation for Athletes with Intellectual Impairments, were tested. After 20’ of warm up, they were asked to perform 2 series of 4 sprints each on 80-meters distance, as fast as possible. During the experiments, we used photocells to measure the duration of the test and a triaxial inertial sensor was placed at the L5 vertebra, to record four spatial-temporal parameters, for each of the 24 sprints: velocity (v); step frequency (f); step length (p); smoothness performance index by normal jerk (µ) [3,4]. The metabolic assessment was reached through lactate (lac) measurement six times during each test: at baseline, every 2 sprints and after 5’ recovery from the last sprint. Furthermore, the athletes were asked to report a subjective evaluation on their physical status (Ph) and on the level of the performance (P), based on the simplified version of the SMLS, composed by three faces (good=1, neutral=2, bad=3), after each sprint. The statistical analysis compared different groups according to their perceived physical status (Ph1, Ph2, and Ph3) and to their perceived level of performance (P1, P2, and P3). The one-way ANOVA and the Tukey test (p<0.05) were used to assess the significant differences between the groups.

RESULTS

Table 1 shows the results: the physical status (reported as good) was significantly correlated with lower levels of lactate as well as better kinematics parameters were found in cases where the II athletes stated their performance as good.

Table 1. Kinematics and metabolic parameters of the three subgroups for Ph and P status (mean±SD). Statistical significant differences between subgroups 1-2(*), 1-3(**) and 2-3(***), p<0.05.

<table>
<thead>
<tr>
<th>Groups</th>
<th>v [m/s]</th>
<th>f [step/s]</th>
<th>p [m]</th>
<th>µ [-]</th>
<th>lac [mmol/l]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ph1</td>
<td>8.40±0.50</td>
<td>3.92±0.18</td>
<td>2.14±0.04</td>
<td>4.90±0.61</td>
<td>7.47±3.84</td>
</tr>
<tr>
<td>Ph2</td>
<td>8.33±0.34</td>
<td>3.90±0.16</td>
<td>2.14±0.01</td>
<td>4.98±0.74</td>
<td>15.33±2.46</td>
</tr>
<tr>
<td>Ph3</td>
<td>8.15±0.21</td>
<td>3.88±0.10</td>
<td>2.12±0.02</td>
<td>5.22±0.71</td>
<td>17.70±3.58</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Groups</th>
<th>v [m/s]</th>
<th>f [step/s]</th>
<th>p [m]</th>
<th>µ [-]</th>
<th>lac [mmol/l]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ph1</td>
<td>8.78±0.25</td>
<td>4.07±0.11</td>
<td>2.16±0.02</td>
<td>5.09±0.41</td>
<td>11.70±5.20</td>
</tr>
<tr>
<td>Ph2</td>
<td>8.25±0.10</td>
<td>3.88±0.08</td>
<td>2.13±0.02</td>
<td>5.23±0.72</td>
<td>17.97±3.47</td>
</tr>
<tr>
<td>Ph3</td>
<td>7.94±0.08</td>
<td>3.76±0.04</td>
<td>2.12±0.02</td>
<td>4.74±0.79</td>
<td>10.57±5.54</td>
</tr>
</tbody>
</table>

DISCUSSION

A simplified version of the SMLS might be useful to help élite II athletes to communicate their physical condition after any athletic training or competition and their perceived level of performance. Further studies will be necessary to verify the reliability of the simplified version of the SMLS and eventually to standardize it. However, the metabolic and kinematic evaluation still remain the only reliable analysis, to ensure the best performances without compromising the safety of the II athletes.

REFERENCES

Preliminary comparison between actigraphic measures and sleep diary reports in people with Mild Cognitive Impairment

S. Pancani\textsuperscript{1}, L. Fabbri \textsuperscript{1}, L. Martini\textsuperscript{1}, I. Mosca\textsuperscript{1}, F. Gerli\textsuperscript{1}, F. Vannetti \textsuperscript{1}

\textsuperscript{1}Don Carlo Gnocchi Foundation, IRCSS, Italy

INTRODUCTION

Mild cognitive impairment (MCI) is the transitional state between intact cognitive function and mild dementia \cite{1}. Poor cognitive functioning has been shown to introduce a bias in estimating sleep duration \cite{2}, which indeed needs a careful assessment as it has important implication on cognitive decline. The use of actigraphic measures might thus represent a viable and relatively inexpensive alternative to sleep diaries. This study is a preliminary investigation on subjective-actigraphic sleep discrepancy in people with MCI.

METHODS

Five subjects with MCI, aged 70–79 years, wore an actigraph (GENEActiv, Activinsights, United Kingdom) and kept a sleep diary for ten consecutive nights. Baseline data on subjective sleep quality (scale range: 1, very poor, to 5, very good), number of awakenings (minimum 5 minutes duration of the awake phase), depressive symptoms and cognitive functioning were also recorded. To discriminate between wake and sleep status from acceleration data measured by the device, activity counts were estimated using the zero-crossing technique \cite{3}. Activity counts were then collapsed in 1-minute epochs and used in the algorithm proposed by Sadeh et al. for sleep-wake identification \cite{4}. A Student t-test for paired samples (significance \(p<0.05\)) was used to compare total sleep time (TST) and number of awakenings estimated by the actigraphic data and reported by patients on diaries.

RESULTS

Demographic and clinical characteristics of the five participants are reported in Figure 1a together with sleep parameters measured by the actigraph and recorded on diaries, averaged over ten nights. No significant difference (\(p=0.935\)) was found in the assessment of number of awakenings while a significant discrepancy was found in the estimation of TST (\(p=0.014\), Figure 1b). Participants reported an overall poor (score 2) to fair (score 3) sleep quality.

![Figure 1. a) Characteristics of the study sample presented as mean±SD (CES-D: Center for Epidemiological Studies Depression, MoCA: Montreal Cognitive Assessment); b) Actigraphic and subjective estimation of total sleep time (TST).](image)

DISCUSSION

Participants presented a significant underestimation of sleep time, confirming a mismatch between subjective reports and objective measurements. The reported poor quality of sleep needs further examination by assessing additional sleep parameters, such as the sleep-onset latency. Results obtained in this preliminary study are sufficiently encouraging to warrant a further investigation, which will be conducted on a larger sample of 12 subjects, on clinical characteristics assessed at the baseline as possible determinants of the observed disagreement and reported poor quality of sleep.

REFERENCES

\cite{1} Petersen RC. J Intern Med. 2004; 256(3):183–94.
\cite{3} Aktaruzzaman, et al. Comput Biol Med. 2017; 89, 212-221
INTRODUCTION
Technical evaluation in the sport of figure skating is characterized by a subjective marking system. Figure skating coaches are responsible for quickly and accurately discerning the quality of technical elements and in most cases the focus is on the overall aesthetic appearance of a performance [1]; however, the landing of a jump is widely acknowledged as one of the most critical elements of a skater's program and one of the major causes of injuries [2]. Figure skating has an inherent risk of injury because of the technical and physiologic demands on the young athletes involved. It is important to have an understanding of the sport from a biomechanical and physiologic perspective [2]. Female figure skaters training as early as 5 years of age, and in a training program, the athlete must avoid applying stress to the neuromuscular and skeletal systems that can cause tissue breakdown and resultant injury. Therefore, our aims were to identify the biomechanical variables that contribute to low injury risk in executing landings and to establish whether landings rated as biomechanically optimal are also awarded technical success. For this purpose, the analysis of an axel jump was selected, which is one of the most frequent figure skating jumps, focusing on information that has implications for injuries prevention programs.

METHODS
After appropriate informed consent by the parents, 10 female competitive figure skaters (mean±SD age of 13.31±1.97 years and 19.11±1.86 BMI of Kg/m²) were acquired while executing 3 consecutive axel jumps at the Motion Analysis Laboratory of DEI-UNIPD. Data were collected at 340 Hz using a 12 camera stereophotogrammetric system, a plantar pressure system and an 8 channels surface electromyographic system (Semg). Markers were applied as in [3] and Semg of the following muscles was acquired: Tibialis Anterior (TA), Gastrocnemius Lateralis (GL), Rectus Femoris (RF) and Biceps Femoris (BF) were collected bilaterally and onset and offset activation timing was obtained [4] and peak of the envelope computed [5]. Peak of Pressure, its position in % of the task duration, the Centre of Pressure displacement, vertical ground forces, 3 dimensional joint rotations and moments [3] were extracted.

RESULTS
Results of these analyses were twofold (Fig. 1): a biomechanical profile of axel landings was obtained, and jump landing strategies rated by the coach empirical evaluations were in agreement with biomechanics assessment of the same performances. In term of joints rotations an excessive trunk abduction-adduction range of motion, accompanied by excessive knee flexion on the landing leg, reduced extension of the contralateral leg was associated by high valgus moments, high hip abduction moments, pure control by the hip-knee-ankle flexor-extensor muscles during landing.

DISCUSSION
This methodology can be adopted to optimize the preventive management by providing an early detection of subjects at risk. Results of this study may assists the clinician in appropriately diagnosing and treating these athletes.

REFERENCES
Gait changes in response to deep brain stimulation (DBS) in primary dystonia: a case report.
R. Carbonetti1, A. Colazza1, M. Petrarca1, S. Cossu2, C.F. Marras2, F. Frascarelli1, E. Castelli1
1 MARlab, Neurorehabilitation Division, “Bambino Gesù” Children’s Hospital, IRCCS, Rome, Italy.
2 Neurosurgery Unit, Department of Neuroscience and Neurorehabilitation, “Bambino Gesù” Children’s Hospital, IRCCS, Rome, Italy.

INTRODUCTION
Surgical treatment is an important option in medically refractory cases of inherited and idiopathic isolated dystonia. To date, several clinical trials have proven the benefit and safety of DBS with the globus pallidus internus (GPI) being the target. [1]
The aim of our study is to evaluate and quantify possible changes of gait and the effectiveness of one-month integrated neuro rehabilitation training following bilateral GPI DBS in a 19teen years old girl affected by primary generalized dystonia.

METHODS
We prospectively performed walk instrumental evaluation by using Gait Analysis BTS Smart-DX 1000. Several parameters were measured preoperatively, postoperatively and after a month of neuro rehabilitation training (NT).

RESULTS
The gait analysis shows a change mainly at the hip joint in the sagittal plane (figure 1). After DBS we observed an increase of gait velocity (from 0.30m/s to 0.50 m/s) and stride length (from 0.68 m to 1.1 m). After one month of NT the Hip’ Kinematics remained unchanged but we observed an improvement of the right double support time (from 4.31±0.02 % to 13.18±5.85 %) with a reduction of the right single support phase (from 65.01±1.63 % to 64.6±2.95 %) and relative reduction of the left swing phase (54.65±0.58 % to 45.77±1.95 %)

DISCUSSION
The changes found in the gait analysis, pre/post-surgery, show the research of a new coordinating structure in the girls’ gait control. To corroborate this thesis, we observe, after a month of NT, a slight physiological fall in the gait performance with a slight reduction in degrees of freedom probably due to the reorganization of the coordinative dynamic structure in accordance with Bernstein's theory on motor learning [2].

REFERENCES
INTRODUCTION
Moving platform are introduced in the field of the study of posturography since '70 years [1] and recently they were robotized, among them, the CAREN system (Computer Assisted Rehabilitation Environment) represents one of the most complex [2]. Commercial platforms have two limits: they are sold with limited and pre-configured solutions and/or they are expensive.

METHODS
In order to overcome the above mentioned limits, we developed an ad hoc robotized platform: DORIS (Dynamic Oriented Rehabilitative Integrated System). The first aim was to realize a versatile solution that can be applied both for research purpose but also for personalizing the training of the equilibrium and gait. The second one is to realize a solution that can be integrated with motion analysis systems, virtual reality and other robotic devices.

RESULTS
We reached these goals by means of a 6 Dof Stewart platform that was realized utilizing 6 linear actuators with ball screws for supporting a plate of 120 cm of diameters. The linear actuators reach accelerations until 1.5 g and excursion of 40 cm allowing a multipurpose range of movement obtained by means of a computer numerical control (cnc). Each actuator is provided by a monoaxial ad hoc built load cell with a range of sensitivity [0.1 ÷ 100] kg. The force cells are used for the realization of a reactive interaction with the force applied on the platform. An Ethernet WiFi router guarantees the communication between the cnc and the external devices. The platform is mounted on an actuated rotating support for enhancing the limited yaw range because of the Stewart configuration. In order to facilitate the use with patients the plate of the platform was mounted at the floor level taking advantage from the availability of a room under the Movement Analysis Laboratory slab. The platform is first elevated only when a translation on horizontal plane is necessary, avoiding impacts with the adjacent floor, see Figure 1.

DISCUSSION
The adopted solution guarantees to be useful for both postural assessment and training. For example, in that direction, the platform is a suited tool for gait interaction enhancing the previous solutions described. The full control of its movement and of human dynamic interaction is a further benefit for the identification of innovative solutions for research and treatment in a field that is strongly investigated, but still open.

REFERENCES
Valutazione e monitoraggio nella riabilitazione del paziente con compressione radicolare: ecografia ed elettromiografia di superficie

C. Pinzini¹, R. Blanco², C. Carpenedo³, G. Martinis¹

¹ CdL in Fisioterapia, Università degli Studi di Udine, Udine, Italy
² SOC di Neurologia Presidio Ospedaliero-Universitario Integrato – ASUIUD, Udine, Italy
³ Dipartimento di Medicina Riabilitativa IMFR Gervasutta - ASUIUD, Udine, Italy

Introduzione: Le radicolopatie provocano deficit sensitivo-motori che possono rendere necessario il trattamento riabilitativo, per il recupero o l'eventuale compenso di tali deficit. L'utilizzo di indagini strumentali, impiegate a scopo diagnostico, non trova applicazione nel processo riabilitativo, sia per le caratteristiche di invasività che di elevati costi che le caratterizzano.

Obiettivo: Lo studio ha avuto lo scopo di monitorare, mediante tecniche neurofisiologiche e di imaging non invasive e a basso costo, il recupero (funzionale e strutturale) della muscolatura degli arti inferiori deficitaria in seguito a radicolopatia, in pazienti sottoposti a trattamento riabilitativo.

Materiali e metodi: È stato studiato un campione di 4 soggetti (età media di 44,5±15,0 anni, 3 maschi, 1 femmina) con compressione radicolare lombare causata da ernia discale a livello L4-L5 o L5-S1. Ogni soggetto è stato valutato al (t0) di pre-trattamento, al (t1) dopo 2 mesi di trattamento ed al (t2) con un follow up a distanza di 6 mesi da t0. Il trattamento riabilitativo prevedeva una rieducazione motoria, posturale, propriocettiva e dell’equilibrio, il rinforzo della muscolatura compromessa, il training del passo e l'elettrostimolazione della muscolatura denervata. Le indagini strumentali utilizzate per le valutazioni fornivano sia misure neurofisiologiche, mediante elettromiografia di superficie (BTS Freeemg 1000 e EMG-Analizer) di parametri quantitativi di potenza muscolare (valore Root Mean Square - RMS mediato su due contrazioni isometriche di 5 sec) e affaticamento muscolare (SLOPE – trend dei valori di Freq Mediane in funzione del tempo in contrazioni isometriche di 30 sec); sia misure morfologiche, mediante ecografia muscolo-scheletrica (LOGIQe), della sezione trasversa del muscolo e dell’angolo di pennazione delle fibre [1], nelle condizioni di riposo e durante contrazione isometrica massimale (modalità trapezoidale, 12 MHz, sonda lineare); è stato inoltre effettuata una valutazione clinica della forza muscolare mediante l’MRC Scale, con punteggio da 0 a 5. Il protocollo scelto prevedeva la valutazione (al t0, al t1 e al t2) dei muscoli tibiale anteriore (TA), bicipite femorale (BF) ed estensore comune delle dita (ECD) bilateralmente, con singola registrazione ecografica [2] ed elettromiografica [3] e MRC Scale.

Risultati e discussione: Il test di forza muscolare è risultato essere fondamentale per inquadrare l’evoluzione del quadro clinico, registrando in media un incremento della forza muscolare a carico dei muscoli lesionati al t1 rispetto al t0 (55% TA, 31% ECD, 26% BF); per l’arto controlaterale sano non sono state riportate variazioni. Queste evidenze sono risultate in accordo con i dati oggettivi strumentali: a) si è registrato un aumento della potenza muscolare per tutti i muscoli indagati, come incremento del valore RMS (66% TA, 81% ECD, 50% BF) ed è stato registrato un incremento del valore RMS anche dei muscoli controlaterali (75% TA, 14% ECD, 43% BF); non sono state registrate significative differenze dei valori di SLOPE tra t1 e t0. b) si è registrato un incremento della sezione trasversa dei muscoli coinvolti dalla lesione (5% TA ed ECD, 11% BF) e dell’angolo di pennazione in contrazione isometrica (32% TA, 6% BF, mentre per l’ECD è risultato sostanzialmente invariato) e a riposo (68% TA, 17% ECD, 13% BF). Per quanto concerne il follow up a (t2), il tempo di osservazione non è ancora concluso.

Conclusioni: L’elettromiografia di superficie e l’ecografia muscolo-scheletrica si sono rivelate utili strumenti per la valutazione ed il monitoraggio del processo di recupero funzionale dei muscoli con deficit motori in seguito a lesione nervosa periferica. La complementarietà di queste due tecniche diagnostiche hanno permesso di indagare sia gli aspetti funzionali che strutturali della muscolatura coinvolta dalla lesione, fornendo importanti indicazioni sul processo di recupero in seguito a trattamento riabilitativo. Grazie alla loro non invasività, semplicità di utilizzo e basso costo, potrebbero essere utili strumenti da integrare ai test clinici come strumenti valutativi in ambito clinico riabilitativo.

BIBLIOGRAFIA
A NOVEL SPINE PROTOCOL FOR THE ASSESSMENT OF FORWARD BENDING, LATERAL FLEXION AND AXIAL ROTATION

B. Piovanelli¹, P. Pedersini¹, J. Pollet², S. Piotti², S. Pedretti², R. Buraschi¹, S. Negrini¹-²

¹IRCCS Don Gnocchi Foundation Milano, Clinical Research, Milano, Italy.
²University of Brescia, Department of Clinical and Experimental Sciences, Brescia, Italy.

INTRODUCTION

The actual Gold Standard for spine assessment are x-rays, even if they just give a static view of the spine. Currently there are no accurate methods to thoroughly assess spine mobility in clinical practice: this is normally evaluated by physicians and therapists only observationally, and sometimes with a total Range of Motion measurement. Through optoelectronic systems it's possible to have an objective dynamic analysis of the spine during movement. The data collected would allow a measure for an objective and standard assessment of the spine.[1,2]

METHODS

Subjects participated after giving the written informed consent and the study was approved by the local ethical committee. The experimental protocol requires eight optoelectronic cameras and the positioning of 32 markers on PSIS and ASIS and on selected vertebrae: C7, T3, T7, T12, L1, L2, L3, L4, L5 and S2. Three markers were applied on each vertebra: one on the spinous process and the other two over the right and left transverse processes (except for S2). The subjects performed FB, LB and AR both sides at least three times at a non-imposed speed from standing to the maximum joint excursion, and back.

RESULTS

The research was conducted on a sample of 37 subjects (28 males and 9 female), aged 23 ± 2.12. The series of graphs (Figure 1) of each subject have been examined and provides us qualitative and quantitative information (symmetry, slope and mobility) about the movement patterns. All the FB graphs are symmetrical and have fluid curves. Increased ROM during the functional tests was observed. It is highlighted the motor's learning and muscular fatigue phenomenon, through the analysis of the anticipatory postural adjustments (APAs). The series of graphs of LB and AR show asymmetry between the right and left movements, in which there is a dominant side with a greater ROM. From the graphs of AR it is possible also to recognize the vertebral alignment on the sagittal plan, discern the position of the vertebrae in space, differentiating the most from the least prominent.

DISCUSSION

The optoelectronic system has shown to be able to provide information not only on the amplitude but also on the quality of the spine movements. Through the results of this study, we can trace a motion profile of each single subject, and group the strategies adopted by participants to carry out the required movements.

REFERENCES


Figure 1: Graphical representation of Forward bending, Lateral bending, Axial rotation of spine.
Is it possible to describe the physiological movement of cervical vertebrae using an optoelectronic system?

B. Piovanelli¹, S. Moschin¹, S.G. Lazzarini¹, L. Belloni², M. Repelo², M. Spoti², V. Cappellini¹, S. Negrini¹-²

¹IRCCS Don Gnocchi Foundation Milano, Clinical Research, Milano, Italy.
²University of Brescia, Department of Clinical and Experimental Sciences, Brescia, Italy.

INTRODUCTION

It has been estimated that about 70% of adults are afflicted by neck pain during their lives¹,², 10 to 40% of adults are bothered by neck pain each year³. The use of optoelectronic technologies allows to acquire general parameters on joint movements. The aim of this work is to study the cervical spine using a dynamic assessment through functional movements, employing a non-invasive optoelectronic infrared system, in order to describe the assessment protocol that will be eventually applied to a larger sample. Is it possible to achieve an objective and reproducible assessment of cervical spine kinematic through a non-invasive protocol with an optoelectronic infrared system, focusing on intersegmental motion of the lower cervical spine?

METHODS

10 healthy subjects participate the experimental protocol requires the positioning of eight optoelectronic cameras and 31 passive markers on specific landmarks, which are sternum, bilateral internal and external collar bones, bilateral acromions, nasion (a distinctly depressed area directly between the eyes, just superior to the bridge of the nose), bilateral zygomatic processes of the frontal bone and selected vertebrae: C3 (if possible), C4, C5, C6, C7, T1 and T3. Three markers are applied on each vertebra: one in correspondence to the spinous process and the other two over the transverse processes. Each subject performs anterior flexion, extension, lateral bending and axial rotation at least three times at a non-imposed speed from neutral position to the maximum joint excursion, and back.

RESULTS

This analysis allowed us to describe movement of each cervical vertebrae. The graphs (Figure 1) show the movements of the cervical vertebrae during anterior flexion (except for C1 and C2, which are not well markerizable) lateral bending and axial rotation. The difference in movement between the high and low cervical and the slight movement of the thoracic vertebrae can be seen. This protocol allows us to see how much and how each vertebra it moves in the planes.

DISCUSSION

Considering biomechanical movements of the spine, the computerized study of neck functional movements may constitute a useful tool in the evaluation of cervical diseases at baseline and follow-up. We have tried to markerize all the vertebrae possible because we think it is essential to verify the functional movement of all the joints. In this way we do not consider the cervical spine as a single rigid line, which it is not. This could allow us to see the presence of joint blocks or pathological movement patterns.

REFERENCES


Figure 1 Movements of the cervical vertebrae during anterior flexion, lateral bending and axial rotation.
INTRODUCTION
The majority of stroke patients has limited use of upper limb, ranging from about 80% in the first days after stroke, to 30% – 60% after six months from lesion. Robotic therapy improves motor control of the paretic upper limb poststroke and EMG biofeedback device offers information to patient about its muscle activation and strength, allowing the control of computer interfaces. This study shows preliminary data about EMG biofeedback armband for performing specific gesture with paretic hand after stroke. The aim was to investigate the relationship between clinical and instrumental data collected.

METHODS
The device is a wearable armband developed by the Istituto Italiano di Tecnologia (Genova) in collaboration with Morecognition Srl (Torino) and the IRCCS San Camillo Hospital Foundation (Venezia). The device is composed by 8 dry bipolar sEMG electrodes able to detect muscles activation at the level of patients' forearm, then through real-time processing, the main components of the acquired sEMG are extracted and exploited for controlling artificial environments. Patients' muscle activation were recorded in rest position and while performing 10 different voluntary gestures of the hand. During each repetition of a gesture, the patient had to reach a specific target contraction value and then relax the forearm up to the rest condition. Instrumental outcome were the amount of time needed to reach the target and the time needed for muscles to relax. Furthermore, a parameter of ability to control the device was define as Contraction Ratio, which is the ratio between the maximum MVC and the baseline of forearm muscle signals. A minimum Contraction Ratio threshold, equal to 1.5, was chosen to verify if the patient could properly use the device. Consecutive patients after first single stroke, without severe cognitive impairments were enrolled and assessed by: Fugl-Meyer Upper Extremity (F-M UE), Functional Independence Measure (FIM), Reaching Performance Scale (RPS), Box and Block Test (BBT), Modified Ashworth Scale (MAS), Nine Hole Pegboard Test (NHPT). Descriptive statistics and regression models were used to infer which of the clinical scales were able to predict a valid control of the device.

RESULTS
A sample of 27 stroke patients were tested: 6 (22%) patients cannot overcome the minimum Contraction Ratio threshold of device, 5 (19%) patients can control a part of gesture, and 16 (59%) patients can perform all the 10 movements. Linear regression models indicated that ability of using the device was significantly predicted by the F-M UE score (OR = 1.09, CI95%: 1.0003; 1.19) and not significantly from MAS (OR = 0.63, CI95%: 0.33; 1.19). Instrumental data showed that time of reaching task and relaxing is higher for finger movements (thumb abduction time contraction = 5.99s, CI 95%: 2.96-0.03, and time relaxing = 2.76s, CI 95%: 2.11-3.40) but the Calibration Ratio is higher for wrist movements (ulnar deviation= 7.73, CI 95%: 5.61-9.85).

DISCUSSION
The ability to control the device is positively influenced by high levels of motor performance associated with low level of spasticity in upper limb motor function. Instrumental data indicated that wrist-reaching movements are easier to control than fingers movements; in fact, the muscle recruitment varies from baseline much more in wrist movements, than in fingers gesture of paretic hand in stroke patients.

REFERENCES
Robotic rehabilitation effect on upper limb recovery in post-acute stroke

D. Quaglia1, M. Gasperi1, R. Coser1, G. Grisenti1, M. Scartozzi1, E. Girardi1, N. Mazzini1

1 Villa Rosa Rehabilitation Hospital – APSS Trento, Pergine Valsugana (TN), Italy

INTRODUCTION

In the last decade, neurorehabilitation robotic technologies have become widely spread and scientific evidence of their clinical effectiveness has increased [1]. Functional recovery of the upper limb is one of the main rehabilitation goals for post stroke hemiplegic patients and the use of robotic technologies is recommended in stroke guidelines [2]. The main objective of this study is to evaluate the robotic training effect on the upper limb neuromotor outcome after stroke. In addition, another aim is to evaluate the potential effect on motor recovery speed during the hospitalization time.

METHODS

A retrospective observational study of 106 post-acute stroke patients (< 6 months) 71±13 years old, consecutively hospitalized at Villa Rosa Rehabilitation Hospital was performed. 64 of these patients received only conventional treatment (TC), while the remaining 42 patients received both conventional treatment as well as rehabilitative training with robotic systems (TR). The recommendation or contraindication to use these robotic technologies was decided by the physiatrist after clinical-functional assessment of the patient. The technologies consisted of the robotic glove Gloreha Professional Idrogenet and the exoskeleton Armeo Spring Hocoma with anti-gravity support for the upper limb weight. The rehabilitation outcome was evaluated with the FMA-m (Fugl-Meyer Assessment for the arm-hand motor function 0-66 score), that was assessed at hospital admission (T0) and at hospital discharge (T1) [1-3].

RESULTS

Figure 1a: the patient subgroup treated with robotic technologies in addition to conventional treatment (TR) showed a better rehabilitative outcome trend for FMA-m values lower than 50. In particular, the difference between subgroups become clinically significant for values lower than 30.

Figure 1b: the patient subgroup treated with robotic technologies in addition to conventional treatment (TR) that had an initial FMA-m lower than 30, tended to have faster neuromotor recovery of the upper limb.

Speed parameter is calculated as the mean recovery of FMA-m in two weeks time, corresponding to the duration of a standard cycle for robotic technology training.

DISCUSSION

Data analysis show that robotic therapy integration in the upper limb and hand rehabilitation process has a positive effect on outcome and on motor recovery speed. In particular the highest benefits are obtained in patients with an initial FMA-m lower than 30 at hospital admission, corresponding to no or poor movement capacity of the arm-hand.

REFERENCES

INTRODUCTION
Increased activity of premotor and motor areas of the brain, well-known as movement-related cortical potentials (MRCPs), reflects the obligatory processes underlying the preparation of any voluntary movement [1]. To become apparent, MRCPs require the segmentation of the electroencephalographic (EEG) signal around a movement-related trigger [2]. Several techniques have been applied for the identification of movement initiation [3-4], mostly in fine and simple movements (e.g. finger flexion), but recently also in complex movements (e.g. step initiation). Nonetheless, it is conceivable that the resulting time reference may vary due to the measurement instrument used to provide the trigger or to the relevant biomechanical parameter used. Therefore, the aim of this study is to perform a comparative assessment to determine whether and how trigger identification techniques affect the MRCP in step initiation.

METHODS
Eleven able-bodied participants (7F and 4M; age 22±4 years) were recruited for the study. They were asked to stand on a force plate (FP) feet shoulder-width apart. After initial familiarization, subjects were instructed to perform a self-initiated forward step towards a second FP juxtaposed to the first at ground level. The task was considered concluded when the participant restored the initial posture on the second FP. Then they were requested to perform the backward-oriented step using the same leading leg utilised in the former task. At the end of each step, they were asked to stay still and relax, because this time window was considered the baseline for the following step on the EEG signal. Overall, 200 forward- and 200 backward-oriented steps were recorded. Brain activity was recorded through 64-channel EEG, whereas the following movement-related triggers were considered: (i) electromyography (EMG), activation of the tibialis anterior [3]; (ii) motion capture, CoM (medio-lateral component) and (iii) Heel Displacement (HD, vertical component); (iv) FP, ground reaction force (antero-posterior peak).

RESULTS
Repeated-Measures ANOVAs on the MRCP amplitude and peak latency showed a main effect of the triggering technique (p=0.003 and p<0.001 respectively). Specifically, force plates signal amplitude (-11.56±1.4 μV) was larger than motion capture (-5.0±0.5 μV and -6.5±1 μV) and EMG (-7.2±0.9 μV).

DISCUSSION
Different instruments allow the identification of a trigger for the MRCP analysis, varying in terms of time delay and resulting in different amplitudes and timing of the MRCPs. The comparative analysis indicates that, in terms of signal strength, cost and set up time, force plates are the best instrument. Indeed, to investigate step initiation, the amplitude of the MRCPs was enhanced when triggered to the force plate. The present study enriches existing literature related to MRCPs in locomotion tasks, confirming the initial hypothesis that during stepping tasks the MRCPs are influenced by the adopted trigger.

REFERENCES
The neurorehabilitation device Equistasi® impacts positively on the gait of Parkinson's disease subjects
F. Spolaor¹, A. Guiotto¹, D. Pavan¹, L. Arab Yaghoubi¹, A. Peppe³, P. Paone³, Z. Sawacha ¹, D. Volpe²
¹ Department of Information Engineering University of Padova, Padova, Italy
² Parkinson Excellence Center of the Fresco Institute for Italy, “Villa Margherita”, Vicenza, Italy
³ IRCCS Fondazione Santa Lucia, Roma

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, particularly, the gait cycle is influenced by rigidity, postural instability and camptocormic posture; in parkinsonians the stride and speed of the gait are decreased [2].

The aim of this study was to investigate the effects of Equistasi®, a wearable device based on focal mechanical vibration proposed as an innovative rehabilitative strategy for the treatment of motor symptoms in people affected by PD.

METHODS
Twenty five subjects participated in the study (BMI 26.2±3.3 kg/m², age 64.4±11 years). Subjects walked barefoot at their preferred walking speed on an 8m walkway at the BioMovLab (University of Padua) before and after 4 weeks of Equistasi® device treatment. A minimum of three walking trials per subject were collected. Gait analysis was performed with a 6 cameras stereophotogrammetric system (BTS) synchronized with 2 force plates (Bertec) and a surface electromyography (SEM) system (FREEEMG1000, 1000 Hz, BTS). The kinematics protocol reported in Volpe et al 2016 [3] was applied. The electrical activity of 4 muscles was collected bilaterally: Rectus Femoris (RF), Tibialis Anterior (TA), Biceps Femoris (BF) and Gastrocnemius Lateralis (GL). Three categories of variables were extracted: in term of kinematics, stride length (m and % of height), stride time (s), velocity (m/s), stance and swing (% of stride time), cadence (step/min) and step width (m); in term of joint kinematics, flexion@extension, abduction@adduction and internal@external rotation angles of trunk, hip, knee (only flexion@extension) and ankle joint; in term of SEMG, Peak of the Envelope (PoE in AV) and Peak of the Envelope occurrence (PPoE) within the gait cycle.

RESULTS
After treatment the following changes were observed (see Figure 1): cadence and step width decreased, stride time and stride length increased, the stance phase decreased and the swing phase increased (p<0.03, Paired T test). With respect to joints kinematics, an increment in pelvis rotation, in trunk obliquity and rotation were highlighted (p<0.04). Pearson’s correlation showed that ankle and knee angles range of motion were increasing accordingly to GL’s PoE increment. Mean and standard deviation of ankle joint were reported in Figure 1. Overall the adoption of Equistasi led to encouraging results, assessing a positive effect of the mechanical focal vibration as stimulation of proprioceptive system in PD’s patients. These effects may open a new possibility on PD’s management.

DISCUSSION
Overall the adoption of Equistasi led to encouraging results, assessing a positive effect of the mechanical focal vibration as stimulation of proprioceptive system in PD’s patients. These effects may open a new possibility on PD’s management.

REFERENCES

Figure 1: cadence and step width increase (in blue ankle dorsi@plantar flexion before Equistasi treatment, in red after Equistasi treatment, in yellow healthy subjects
INTRODUCTION
Fragile X Syndrome (FXS) is the leading form of inherited intellectual disability and autism spectrum disorder, caused by a tri-nucleotide CGG repeat expansion in the promoter region of the FMR1 gene [1]. The cognitive profile in FXS includes deficits in executive control and in visuospatial abilities, as well as in language and severe behavioural alterations with hyperactivity, impulsivity, anxiety; the condition often is associated with medical comorbidities among which epilepsy [1]. On the other hands in these subjects the most frequent musculoskeletal manifestations include severe flexible flat feet, excessive laxity of the joints, and possible scoliosis [2], that justifies a referral for gait analysis evaluation in FXS children. However motion analysis systems which are currently most widely used in rehabilitation do not allow kinematic data to be collected automatically without the attachment of markers, controlled conditions and/or extensive processing times. These limitations have hampered the use of motion capture in children with Fragile X Syndrome. The aim of the present study was to verify the feasibility of introducing gait analysis evaluation in FXS children by adopting a combined approach of markerless motion capture and surface electromyography (sEMG) within ambulatory assessment conditions.

METHODS
After appropriate informed consent by the parents, four FXS children (mean±SD age of 10.4 (6.0) years and 18.7 (4.7) BMI of Kg/m²) were acquired at the Pediatric Department of Padova Hospital through 4 synchronized GoPro Hero cameras combined with an sEMG system (FreeEmg, BTS, 1000Hz) that collected the activity of Tibialis Anterior (TA), Gastrocnemius Lateralis (GL), Rectus Femoris (RF) and Biceps Femoris (BF). Each subject performed several gait trials and at least three trials per subjects were processed. Sagittal plane kinematics was obtained as in [3] (Fig.1-top) and hip, knee and ankle flexion/extension joints rotations were computed together with spatio-temporal parameters; in term of sEMG analysis, onset and offset activation timing was obtained [4] and peak of the envelope computed [5]. Pathological subjects’ data were compared with normative bands obtained during a preceding study [6].

RESULTS
Joint Kinematics Results (Fig. 1 (bottom)) showed an asymmetric gait pattern, reduced knee flexion/extension range of motion, an overall altered hip and ankle joint kinematics at loading response and pushoff phases. Reduced sEMG activity was observed on left side muscles compared to right ones. Compressively lower sEMG activity was recorded on GL and RF with respect to TA and BF.

DISCUSSION
Beside the small sample subjects, preliminary results showed the presence of an altered gait pattern on each FXS child both in term of lower limbs muscles activity and joint kinematics. These data could be used for planning interventions.

REFERENCES
Lifting biomechanics: a combined approach of plantar pressure and surface electromyographic analysis.

Spolaor Fabiola1, Annamaria Guiotto1, Federica Cibin1,2, Davide Pavan1, Zimi Sawacha1
1 Department of Information Engineering, University of Padua, Padua, Italy
2 BBSof srl, Spinoff of University of Padova

INTRODUCTION
Complexity and multidimensional nature of Low back pain’s (LBP) risk factors pose a significant challenge for risk management strategies aimed at minimizing the level of exposure [1]. Abnormal foot posture and function have been associated with LBP [2]. However, based on the evidence that LBP patients display alterations in trunk and abdominal muscles recruitment patterns in meeting lifting task demands, it seems important also to assess changes in muscle activation patterns related to this task. The aim of our study is to understand the relationship between changes in posture and muscles activation during different lifting task.

METHODS
Twenty healthy subjects equally divided in female (mean ± SD BMI and age respectively of 22±2.3 kg/m² and age 24±2.4 years) and male (mean ± SD BMI and age respectively of 23±1.3 kg/m² and 24±2.3 years) were asked to perform 3 consecutive squat lifts with different weights (4/8/12/16 Kg for the female and 6/12/18/24 Kg for the male [3]) at three different heights (floor to pelvis, floor to shoulder, pelvis to shoulder, Fig.1). Kinematics, kinetics, sEMG and plantar pressure analysis were performed through a stereophotogrammetric system (BTS) synchronized with 2 force plates (Bertec), an 8 channels sEMG (BTS) and Novel PedarX system. The signals from Rectus Femoris (RF), Rectus Abdominis (RA), Biceps Femoris (BF) and Erector Spine (ES) were collected bilaterally and Peak of the Envelope (PoE) and the Position of the Peak of the Envelope (PoPE) in % of the task duration were extracted [4]. Peak of Pressure (PoP), its position (PoPP) in % of the task duration and the Centre of Pressure (COP) displacement were extracted. Pearson correlation analysis and One way Anova (p<0.05) across these variable were calculated (IBM Spss Statistics 19).

RESULTS
Positive significant correlations were obtained between the following variables (Fig1):
- the peak of COP excursion in anterior-posterior direction and the PoE of ES bilaterally,
- the PoP on the right foot and the right PoE of ES,
- the peak of the COP excursion in medial lateral position and the PoE of RA bilaterally,
- the peak of COP excursion in anterior-posterior direction bilaterally and the left ES PoE,
- the PoP on the right foot and the right PoE of ES,
- the left peak of COP excursion in the medial-lateral direction and the right PoE of ES,
- the PoP on the left foot and the left PoE of ES.

DISCUSSION
The variation in the adaptations assessed by changes in both muscles activation and plantar pressure may provide interesting insight in the analysis of the neuromotor control strategy adopted to stiffen the spine. Even though our study only involved healthy subjects, results seems to reflect the “guarding strategy” theory, where subjects with LBP modify trunk muscles activation during lifting task. The study has already been extended to a pathologic group and data are under processing.

REFERENCES
INTRODUCTION
The wide-spread application of inertial measurement units (IMU) to the analysis of motor and locomotor functions is based on some aspects: operative ease, low-cost, possibility to drive real-time analysis and feedbacks. The basic hypothesis for an effective IMU-based movement analysis is that the IMU reference frame can be assumed rigidly associated with the anatomical segment. In the present study we aim at assessing the previous hypothesis concerning IMU stability. Three commercial IMUs, 4 body segments, more than one IMU's locations (four on the thigh, three on the shank and on the foot) were considered in order to identify recommendable or unsuitable operative choices.

METHODS
One healthy adult subject underwent a gait analysis based on the LAMB protocol and measured by a SMART optoelectronic system (BTS, Italy), performing different locomotor tasks (gait, step ascending and descending, sit-to-stand). A set of different IMUs were fixed with biadesive tape onto body segments, each IMU were marked by three small-sized not-aligned markers in order to identify an IMU local reference frame. The position of each LAMB marker was computed relative to the local reference frame of any IMU located on the same body segment, in the hypothesis that both marker and IMU are rigidly fixed onto the same anatomical segment. The stability index (SI) associated to each IMU/IMU_location/task set was computed as the module of the standard deviations of each component of the relative coordinate of each marker in the IMU reference frame. Overall stability indexes are tested with ANOVA and post-hoc and reported as average, grouping data according to IMU model and anatomical segment.

RESULTS
Experimental data (here not reported) showed that proximal location on the thigh and dorsal location on the foot should be avoided. It is recommended a middle location on the shank. The mechanical stability of each IMU model on the considered segments is summarized in Table 1.

<table>
<thead>
<tr>
<th>IMU</th>
<th>Weight (g)</th>
<th>Size (mm)</th>
<th>SI (mm) pelvis</th>
<th>SI (mm) thigh</th>
<th>SI (mm) shank</th>
<th>SI (mm) foot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xsens Mtw</td>
<td>27.5</td>
<td>58 x 14 x 34</td>
<td>7 *</td>
<td>10 *</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Cometa Wavetrack 2015</td>
<td>5.3</td>
<td>32 x 25 x 7</td>
<td>9</td>
<td>12 *</td>
<td>6 *</td>
<td>3</td>
</tr>
<tr>
<td>Cometa Wavetrack 2018</td>
<td>10.0</td>
<td>35 x 24 x 10</td>
<td>10</td>
<td>11</td>
<td>5</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 1 - IMUs: features and stability upon anatomical segments (* p< 0.05, across IMU differences)

DISCUSSION
The assumption that an IMU is rigidly fixed onto an anatomical body segment is fundamental to further perform computation of segments orientations and joint angles. The stability of markers versus skeletal rigid frames has already been verified [1]. In the present study we considered different IMUs (their between-difference here considered is only in terms of weight and size) and different IMU locations. The results, obtained from one subject, evidenced that the different IMUs are substantially equivalent in term of stability. Even when a difference in stability was significant, its value was very small. A possible interpretation of those small differences may consists in a stabilizing effect of a larger IMU mass and size. Nonetheless this larger dimensions may have a negative effect in terms of encumbrance onto the body and possibly interfering with the task performances. Therefore the operative choice about IMU and IMU location should result as a trade-off among different quality features.

REFERENCES
Wearable sensor use for assessing walking dynamic balance in gait ataxia: comparisons between different stability indexes.

M. Serrao1,2, G. Chini1, A. Ranavolo3, T. Varrecchia4, C. Conte1,3, C. Casali1, F. Pierelli1, Draicchio1
1Dipartimento di Scienze e Biotecnologie Medico-Chirurgiche, Sapienza Università di Roma, Latina, Italia
2Laboratorio di Analisi del Movimento, Policlinico Italia, Roma, Italia.
3Department of Occupational and Environmental Medicine, Epidemiology and Hygiene, INAIL, Monte Porzio Catone, Rome, Italy
4Dipartimento di Ingegneria,Università Roma Tre, Roma, Italia

INTRODUCTION
Gait and balance impairments are the most characteristic motor features of gait ataxia, greatly influencing the patients’ independence in daily life activities, quality of life and risk of falls. These gait abnormalities are the consequence of poor limb coordination and also reflect the adaptive and compensatory strategies adopted by patients to maintain stability during walking [1]. The objective assessment of the gait stability is essential in this disease in order to follow the gait decline as well as to evaluate the response to the rehabilitation. In this study, we recorded the gait of a sample of patients with ataxia using a wearable inertial sensor to evaluate a series of stability indexes. Our aim was to established which index, among several, is the most sensitive for this disease.

METHODS
Seventeen patients affected by primary degenerative cerebellar ataxia and sixteen age-matched healthy adults were studied by means of an inertial sensor (G-STUDIO, BTS, Milan, Italy) to measure trunk kinematics during over-ground walking. The trunk acceleration of ataxic patients and healthy controls was recorded in the three spatial directions (anterior-posterior, medio-lateral and vertical). Trunk stability was quantified by four stability indexes, in each spatial direction: i) maximum Lyapunov exponent; ii) recurrence quantitative analysis; iii) coefficient of variations (stride-to-stride); iv) harmonic ratio. T-test or Mann-Whitney were used to compared values between patients and controls. Spearman test was used to correlated the indexes values with the number of falls/year.

RESULTS
Significant differences (p<0.05) were found in the maximum Lyapunov exponent, coefficient of variation and harmonic ratio values between patients and controls with an high size effect (Figure 1). All the three significant indexes were positively correlated with history of falls. Conversely, no differences were found for the recurrence quantitative analysis.
DISCUSSION
Our results indicate that Lyapunov exponent, harmonic ratio and stride-to-stride coefficient of variation should be taken into consideration in the gait assessment of patients with ataxia in order to better follow the gait decline as well as to optimize balance rehabilitation to prevent falls. Further studies should evaluate whether these stability indexes explore different aspects of balance disorder.

REFERENCES
Time-course of running treadmill adaptation – pilot study

L. Simoni1,2, G. Pasquini1, S. Pancani1, F. Vannetti1, C. Macchi1, S. Pogliachi2

1 Don Gnocchi Foundation IRCCS, Florence, Italy, 2 Department of Neurosciences, Biomedicine and Movement Sciences, University of Verona, Italy

INTRODUCTION

Studies on running kinematics and energetics usually take place on a treadmill, because it offers many advantages in studying the running gait compared to overground. Treadmill running, however, can be considered equal to overground running only when runners are expert in the use of the device [1]. There are several aspects of running, both related to kinematics and energetics, that seem to be modified by repeated treadmill practice, but timing and mechanisms of adaptation have not been yet widely studied in literature [2]. The purpose of this study was to establish the effects of three 15-minutes running sessions, on novice treadmill runners both in terms of kinematic and energetics adaptation process.

METHODS

Eight males recreational runners (age 43±10 years, mass 72±6 kg, height 177±5, half-marathon seasonal best 1h40±20’), unexperienced in the use of treadmill, participated in the study. Participants performed three treadmill running trials of 15’ at comfortable self-selected speed, in one week. Spatio-temporal and metabolic running parameters were observed, using a marker-less optical system (Optogait, Microgate, Bolzano) and a portable ergospirometric device (Oxycon Mobile, Vayre Medical). Mean values and standard deviation for each parameter were registered at minute 5, 10 and 15. A repeated measure two-way ANOVA was used to determine if there were any within-subject significant differences in each dependent variable across the time point and the three subsequent running sessions. A post-hoc pairwise comparison was used to determine between which time points or running sessions there were differences.

RESULTS

- Contact time increases and Cadence decreases in function of time, probably cause to the search for a run pattern more stable and similar to those of overground running [3]. In our sample, a 15’ trial is sufficient to adapt these parameters. In line with these results, a significant decrease in running energetic expenditure across time could be expected. Nevertheless, time appear to influence significantly VO2 and RER, but adaptation timing and mechanisms are not clear. Further studies with a sample more homogeneous in terms of level of performance, may be necessary to study adaptation of metabolic parameters more in depth.

DISCUSSION

An adaptation process is observed for spatio-temporal running parameters across the time point. Contact time increases and Cadence decreases in function of time, probably cause to the search for a run pattern more stable and similar to those of overground running [3]. In our sample, a 15’ trial is sufficient to adapt these parameters. In line with these results, a significant decrease in running energetic expenditure across time could be expected. Nevertheless, time appear to influence significantly VO2 and RER, but adaptation timing and mechanisms are not clear. Further studies with a sample more homogeneous in terms of level of performance, may be necessary to study adaptation of metabolic parameters more in depth.

REFERENCES

Spectral characterization of tremors using accelerometer and gyroscope inertial sensors

H. Briegas 1, R. Soussé1, M. Conti2, R. Jauregui1 S. Balocco3,
1 Dycare, Barcelona, Spain. 2 Conti’s affiliation, MedSport Human Performance Lab, Como & Varese, Italy. 3 Dept. Mathematics and Informatics, University of Barcelona, Barcelona, Spain

INTRODUCTION

Every human body has a tremor. The healthy condition (called basal tremor) is characterized by a low intensity shaking, whereas high intensity tremor might be pathologic or intentionally mimicked to simulate physical disability. The aim of this study is to characterize basal and mimicked tremors, using simultaneously accelerometer and gyroscope signals. Then, a machine learning approach has been applied to discriminate the two types of tremors and a new set of features is proposed.

METHODS

Dycare® inertial measurement system has been chosen, since it combines accelerometer and gyroscope in a single device and has an optimal sampling frequency of 102.4Hz. In order to characterize the basal tremor, a total of 30 basal tremor signals from 30 healthy subjects (mixed sexes, aged between 11-80 years) were acquired. 12 of these volunteers were also asked to mimic a pathological tremor. Each recording was performed holding the arm outstretched in front of the body. Then, the fast Fourier transform (FFT) of the signals was computed. The characterization of the basal and mimicked tremor is obtained averaging the spectra between subjects and analyzing the peak frequencies (Figure 1). To discriminate the two classes, a Random Forest classifier is trained with the following features: the spectral main frequencies, amplitudes, form factor, root mean square, mean and standard deviation. Since the number of samples for mimicked tremor (12) is highly unbalanced compared to basal tremor (30), only 12 samples per class are considered (one for each subject).

RESULTS

The signal analysis reported similar results in gyroscope and accelerometer signals. However, relevant characteristics can be observed when basal versus mimicked tremor signals are compared: (1) In both spectra there are two peaks, and the second peak is located between 8-12Hz in each signal. (2) In basal signals, the first peak has always lower amplitude than the second one (while it does not happen in mimicked signals) (3) The first basal peak is located around 2Hz in basal tremor while it is located around 6.75Hz in the mimicked one (4) The peak amplitudes of basal signals are lower than the mimicked ones. The classifier trained with set of features described in the method section reached an accuracy of 83% when discriminating between both tremor classes.

![Basal and Mimicked Spectra](image)

Figure 1: Accelerometer (blue-left) and gyroscope (orange-right) signals, obtained averaging the FFT spectra. The rows represent the basal (above) and the mimicked (below) measurements, respectively.

In both signals (accelerometer and gyroscope), the peaks in the spectra are located at 2Hz and 8-12Hz in the basal plot (above) and at 6.75Hz and 9Hz in the mimicked signal (below). Red circles highlight the peaks in the plots.

DISCUSSION

From the basal signal characterization, it is found that the second peak at 8-12Hz can be associated with the basal tremor, as it is also reported by [1]. Thus, we can infer that the second peak in mimicked tremors might belong also to basal tremor. Besides, only when the tremor is mimicked, the first peak displays a higher amplitude and a higher frequency than the one from the basal signals. Finally, the classifier has demonstrated to be useful to automatically classify the two tremor types. However, a higher number of subjects would be beneficial to obtain a more reliable classification. The reported indicators open the door to further accurate tremor characterisation, but also to the option of precisely discriminate basal from mimicked tremors. Moreover, compared with other measurement systems, inertial sensors represent a less expensive, simpler and faster measurement solution.

Assessment of the knee angle in the human gait using inertial sensors
R. Sousse1, J. V. Ferrer-Roca2, M. Conti3, R. Jauregui4, S. Balocco4
1 Dycare, Barcelona, Spain. 2 CAR, Sant Cugat, Spain 3 MedSport Como & Varese - Italy
4 Dept. Matematics and Informatics, University of Barcelona, Barcelona, Spain

INTRODUCTION
Optical motion capture systems (OMC) are considered the gold standard for human gait motion analysis. However, such systems require a complex experimental setup (expensive cameras, and highly trained staff) and a reduced portability. Nowadays, new measurement devices based on inertial measurement units (IMU) aroused in the market [1]. The aim of this study is to compare the knee flexion/extension angle along the gait cycle – as it is a relevant angle when studying the foot to ground contact – using the DyCare® IMU sensors and an optical motion capture system (OMC).

METHODS
Ten subjects walking in a treadmill (27.3± 9.3 years; 1.80± 0.10 m; 73.37± 7.93 Kg) were simultaneously evaluated at three different gait paces (2km/h, 4km/h and 6km/h) using IMU and OMC systems. The 3D OMC system (Proreflex Qualisys) consists in eight infrared cameras having a image rate of 300 Hz (fig.1-a). At the same time, two DyCare® IMU sensors, having a sampling frequency of 100Hz, were attached to two cluster plates (thigh and leg). In order to compare both data-sets, each subject and speed acquisition must be firstly aligned as follows:
1 – Each pair of signals (OMC and IMU) is firstly separated in segments belonging to separate step cycles. That is done through the identification of the maximum peak of each repetition.
2 - Since each cycle has a different duration, for each signal, all the segments are aligned to each other using Dynamic Time Warping (DTW). A point-wise average and standard deviation profiles are obtained from the aligned segments (fig.1b).
3- Then, the IMU is compared versus OMC. Since the two acquisitions don't have the same sampling, the average and standard deviation profiles of each system are aligned using DTW. The comparison between both data-sets is performed by computing, for each subject and speed, the RMSE and Pearson correlation score is reported to quantify the angular error, and the global waveform similarity.

RESULTS
Over all the 30 signals, the mean and standard deviation (STD) of the RMSE obtained are 4.7° ± 1.5°. This corresponds in percentage to an average and STD of 7.8% ± 2.5% of the signal angular range. An average Pearson's correlation coefficient of 0.992 ± 0.004 is reached. When the signals of each gait pace are analyzed separately, the results are not considerably different from each other.

DISCUSSION
This study shows that IMU system can be a valid alternative to OMC systems. Furthermore, comparing the results obtained in this study with respect to previous research [1,2,3], a strong similarity between the measurements is reached as can be noticed by observing the Pearson’s correlation score obtained, (fig. 1-b). Such score outperforms the results reported in [2] and [3] and is comparable to [1]. If we observe the RMSE score instead, the IMU System outperform only [3], while it gets slightly worst results than [1], while [3] does not report this score.

REFERENCES
Analysis of temporal gait parameters during walking on sand using inertial wearable sensors.
G. Pacini Panebianco¹, M. C. Bisi¹, A. L. Mangia², R. Stagni¹, R. Fantozzi¹, S. Fantozzi¹
¹University of Bologna, Bologna, Italy; ²CIRI SDV-TS, Ozzano dell’Emilia, Italy

INTRODUCTION
Walking on sand (WOS) was demonstrated to increase the amount of burned calories in healthy subjects [1], lower limb flexion during swing in patients with multiple sclerosis [2] and to provide different loading conditions. [3] Most of the studies assessing WOS were performed in natural beach environment, investigating energy consumption [1]. The quantitative analysis of joint kinematics and mechanical work has been performed using stereophotogrammetry and force platform, respectively, only in controlled laboratory conditions [2,4], with difficulties in the replication of the sand surface and far from an ecological evaluation of WOS. Thanks to their portability and limited invasiveness, inertial measurements units (IMUs) allow kinematic measurement out of the laboratory. The present work aims to characterize WOS, analysing the estimation of gait temporal parameters (GTPs) from IMU’s data in three different conditions: hard surface, wet and dry sand.

METHODS
Five healthy subjects (3F,2M; 35±7years; 171.5±11.5m; 60.8±7.5kg) were recruited for the study. Measures of angular velocity were collected using two tri-axial IMUs (Cometa, Italy, fc142Hz) located on the lower shanks. Participants completed three walking tasks at self-selected speed in different conditions: hard surface (even concrete blocks), wet and dry sand. The same walking tasks were also filmed using a GoPro (Hero4, USA, fc120Hz). IMU led flashing was video-recorded and used for synchronization. For each participant and each condition, 96 steps were analysed, being the minimum number of steps available in all conditions. Gait events identified from videos were assumed as reference. From IMUs, GE’s were identified using the algorithm by Salarian et al. [5] (previously validated for walking on hard surfaces). GTPs (i.e. stance, step, stride and swing time) were derived from GE’s in all three conditions. The error was defined as the difference between GTPs estimated from IMU against GoPro. Dispersion around median value of the errors (Dm) was calculated as 75th percentile minus 25th percentile value of the error. A linear mixed model was adopted to perform statistical analysis using R software (R-Core Team., Austria, 2017)

RESULT
Error in stance and swing time detection significantly increased from hard surface (Stance Dm 56ms; Swing Dm: 55ms) to wet (59ms; 56ms) and dry sand (137ms; 138ms) condition. Conversely, no difference was found in stride and step detection errors (Figure 1a). Successively, the estimated stride and step time were found to be different across all conditions increased from hard surface to dry sand (Figure 1b).

![Figure 1. Minimum, 25th percentile, median, 75th percentile and maximum values of: (a) estimation errors and (b) GTPs as related to the different walking conditions (* p<0.05 ** p<0.001)](image)

DISCUSSION
Even though errors in stance and swing time tended to triple from hard surface to dry sand condition, preliminary accuracy results suggest that the use of IMUs for the estimation of GTPs can be adopted in gait performance assessment. Findings from this study warned to be cautious on the interpretation of increasing trend associated to stance and swing time across different conditions, since this variation resulted to be lower than accuracy in their estimation. Future research will focus on assessing more accurate methods to obtain a comprehensive characterization of WOS in real and ecological conditions.

REFERENCES
Quantitative characterization of motor control during gait in Dravet Syndrome using wearable sensors: a preliminary study

R. Stagni 1, M.C. Bisi 1, R. Di Marco 2, F. Ragona 3, M. Duso 2,4, S. Masiero 2,4, A. Del Felice 2,4

1 DEI-Università di Bologna, 2 University-Hospital of Padova, 3 Istituto Neurologico C Besta, Milano; 4 Neuroscience Dept - University of Padova

INTRODUCTION

Dravet syndrome (DS) is a severe genetic epileptic encephalopathy mainly caused by SCN1A mutations [1]. Children usually develop frequent and pharmaco-resistant seizures of several types. Besides cognitive delay, patients later develop gait alterations resulting in progressive gait deterioration [2]. Although related of the evolution of the pathology, an objective characterization of DS gait is still missing, both due to the variability of the observed alterations and to the extreme difficulty in laboratory assessment of these subjects. A characterization of DS gait would provide insight in the mechanisms underlying the alteration of motor control and, eventually, integrate monitoring of the pathology development. The limited invasiveness of wearable inertial sensors can significantly simplify the routine assessment and, in recent years, non-linear analysis of lower trunk acceleration has provided novel insight in the development of motor control [3,4]. The aim of the present study was the preliminary characterization of DS gait in terms of its dynamics, as related to control, using non-linear indexes.

METHODS

Ten subjects (2M/8F; median 18y, min-max 14-32y; 159cm, 124-195cm; 55kg, 45-80kg) diagnosed with DS participated in the study. At neurological examination, 8 subjects showed extrapyramidal signs, 7 pyramidal signs, and 2 myoclonus. All but one presented with a variable degree of ataxia. Three wireless tri-axial inertial sensors (Opals, APDM, 128 Hz) were strapped to the lower trunk and shanks of each subject. Subjects walked back and forward along a 6 m straight path during continuous data acquisition. Turns and pausing intervals were quantitatively identified and excluded from the analysis, as well as the initial and final stride of each walking segment. Sixty strides were analyzed for each subject. The fundamental frequency of lower trunk acceleration was calculated to estimate gait cadence. Harmonic Ratio (HR), Recurrence Quantification Analysis (RQA: AvgL, DET, RR) and Multiscale Entropy (SE: τ=1..6) [5] indexes were calculated from trunk acceleration signal in V, AP, ML direction. Results were compared to reference control groups from 6 to 25 years of age.

RESULTS

Fundamental frequency of DS subjects resulted comparable to that of young healthy adults.

DISCUSSION

Results allowed to differentiate DS gait from that of reference populations of all ages. In particular, rhythmicity, regularity and symmetry of DS gait are always the lowest in all directions, while control results less automatic and recurrent in the sagittal plane (V and AP), and more automatic and less complex in the ML direction. In line with gait patterns observed with integrated stereophotogrammetric analysis, limited sagittal recurrence in the sample population is potentially related to a substantial lack of propulsion, especially at the ankle, counterbalanced by trunk anterior leaning, remaining of traits of parkinsonian gait, while lower automaticity is suggestive for signs of ataxia. Preliminary results seem to relate to clinical signs of the sample population.

REFERENCES

Wearable robotic exoskeleton for overground gait rehabilitation in complete spinal cord injured patients

S. Mazzoleni 1, E. Battini 1, A. Rustici 2, G. Stampacchia 2

1 The BioRobotics Institute, Scuola Superiore Sant’Anna, Pontedera, Italy, 2 Spinal Cord Injury Unit, Pisa University Hospital, Pisa, Italy

INTRODUCTION
In the last two decades there has been a growing interest in research and clinical applications of robot-assisted rehabilitation [1]. Robot-based rehabilitation treatments are usually based on the motor learning concept, resulting from intensive, repetitive and task-oriented motor activities [2]-[4]. Currently the use of overground robotic exoskeleton in gait rehabilitation is growing [5] with the objective of improving mobility of patients with severe lower limbs disability. The aim of this study is to investigate the effects of an overground robotic exoskeleton gait training in complete spinal cord injured (SCI) patients in terms of improvements in quality of life and patient-robot interaction.

METHODS
Sixteen SCI patients (12 men, mean age: 35.3 ± 10.3 years, range: 22-48) were recruited for this study. SCI patients underwent n=20 robot-assisted gait training sessions based on an overground robotic exoskeleton (Ekso GT, Ekso Bionics, USA) three sessions per week. The 10 Meter Walk Test (10MWT), 6 Minute Walk Test (6MWT), Time Up and Go (TUG) test and the Endurance test were assessed at T0 and T1. During the robot-assisted gait training the following gait parameters were recorded: (i) standing time, (ii) walking time, including latency between consecutive steps, and (iii) number of steps.

RESULTS
All recruited patients complete the study without suffering any adverse effects. Table 1 shows the results of gait tests and gait parameters. Statistically significance changes were observed on 6MWT, TUG and 10MWT and Number of steps.

Table 1. Values of gait tests and parameters at T0, T1 and change, expressed as mean ± standard deviation. Legend: * p<0.05, ** p<0.001

<table>
<thead>
<tr>
<th>6MWT (m)</th>
<th>T0 (36.19 ± 10.91)</th>
<th>T1 (49.00 ± 10.68)</th>
<th>Change (12.81 ± 0.22)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10MWT (m/s)</td>
<td>0.11 ± 0.04</td>
<td>0.15 ± 0.04</td>
<td>0.03 ± 0.00</td>
</tr>
<tr>
<td>TUG (s)</td>
<td>99.00 ± 44.20</td>
<td>69.03 ± 19.95</td>
<td>-29.97 ± 24.25</td>
</tr>
<tr>
<td>Endurance (m)</td>
<td>23.93 ± 12.27</td>
<td>34.50 ± 16.32</td>
<td>10.57 ± 4.04</td>
</tr>
<tr>
<td>Walking time (min)</td>
<td>17.91 ± 5.91</td>
<td>23.43 ± 12.30</td>
<td>6.24 ± 6.39</td>
</tr>
<tr>
<td>Standing time (min)</td>
<td>33.88 ± 10.97</td>
<td>28.43 ± 13.55</td>
<td>-5.45 ± 2.57</td>
</tr>
<tr>
<td>Number of steps</td>
<td>271.63 ± 128.45</td>
<td>724.21 ± 431.31</td>
<td>452.59 ± 302.86</td>
</tr>
</tbody>
</table>

DISCUSSION
The results of this study show that the robot-assisted gait training based on overground robotic exoskeleton in complete SCI patients provide improvements in term of patient-robot interaction (Table 1). Indeed gait tests and gait parameters show an improvement in terms of covered distance and gait abilities under robotic assistance. These findings confirm our preliminary results on the appropriate use of clinical tests commonly administered to assess gait functions in incomplete SCI patients even to provide an assessment of complete SCI patients during robot-assisted gait training [6].

REFERENCES
INTRODUCTION
Despite the documented health benefits of combining functional electrical stimulation with indoor rowing (FES Rowing) in paraplegia [1], crucial issues seem to exist. A pivotal concern is the determination of which, when and how to stimulate the leg muscles during FES rowing. FES-Rowing system have been focused on the stimulation of quadriceps and hamstrings with current pulses of constant amplitude and duration [2]. Here we sample surface electromyograms (EMGs) from multiple muscles in both right and left leg to assess when and to which extent each muscle contributes to the lower limb movements observed during indoor rowing.

METHODS
18 elite rowers (range: 14-30 years, 163-195 cm) were instructed to perform 30 consecutive strokes at 24 strokes/min on a rowing machine. Bipolar EMGs were collected bilaterally from tibialis anterior, gastrocnemius, soleus, vastus medialis and lateralis, rectus femoris, biceps femoris and semitendinosus muscles. Electrodes were placed according to [3]. Activation onsets and offsets were estimated from EMG envelopes for each rowing cycle and compared between muscles and sides. Rowing cycles were identified from the data provided by two encoders mounted on the axis of rotation of the flywheel and of the seat. EMGs and encoder data were sampled synchronously and transmitted wirelessly (DuePro, OT Bioelettronica and LISiN, Torino).

RESULTS
Different muscles were activated at different periods of the rowing cycle; ankle dorsiflexors and knee extensors were elicited during recovery and drive phases respectively (Figure A; significant difference between onset and offset between muscles; ANOVA, muscle effect; p<0,05). Side differences in both onset and offset values were occasionally observed for some muscles, although these differences amounted to less than 7% of the rowing cycle (cf. tibialis anterior left-right onset values in Figure A). Pearson correlation analysis did not reveal any asymmetric modulation in the amplitude of EMGs collected bilaterally for all muscles (R>0.74 p<0.05; Figure B). These group results are illustrated in the Figure for a representative participant and muscle set.

DISCUSSION
Our results suggest that: i) muscles other than hamstrings and quadriceps are elicited during rowing; ii) timing of activation is muscle dependent but it is not side-dependent. It seems therefore that including ankle dorsiflexors in the stimulation loop and patterning stimulation specifically for different muscles, equally for both legs, would likely improve the benefits of FES Rowing in paraplegia.

REFERENCES
Time-frequency correlation analysis of surface EMG signals: cross-energy localization during gait
A. Strazza¹, F. Verdini¹, A. Mengarelli¹, S. Cardarelli¹, S. Fioretti¹ and F. Di Nardo¹
¹Department of Information Engineering, Università Politecnica delle Marche, 60131 Ancona, Italy

INTRODUCTION
The purpose of this work is to assess the correlation in time-frequency domain, i.e. cross-energy density, of the surface EMG signal of ankle muscles usually involved in able-bodied walking. The cross-energy density has been identified by means of Continuous Wavelet Transform (CWT), a time-scale analysis method for multiresolution decomposition of continuous-time signals, providing a good localization in time-frequency domain [1].

METHODS
Five healthy young adults were recruited for the study. Electromyographic signals were acquired (sampling rate: 2 kHz) and processed by the multichannel recording system, Step32 (Medical Technology, Italy). Each subject was instrumented, bilaterally, with foot-switches and sEMG probes. Probes were applied over Tibialis anterior and Gastrocnemius lateralis (TA, GL), following the Winter’s guidelines [2]. sEMG signals were processed by means of CWT. Mother wavelet Daubechies of order 4 with 6 levels of decomposition (db4) was chosen to implement the wavelet transform. CWT was applied for removing noise from sEMG signals and to identify the correlation between antagonist muscles in time-frequency domain (CWT co-scalogram function). Cross-energy density was identified as the interval in time-frequency where the co-scalogram is exceeding the 72% of the peak value of cross-energy density in both time and frequency domain.

RESULTS
For GL, the energy density in time occurred from 13% to 17% of GC with a lower energy, and in mid-stance, from 25% to 53% of GC. The maximum energy density in frequency was detected in frequency band between 65-167 Hz (Fig 1B). For TA, the energy density in time occurred in early stance, from 2% to 14% of GC and in swing phase from 73% to 88% of GC. During mid-stance phase, a lower energy density of TA is detected between 30% to 34% of GC. The energy density in frequency was detected in frequency band between 60 and 220 Hz (Fig. 1C). The localization of TA and GL correlation (cross-energy density) was assessed in mid-stance phase, between 30% and 35% of GC in time and between 65-164 Hz in frequency domain (Fig. 1A).

Fig. 1 Panel A: the 2D color representation of the co-scalogram between TA and GL signals. Panel B e C: scalogram for sEMG signals from TA and GL.

DISCUSSION
The localization in time of maximum cross-energy density, performed in the present study, could be interpreted as the time-interval where the sEMG signal reached its peak value of cross-energy. The localization in frequency of maximum cross-energy density, was interpreted as the frequency-band where EMG signals of TA and GL showed the maximum frequency content of their superimposition. Thus, cross-energy density performed by CWT co-scalogram function could be considered as a marker to assess ankle muscles synergies.

REFERENCES
Effects of a wearable proprioceptive stabilizer on kinematics and spatio-temporal gait parameters in young with genetic ataxias

A. Romano¹, M. Favetta¹, T. Schirinzi¹, G. Vasco¹, S. Summa¹, S. Minosse¹, E. Castelli¹, M. Petrarca¹

¹MARlab, Neuroscience and Neurorehabilitation Department, Bambino Gesù Children’s Hospital – IRCCS, Rome, Italy

INTRODUCTION

Genetic ataxias are a degenerative disease of cerebellum, brain stem, and spinal cord, in which gait and limb ataxia are key clinical features [1]. Focal mechanical vibration was found effective in improve limb and gait ataxia in adults with hereditary ataxias [2]. Equistasi® is a medical wearable device composed by nanotechnology fibers that transform body temperature into mechanical vibration (<0.8N, ≃9000Hz) able to generate a variation of muscle length of max 0.002mm [3]. This is a preliminary study to evaluate the effect of Equistasi® focal mechanical vibration on kinematic and spatio-temporal parameters in three young patients with genetic ataxias through 3D gait analysis.

METHODS

Two patients (one boy and one girl) with Friedreich’s ataxia and one boy with congenic ataxia from mutation of PMM2 gene were evaluated by 3D gait analysis. Media age was 14.7±1.7yo. Three evaluations were carried out with 21 days apart (T0, T1, T2). For each evaluation five strides were recorded for each patient and averaged together, the full body Plug-in-Gait (PiG) model was used. Kinematics data were collected for pelvis and lower limb. Three weeks of treatment with Equistasi® were conducted for each patient between T0 and T1.

RESULTS

The analysis of the kinematic data of lower limbs is shown in Fig. 1. Spatio-temporal parameters shown: a progressive increase in stance phase duration (T0: 62.0±4.2%; T1: 63.0±4.3%; T2: 63.6±4.5%) with increased double support phase (T0: 23.9±0.08%; T1: 25.0±0.06%; T2: 25.8±0.06%) and a reduction of the walking speed (T0: 1.01±0.22m/s; T1: 0.92±0.18m/s; T2: 0.89±0.17m/s) with reduction of the stride length (T0: 1.12±0.13m; T1: 1.08±0.15m; T2: 1.05±0.11m) among all three condition; slight reduction of the support base between T0 (0.23±0.087m) and T1 (0.21±0.065m) and its enlargement in T2 (0.25±0.066m). No changes in the other parameters.

DISCUSSION

Data shown an efficacy of the treatment in improvement ankle first rockers, restrain of pelvic movements degeneration and a positive effect on balance during gait. Majority of improvements found seems to be treatment dependent and regress at its end. Our result suggest that focal mechanical vibration could be a useful instrument to support rehabilitation in ataxic person confirming previous findings and expanding them to young patient. Future studies are needed to confirm present finding.

REFERENCES

Specific gait training positively impacts biomechanics pattern in MS patients.
C. Tramonti1, S. Di Martino1, C. Chisari1
1Unit of Neurorehabilitation, University Hospital of Pisa, Italy.

INTRODUCTION
Disease progression in patients with Multiple Sclerosis (MS) present a variable course, with almost 85% of patients reporting ambulatory dysfunctions as their main complaint [1]. Considering that ambulatory function is necessary for daily activity, promoting customized strategies addressing patients’ walking abilities may have significant functional importance. Accordingly, our group pointed out how a task-oriented circuit training (TOCT) provides a valid tool in promoting functional recovery, with a positive impact on quality of life in MS [2]. The aim of our study is to quantitatively test the efficacy of this specific intensive training for ambulatory function on gait kinematics in MS patient with mild-moderate disability. Moreover, we evaluate if modifications in functional abilities during walking tests and quality of life are related to changes in spatio-temporal and kinematic parameters after training intervention.

METHODS
We recruited 19 MS subjects (12 female and 7 male, 3,5<EDSS score<5,5), with either the relapsing-remitting, primary progressive or secondary progressive subtype. All subjects, in a stable phase of disease, performed TOCT treatment accounting for 10 sessions (5 sessions/week). Patients underwent 3-D Gait Analysis (GA), and spatio-temporal and kinematic data were acquired according to Davis protocol. As regard the kinematic pattern, the value of the maximum and the minimum angle reached in each joint (hip, knee, ankle) was calculated. Furthermore, the dynamic range of motion (ROM) of each joint was determined. Outcome measures comprehended: spatio-temporal and kinematic parameters of GA; Timed Up and Go Test (TUG), Six-minute walk test (6MWT), 10 meter Walking Test (10mWT), Physiological Cost Index (PCI), Dynamic Gait Index (DGI) and Multiple Sclerosis Impact Scale (MSIS-29). Functional scales and GA were performed before (T0) and after (T1) the rehabilitative protocol.

RESULTS
Functional measures presented a trend in improvement after training intervention, with significant values revealed for DGI and MSIS-29 scales. Data obtained showed no significant modifications in spatio-temporal parameters after TOCT, with only a trend in reduction in double limb support time. Sagittal plane kinematics revealed an increased range of movements (ROMs) at all lower-extremity joints after training, with significant values for knee joint. The correlation analysis demonstrated that functional scales (TUG T0, 6MWT T0) were significantly related to changes in spatio-temporal parameters (Δ Double Support Duration) and subjective evaluation of disease’ impact (MSIS-29 T0). Finally, a better functional recovery (TUG T1) was associated with improvement in ankle’s angular excursions (Δ Ankle ROM).

DISCUSSION
The main results obtained in our study provide evidence that TOCT training can be an effective approach, able to positively modify motor performance and gait pattern in MS. Moreover, we underline that functional scales, in particular TUG and 6MWT tests, can be related to biomechanics modifications and proposed as predictive factors of motor recovery after specific interventions.

REFERENCES
INTRODUCTION
Assistive robotic devices, specifically designed to share the environment with human users even physically interacting with them for long periods of time, demand to tackle the problem of a safe and dependable human-robot interaction [1], [2]. The proposed work, which focused on the peculiar aspect of the interaction between people with hand disabilities and robotic assistive devices, describes how a hand exoskeleton system, developed by the Department of Industrial Engineering (DIEF) of the University of Florence (UNIFI) to assist people with deficiencies in hand opening, has been used as a test-bench for a control strategy based on surface ElectroMyoGraphy (sEMG). Finally, a subject affected by hand disability has been enrolled for the study and two tests sessions have been carried out to preliminary assess the usability of the system and verify the learning speed of its use.

METHODS
Since the exploited mechanism was already optimized for the tracking of the trajectories of the long fingers [3], the control system had to mainly focus on managing trigger actions. The developed control strategy can be split in two main parts. The first part takes care of classifying the user’s intentions relying on the measurements of the forearm muscular activity captured by EMG sensors, while the second part translates them into appropriate control commands for the actuation system. Different hand gestures are discriminated with a point-in-polygon classifier, fed with the signals coming from two EMG sensors placed on the antagonist muscle bands responsible of fingers/wrist extension and flexion and trained with an internally developed Graphical User Interface. To assess the impact level of the control strategy on the usability of the device, an experimental campaign was carried out at the Rehabilitation Center “Don Carlo Gnocchi” in Florence. One subject (male, aged 54, 1+ MAS1), wearing the exoskeleton, has been asked to grasp objects of different sizes and shapes from those of daily use and move them on a standard shoebox: five trials have been conducted for each object and the average grasping time was calculated. These test sessions have been accomplished twice in a week and the subject performed training in between.

RESULTS
The average grasping times resulted to be quite high compared to common standards for able-bodies, but they have become remarkably lower (about 30% less) in just one week of training. Tests also showed that, in general, the grasping time is longer as the shape gets more complicated; this is since, using a 1-DOF mechanism, an object with an irregular and thin shape might not be grabbed properly. Moreover, lateral grasping arose to be more difficult than the vertical one. This can be attributed to many difficulties encountered by the patient to correctly activate his muscles in different positions (the exoskeleton weight itself is differently compensated).

DISCUSSION
The presented research work aimed to assess the usability of a surface EMG control strategy to actuate a hand exoskeleton by a physically impaired user during the activities of daily livings. The proposed system has been tested on a real patient to validate the discussed approach and quantify the capability of the user in managing the control strategy during objects handling. Tests have highlighted a rapid reduction of the grasping time between the two sessions, which demonstrates that the system presents a quite steep learning curve: an encouraging result for future developments.

REFERENCES