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SIAMOC Società Italiana di Analisi del Movimento in Clinica

FAM FONDAZIONE ALMA MATER

XX Congresso
Della
Società Italiana di Analisi del Movimento in Clinica
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Il congresso annuale della Società Italiana di Analisi del Movimento in Clinica, giunto quest'anno alla sua ventesima edizione, ritorna a Bologna, che già ospitò il terzo congresso nazionale nel 2002. Il legame tra Bologna e l'analisi del movimento è forte e radicato, e trova ampia linfa sia nel contesto accademico che nel ricco panorama di centri clinici d'eccellenza. Il congresso SIAMOC, come ogni anno, è l'occasione per tutti i professionisti dell'ambito clinico, metodologico ed industriale di incontrarsi, presentare le proprie ricerche e rimanere aggiornati sulle più recenti innovazioni nell'ambito dell'applicazione clinica dei metodi di analisi del movimento. Questo ha contribuito, in questi venti anni, a fare avanzare sensibilmente la ricerca italiana nel settore, conferendole un respiro ed un impatto internazionale, e a diffonderne l'applicazione clinica per migliorare la valutazione dei disordini motori, aumentare l'efficacia dei trattamenti attraverso l'analisi quantitativa dei dati e una più focalizzata pianificazione dei trattamenti, ed inoltre per quantificare i risultati delle terapie correnti.

LETTURE MAGISTRALI

Digitising mobility - modernising clinical practice?

Lynn Rochester, Professor of Human Movement Science and Director of Clinical Ageing Research Unit, Newcastle University, UK

Parkinson's and dementia urgently need accurate, low-cost diagnostic tools to aid timely diagnosis, disease stratification, predictive modelling and decision making for intervention optimisation (e.g. medication selection; disease staging and targeted support). How a subject walks - their gait - is often termed 'the 6th vital sign' of brain and body health. This is because poor gait is associated with greater mortality, morbidity, cognitive decline, dementia and fall risk. Gait analysis and discrete gait outcomes are therefore receiving interest as tools to discriminate and predict early disease, track disease progression and identify therapeutic response. Patterns or signatures gait impairment may support enhanced diagnosis even in early/prodromal detection and a window of opportunity for neuroprotective therapy. Despite the promise, gait analysis and the potential of gait outcomes as clinical biomarkers has not reached widespread clinical adoption. Digital technology in the form of wearables offers a pragmatic low-cost solution to measure gait translating assessment from the laboratory to the clinic and home. In this talk I will draw from work of my group to explore the growing body of evidence to support gait as a clinical biomarker. I will highlight the role that digital technology is playing to make this a possibility including opportunities and challenges. Finally, I will look to the future using a large consortium aiming to validate digital mobility biomarkers called Mobilise-D as an example.

Ubiquitous Health: Wearable Computing Systems that Increase Quality of Life and Transform Health Care

Bjoern Eskofier, PhD, Professor, Machine Learning and Data Analytics (MaD) Lab, Friedrich-Alexander-Universität Erlangen-Nürnberg

The fast-growing costs of acute care are pushing the healthcare systems worldwide to a limit. Globally, we are coming to realize that we cannot afford to provide everybody with access to unlimited healthcare services in the light of current demographic changes. An alternative approach is emerging that focuses on "keeping people healthy" through primary and secondary prevention in all phases of life. This paradigm shift in the healthcare systems is demanding research in ambient, sensor-enhanced assistive technologies that "keep people outside of the hospital". Therefore, a fast-growing interest exists for wearable and pervasive computing systems and ambient assistive technology that aim at ubiquitous health support for individuals in the home and community settings.

The talk will present research projects (c.f. Fig. 1) where we implemented ambient sensors for physiological and biomechanical data recording, used pervasive computing systems for monitoring and signal processing, and employed machine learning algorithms and simulation models in order to provide accurate information to patients and caregivers in neurological and musculoskeletal movement disorders with the aim of promoting quality of life of patients and improving health care.

As a model disease for technology development, Parkinson's disease (PD) will be presented. Routinely assessed by observation, the disease's symptoms are rated as part of semiquantitative clinical scores. In an alliance between medicine and engineering, a sensor-based gait analysis system that objectively assesses gait patterns in PD was developed. The system provides spatiotemporal gait parameters and was evaluated in PD patients (n=190) and age-matched controls (n=101). Cross-sectional analysis revealed altered gait parameters and variations represented by short steps, shuffling gait, and postural instability in PD patients that were specific for different disease stages. In addition, gait parameters reflecting the progressive nature of PD corresponded to physician ratings of gait impairment over time. These data demonstrated the feasibility and applicability of more objective sensor-based gait measurement in PD for clinical studies and individual patient care.

The outlook of the presentation will focus on future research directions that aim at contributing to the above mentioned paradigm shift in global healthcare systems by the use of wearable and pervasive computing for ubiquitous health support.

Accuratezza e precisione nella stima di grandezze cinematiche e dinamiche: gold standard e calibrazione

Angelo Cappello, Professore di Biomeccanica, Università di Bologna

Diagnosi e riabilitazione neuromotoria richiedono una valutazione accurata e ripetibile dello stato di un soggetto o di alcune sue funzioni. Gli strumenti utilizzati e le metodologie impiegate sono affetti da errori che inevitabilmente si propagano alle stime in modo diretto od indiretto. Verranno forniti alcuni esempi che dimostrano come la scarsa accuratezza possa portare a conclusioni totalmente erronee sullo stato del soggetto. Verrà quindi presentata una teoria linearizzata per poter definire a priori l'accuratezza richiesta per gli strumenti e le metodologie impiegate. Verranno portati esempi relativi a misure cinematiche e dinamiche dove si dimostrerà che il gold standard dipende anche dal tipo di elaborazione che il segnale dovrà subire. Saranno infine mostrati alcuni esempi di calibrazione a partire dal gold standard: calibrazione anatomica, calibrazione di una pedana di forza, calibrazione di un sensore magneto-inerziale.

L’analisi strumentale nella malattia di Parkinson e nei “disordini del movimento”: realtà e prospettive.

Giovanni Abbruzzese, Professore di Medicina Fisica e Riabilitazione, DINOGMI, Università di Genova

L’approccio diagnostico e terapeutico ai “disordini del movimento” è fondamentalmente basato sulla valutazione semeiologica, anche con l’utilizzo di specifiche scale cliniche. Tale approccio non sempre consente un adeguato inquadramento diagnostico e le misure di outcome si rivelano spesso inadeguate e poco coerenti con la percezione dei pazienti e con la loro qualità di vita. Ad esempio, pur essendo le alterazioni del cammino tra i sintomi maggiormente invalidanti della malattia di Parkinson, la deambulazione non è valutata quantitativamente, ma descritta in termini generali che non sono sensibili ai cambiamenti conseguenti alla progressione della malattia.

L’analisi strumentale del movimento nelle sindromi ipo- e ipercinetiche da disfunzione dei gangli della base può rappresentare, quindi, un indispensabile complemento alla valutazione clinica consentendo d’identificare i soggetti che potrebbero beneficiare maggiormente di un determinato intervento o gli interventi più adatti per determinati sottotipi di soggetti e il monitoraggio dei pazienti nella vita quotidiana.

La sfida, ancora non vinta, sarà quelle di implementare un’innovazione tecnologica (“friendly & patient oriented”) che possa assistere il clinico nella gestione nel tempo dei pazienti con “disordini del movimento”.

Sessione 1 – APPROCCI COMPUTAZIONALI INNOVATIVI PER L’ANALISI DEL MOVIMENTO

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INTRA-SUBJECT CLASSIFICATION OF GAIT PHASES BY NEURAL NETWORK INTERPRETATION OF EMG SIGNALS

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INTRODUCTION

Identification and classification of different gait phases is an essential requirement to temporally characterize muscular recruitment during human walking. Encumbrance and time-consuming experimental set-up are often associated to the measurement of gait phases. The present study proposes a Deep-learning methodology for intra-subject classification of the two main gait phases (stance and swing) during ground walking in conditions similar to daily life, based on the interpretation of surface electromyographic (sEMG) signals alone.

METHODS

Surface EMG signals from tibialis anterior, gastrocnemius lateralis, hamstrings, and vastus lateralis were acquired bilaterally in 12 healthy adult subjects (6 male and 6 female) during ground walking in conditions similar to daily life, including natural deceleration, reversing, curve, and acceleration. Details can be found in [1]. A mean (± standard deviation, SD) of 452±114 strides was considered for each subject. A Multi Layer Perceptron (MLP) model with three layers of 512, 256 and 128 units was used to classify stance vs. swing phases. The neural network was trained separately for each subject on 90% of subject's strides. Then, classification of gait phases was attempted in unlearned step sequences of the same subject (in 10% of subject's strides). Performance of the classifier was tested vs. gold standard, represented by basographic signals measured by means of three foot-switches per foot. A 10-fold evaluation is computed to take into account the possible variability of the results. The present approach did not require specific features to be extracted from the signal, differently from previous studies [2,3].

RESULTS

The mean classification accuracy (±SD) over 10 folds for each one of the 12 distinct subjects was reported in Table 1. Mean (±SD) accuracy over the population was 95.2±1.6%, ranging from 92.6% to 97.2%. Specifically, mean (±SD) accuracy over the population was 96.3% for swing labeled segments and 93.5% for stance labeled segments.

Table 1. Mean classification accuracy (%) and SD over 10 folds for each subject

	Subjects											
	s1	s2	s3	s4	s5	s6	s7	s8	s9	s10	s11	s12
Mean	95.3	92.6	96.4	93.3	94.6	97.2	96.6	97.0	96.4	95.6	94.7	92.6
SD	3.1	1.5	1.1	1.5	2.8	1.9	0.9	0.9	1.1	3.2	3.4	1.8

DISCUSSION

The results of present study support the suitability of Artificial Neural Networks in classifying the main gait phases from sEMG signals alone, without needing human intervention in selecting relevant signal features. On the basis of a mean accuracy of around 95%, the present study proposes a Multi Layer Perceptron model (three hidden layers, maximum size: 512 neurons) as a very suitable model for intra-subject classification of stance vs. swing during ground walking in conditions similar to daily life. High accuracy of the present results suggests testing the reliability of MLP classifier not only to classify swing and stance phases, but also to predict the occurrence of the transition between phases, such as heel strike and toe off.

REFERENCES

[1] Di Nardo F, et al. *Journal of Electromyography and Kinesiology* 2013; 23:1428–1433.
[2] Nazmi N, et al. *Biomedical Signal Processing and Control* 2019; 7:334-343.
[3] Ziegier J, et al. *Proceedings of the IEEE RAS and EMBS International Conference on Biomedical Robotics and Biomechatronics*, 2018; August-2018:978-983.

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IMPAIRMENT OF GLOBAL LOWER LIMB MUSCLE COACTIVATION DURING WALKING IN CEREBELLAR ATAXIAS.

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INTRODUCTION

Cerebellar ataxia (CA) is a movement disorder that can affect all the global and segmental gait parameters [1]. One important compensatory strategy in CA is to increase the coactivation of the antagonist muscles to compensate for muscle hypotonia and to cope for the widened center of mass oscillations. Recently, it has been proposed a new method to analyze the simultaneous coactivation of many muscles [2], irrespective to either agonist-antagonist interaction. Aims of this study were to investigate the time-varying multi-muscle coactivation function during gait in CA patients, to compare the data with those from healthy subjects (HS).

METHODS

23 patients with CA and 23 age-, sex- and speed-matched HS was investigated. CA and HS participants were asked to walk at self-selecting speed and HS were asked also to walk at low speed. During the walk simultaneous acquisition of kinematics and muscle activity was performed, with a motion analysis system: 8 infra-red cameras, 22 reflective markers and 12 probes placed on 12 lower limb muscles. The sEMG signals were processed and then it was calculated the co-activating using the time-varying multi-muscle coactivation function (TMCf) [2]. The following parameters were measured: i) synthetic co-activation index (CI); ii) full width at half maximum (FWHM) and iii) center of activity (CoA).

RESULTS

CA patients showed significant higher values of CI, *FWHM* and lower values of *CoA* than HS. A negative correlation between all coactivation parameters was found with the gait speed (*CI*-GS r=-0.50 p=0.01; *FWHM-GS* r=-0.48 p=0.02; *CoA-GS r=0.48 p=0.2*), while a positive correlation was found between CoA and trunk lateral displacement (*CoA-Disp r=0.57 p=0.005*).

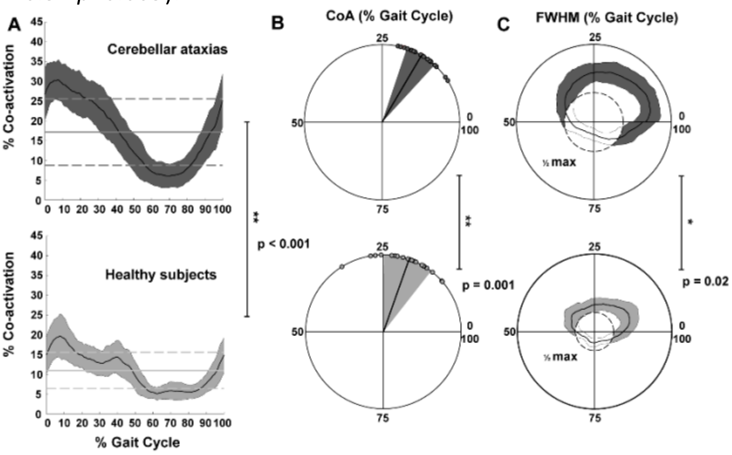

Figure 1: Lower limb global coactivation in CA patients and HS. (A) Time-varying multi-muscle coactivation function and co-activation index (TMCf) curves. (B) TMCf centre of activity. (C) TMCd full width at half maximum

DISCUSSION

The global co-activation was significantly increased in CA patients compared to HS, in terms of both CI and FWHM. In addition, CA patients show a significant shift of the CoA towards the initial contact. Our study suggests that the less severely affected CA patients use the global coactivation as compensatory mechanism during the earliest and most challenging subphase (loading response) to lessen the lateral body sway and thus improving gait stability. This information could be exploited to optimize the rehabilitative treatment aimed at improving the lower limb muscle control during gait.

REFERENCES

[1] Serrao M., et al. Harmony as a convergence attractor that minimizes the energy expenditure and variability in physiological gait and the loss of harmony in cerebellar ataxia. Clinical Biomechanics, 2017, 48: 15-23.
[2] Ranavolo A., et al. A new muscle co-activation index for biomechanical load evaluation in work activities. Ergonomics, 2015, 58.6: 966-979.

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3D BONE ARCHITECTURE IN WEIGHT-BEARING COMBINED TO PRESSURE MEASUREMENTS IN THE DIABETIC FOOT

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INTRODUCTION

The complex structure of the foot skeleton changes over the progression a diabetic foot [1]. Bone alignments also change from non-weight- to weight-bearing [2]; only the latter offers a realistic representation during daily living activities. Quantification of 3D bone absolute and relative alignments are now possible in upright weight-bearing postures by means of the modern cone-beam CT (CBCT) [3]. Previous measurements were limited to 2D and affected by operator-dependent identification of alleged references. The present study aims at correlating dynamic plantar pressure with corresponding 3D bone alignments from CBCT in static weight-bearing in type 1-Diabetes patients.

METHODS

Dicom files of both feet were obtained from CBCT scans in 20 diabetic foot patients. For the present preliminary analysis, the most compromised foot from 6 patients (4M, type 1, 4 with neuropathy, 58±16yrs, 26±2kg/cm^2, 32±11yrs of disease -YOD-, Arch Index 0.25±0.02) was segmented, producing 3D models of the 30 bones. A software tool (Matlab 2017b) performed automatic geometrical calculations based on either anatomical landmarks and axes, or on Principal Component Analysis (PCA, Figure 1). For the joints, planar angles in all three anatomical planes and in 3D were calculated. In this preliminary analysis, metatarsal (M 1-5) and phalanx (P 1-5) bones were analyzed, for their height from the floor (H_), together with absolute (A_) and relative (R_) orientations, i.e. phalanx-to-metatarsal, in the sagittal plane only. Pressure patterns were acquired (EMED q-100), registered and averaged over 5 consistent gait trials for each patient and foot. For the above selected feet (mean contact time -CT- 0.68±0.06s), Peak Pressure (PP) and Pressure-Time Integral (PTI) were extracted at hallux and at first (M1), central and fifth (M5) metatarsals. Pearson's correlation analysis (R3.4.3, The R Foundation) was conducted on all these parameters.

RESULTS

Strong (R^2>0.6) and significant ($p<0.05$) correlations were found. Increasing age, BMI and YOD strongly correlated with increasing dorsiflexion of lateral phalanxes (A_P4, A_P5, R_M4P4 and R_M5P5; R^2 0.81-0.94); YOD also affected central metatarsals lowering (max btw H_M2, H_M3, and H_M4; R^2=0.65). Plantar loading increase at M1 – either PP or PTI - positively correlated with age (R^2=0.88), with the same 3D parameters (R^2 0.68-0.84) and also with M1 lowering (H_M1; R^2=0.78) and M2 elevation (H_M2; R2=0.71). Central metatarsal loading increased with P5 plantarflexion (A_P5; R^2=0.65). PP and PTI strongly correlated to each other at every region.

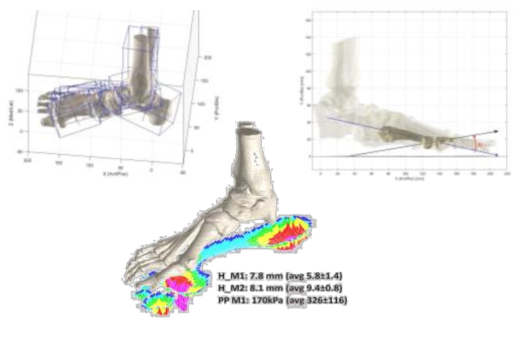

Figure 1. PCA-based reference frames for all foot bones (top left); R_M4P4 angle calculated on relevant 3D bone models (top right). Foot model registered on corresponding pressure map (bottom)

DISCUSSION

Measurements of foot bone architecture can be performed in 3D and in weight-bearing; the combination of these with plantar loading measurements is providing fundamental new insights for a thorough assessment of foot complications. The present initial exploitation on diabetic feet shows interesting though preliminary correlations between these measurements. These techniques will help designing and assessing more effectively orthotics and treatments.

REFERENCES

[1] Giacomozzi C et al. *J Biomech.* 2014;47(11):2654-9.

[2] Hirschmann A et al. *Eur Radiol.* 2014; 24(3):553-8.

[3] Barg A et al. *Foot Ankle Int.* 2018;39(3):376-386.

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EVALUATION OF PARKINSON'S DISEASE PROGRESSION: CHANGES IN SPATIO-TEMPORAL GAIT VARIABLES ALONG THE DIFFERENT STAGES OF HOEHN AND YAHR SCALE

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INTRODUCTION

The Hoehn and Yahr (H&Y) scale is a useful measure of disease progression of Parkinson's disease (PD) [1]. It is used to estimate the severity of PD, based on bilateral motor involvement and the compromise of gait and balance. However, actually, there is no study about the linking between gait impairments and the different stages of H&Y. Our aim was to establish clear links between gait impairments and disease progression to foster the usability of quantitative gait measures as outcome in future disease-modifying clinical trials [2].

METHODS

295 patients with PD (PwPD) were assessed by H&Y scale, modified to a 7-point scale (including stages 1.5 and 2.5), obtained in the medicated and "on" phase. PwPD were evaluated with a baropodometric walkway, and compared to a group of 80 elderly healthy subjects (HS). The spatio-temporal variables of gait were averaged over three trials, in which subjects were asked to walk at their usual velocity on the walkway. Nine gait variables, based on existing gait model [3,4], were analyzed to detect differences in the progression of the disease.

RESULTS

PwPD and HS were not different regarding age (p=0.10) and sex (p=0.32). PwPD were classified into six H&Y staging: 1, 1.5, 2, 2.5, 3, 4. ANOVA showed a significant effect of H&Y staging on all 9 gait variables (p<0.0005 for all variables). No difference was found in any variable between HS and PwPD with H&Y=1 (p=0.49), H&Y=1.5 (p=0.92) and H&Y=2 (p=0.17). On the contrary, with H&Y=2.5, speed and step length decreased (p<0.0005), while double support time (p<0.005), coefficient of variation (CV) of step length (p<0.0005), swing time CV (p<0.0005), stride velocity CV (p<0.0005), step time asymmetry (p<0.005) and swing time asymmetry (p<0.005) increased. Only step time showed no difference (p=0.20). At H&Y=3 no significant differences were found respect to H&Y=2.5, with the exception of step time that became different when compared with HS and the first stages of disease. Finally, all variables of PwPD with H&Y=4 were different compared to all other staging, except for step time asymmetry and swing time asymmetry (P=0.10). The coefficient of determination (R^2) between H&Y and gait speed, step length and step time was respectively 0.27, 0.28 and 0.10.

DISCUSSION

Our results showed a link between gait impairments and disease progression, evaluated with the H&Y. In particular, significant worsening of the spatio-temporal gait variables occurred at H&Y staging = 2.5, in which the disease is bilateral and balance impairment emerges. This finding supports the notion that locomotion in PD is degraded in association to poor balance control [5]. We suggest that, in order to quantify and describe gait impairments in PD for planning and evaluating rehabilitation intervention, it is necessary to analyze separately PwPD according to their H&Y staging.

REFERENCES

[1] Zhao YJ et al. *Movement Disorders* 2010;25(6):710-6.
[2] Mirelman A et al. *Lancet Neurol* 2019;S1474-4422(19):30044-4.
[3] Arcolin I et al. *Gait & Posture* 2018;66:S1-S2.
[4] Lord S et al. *Movement Disorders* 2013;28(11):1534-43.
[5] Giardini M et al. *Neural Plast* 2018;2018:5614242.

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AN EMG-INFORMED MODELLING APPROACH FOR THE PREDICTION OF INTERNAL VARIABLES DURING LOCOMOTION IN PARKINSON'S DISEASE PATIENTS: A FEASIBILITY STUDY

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INTRODUCTION

Gait disorder is one of the cardinal features of Parkinson's Disease (PD); so far, gait analysis is a useful tool in understanding movement impairments in PD [1-2]. Neuromusculoskeletal models have the advantage of enabling additional analysis which might improve the clinical therapy, such as muscle forces and joint stiffness. These variables allow a deeper understanding of neurological and musculoskeletal impairments, linking the neural activity to musculoskeletal disfunction [3].

METHODS

One PD's patient (weight 89kg, height 1.83m, BMI 26.57) who underwent two different rehabilitation treatments (underwater (UW) rehabilitation [2] and proprioceptive stabilizer (EQ) treatment [4]) and five control subjects (mean weight 75kg, mean height 1.69m mean BMI 24.16) were assessed. Data were acquired with an 8 cameras motion capture system (BTS, 200Hz), synchronized with 2 force plates (Bertec, 800Hz) and a 16 channels surface electromyography (sEMG) system (BTS, 1000Hz). In term of kinematics, the same markerset as in [1] was adopted, and the following muscles were acquired: Rectus Femoris, Biceps Femoris, Tibialis Anterior, Gastrocnemius Lateralis. Data were first processed in OpenSim (optimization-based software); inverse kinematics, inverse dynamics, static optimization were run; then CEINMS (informed by experimental EMGs data) muscle forces, torques and joint stiffness were computed.

RESULTS

Muscle forces interplaying over knee and ankle joints have been obtained from an EMG-informed model. Rectus femoris is shown as example in Figure 1a. The PD subject and the healthy cohort (PD red, CS blue) are compared on the left side. On the right, the differences between muscle forces of the same subject before and after the two treatments (PRE-treatment red, POST-UW black, POST-EQ blue) are presented. In Figure 1b the ankle joint stiffness is displayed.

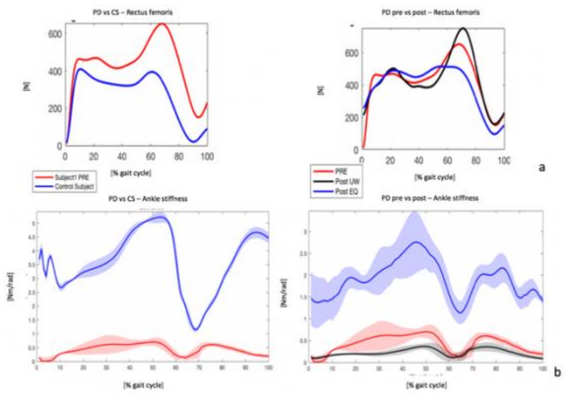

Figure 1. a) Rectus femoris muscle force b) Ankle joint stiffness

DISCUSSION

The pipeline proved to be feasible by adopting routine gait analysis data as input variables. The use of an EMG-informed model introduces a higher level of "subject-specificity" than the one obtained by adopting optimization-based model, giving a more accurate prediction of the muscle forces [3-5]. Stiffness results showed a promising possibility to adopt this variable as a biomarker for highlighting gait improvements in PD's patients and monitoring the disease progression. Further studies are needed in order to validate the model and to extend this approach to a larger population.

REFERENCES

[1] Volpe D, et al. *Gait Posture* 2017; Vol(52):87-94

[2] Chen P, et al. *International Journal of Gerontology* 2013; Vol(7):189–193.

[3] Sartori M, et al. *WIREs Syst Biol Med* 2017; Vol(9):e1368.

[4] Volpe D, et al. *PLoS One* 2014; Vol(17):9-11

[5] Sartori M, et al. *Journal of Neurophysiology* 2015; Vol(114):2509–2527.

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ASSESSMENT OF MOTOR COORDINATION IN STROKE PATIENTS USING UCM THEORY

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INTRODUCTION

The hemiplegia that commonly follows a stroke affects the ability of walking. Gait asymmetry, reduced walking speed, compensatory movements of trunk and nonparetic limb, all contribute to pathological gait [1]. The Central Nervous System (CNS) has the potential to overcome internal or external instabilities exploiting the presence of redundancy to execute a motor task. The uncontrolled manifold (UCM) analysis is a quantitative approach for motor variability and coordination analysis [2]. The UCM hypothesis assumes that the CNS "co-varies" multiple *elemental variables* consistently in order to guarantee a stable trajectory for the task performance variable. The variance of elemental variables can be hence split into two components within the domain of elemental variables: one is projected onto the UCM subspace (V_{UCM}), the other one onto the subspace orthogonal to the UCM (V_{ORT}). Accordingly, the V_{UCM} does not affect the motor performance (i.e., the performance is stabilized with respect to inter-stride variability of the elemental variables), while the V_{ORT} does affect the time course of the task variable. The Ratio of V_{UCM} and V_{ORT} (calculated as $V_{UCM} / (V_{UCM} + V_{ORT}) - 1$) is used as a measure of degree of stability: if Ratio>0, than the performance is said to be stabilized by kinematic synergy of the elemental variables. The aim of this preliminary study is to analyze the effects of stroke on motor redundancy and coordination through the UCM hypothesis during locomotion.

METHODS

Kinematic data (trunk, pelvis and lower limbs) of five stroke patients (4 males; age 68.8±9.7 yrs) was recorded during walking on treadmill at self-selected speed using 6-cameras optoelectronic system (VICON, Oxford, UK) with a sampling rate of 100 Hz. The UCM model described by [3] was used to characterize the movement in the sagittal plane during the stance phase. The COM trajectory was set as "performance variable" while joint angles at lower limbs were the "elemental variables". The variances of elemental variables (i.e., V_{UCM} and V_{ORT}), their Ratio and the Positive Rate of Ratio (PRR; i.e., the amount of positive values expressed as %), were computed for each subject, for both the affected and not-affected limbs, across 43±4 strides.

RESULTS

For each patient, the mean value of the Ratio was always greater than zero for both affected and not affected limbs (Table 1). It's worth highlighting that the Ratio value of the not affected limb was greater than the affected one, for all patients. Finally, the Ratio value was positive (i.e., PRR) for more than the 50% of the stance phase duration, with a greater incidence for the not affected limb.

Table 1. Mean value (standard deviation) of Ratio and PRR, for both the affected and not affected limb.

		P01	*P02*	*P03*	*P04*	*P05*
Affected Limb	MEAN (STD)	0.34 (0.23)	0.05 (0.33)	0.16 (0.09)	0.13 (0.40)	0.44 (0.21)
	PRR [%]	92	58	96	58	100
Not Affected Limb	MEAN (STD)	0.60 (0.19)	0.30 (0.29)	0.48 (0.21)	0.37 (0.22)	0.53 (0.18)
	PRR [%]	98	85	96	89	100

DISCUSSION

Results confirm the persistence of kinematic synergies although the disease; indeed, post-stroke patients seem to be able to adapt their walking stabilizing the COM trajectory. The absence of significant difference in the Ratio between paretic and non-paretic leg could depend on the fact that hemiplegic gait is not an exclusively unilateral functional problem. In fact, the bilateral cyclic nature of gait involves the coordination of both limbs and both cerebral hemispheres. Anyway, the greater value of the Ratio for the nonparetic limb with respect to the impaired one leads to the conclusion that the nonparetic limb retains stronger kinematic synergies. According to these preliminary findings, we hypothesize that the UCM analysis could be a suitable tool to explore the motor variability also in pathological gait.

REFERENCES

[1] Perry J., Garret M., Gronley J.K., Mulroy S.J. *Stroke* 1995; 26(6): 982-989.

[2] Scholz J.P., Schöner G. *Experimental Brain Research* 1999; 126(3): 289-306.

[3] Monaco V., Tropea P., Rinaldi L.A., Micera S. *Human Movement Science* 2018; 57: 227-235.

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AN EXTENSIVE, MULTI-SENSOR DATASET FOR EVENT AND FALL DETECTION IN HUMAN ACTIVITIES THAT INCLUDES VIDEO RECORDINGS AND DETAILED ANNOTATIONS

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INTRODUCTION

Wearable automatic monitoring system that detects or predict falls by analyzing the movement of patients are under evaluation. Promising data-driven approaches based on machine learning or, recently, deep learning embedded techniques have been proposed [1]. However, few human fall datasets that are both large enough and suitable for machine learning purposes are reported in the literature [2]. This study presents a new dataset tailored for the study of human movement and accidental human falls that has been explicitly designed for the application of machine learning techniques. The main characteristics of the presented dataset are: a) extensive number of tests; b) body network with seven wearable multi-sensor devices; c) synchronized recordings of both videos and time series of inertial sensors readings; d) complete annotations of sequences with detailed temporal intervals, essential to supervised machine learning.

METHODS

The dataset includes the recording of 34 healthy subjects (11 male, 23 female) in the age range of 19-70 years performing 10 activities of daily living (ADL) and 8 activities including a single fall in a controlled environment (Table 1). Activities are repeated either two (ADL) or five times (Fall) by each subject for a total of 60 trials per subject. The volunteers wear a body network of seven embedded multi-sensors strapped on different body positions: belt, left and right wrist, left and right shoulder, left and right ankle. Each multi-sensor records accelerometer, gyroscope, barometer and magnetometer data and is connected with a Bluetooth mobile gateway. A video is recorded for each trial, and synchronization is provided between video and sensor readings. Each video is annotated, on a frame-by-frame basis, by marking temporal intervals in which specific events (e.g. slip, fall) actually occur.

Table 1. List of activities in the dataset

Code	Description (ADL)	Code	Description (Fall)
N01	Walking	CF01	Fainting from a chair
N02	Jogging	CF02	Fall while trying to get up from a chair
N03	Stumble while walking but remain up	CF03	Fall while trying to sit down in a chair
N04	Pick an object from the ground	MF01	Fall forward while walking
N05	Gently jump without falling	MF02	Fall laterally while walking
N06	Walking upstairs and downstairs	MF03	Vertical fall by fainting
M01	Standing, lay on a "bed" and get up	MF04	Fall backward while walking
T01	Stumble while walking and use a table to avoid falling	TF01	Falling with use of hands in a table to dampen fall
C01	Sit in a chair, wait and get up		
C02	Try to get up and collapse in a chair		

RESULTS

The dataset includes about 2000 sequences, each corresponding to a specific trial performed by a single volunteer. Each sequence includes a) HD video recording b) seven different time series (each including multi-sensors readings) c) subtitle file marking the synchronization points for each sensor and the temporal intervals corresponding to specific events.

DISCUSSION

The main relevance of the dataset described is in enabling the application of machine learning methods for automatic detection of events (falls in particular) in human activities. The detail and extension of data recordings in the sequences contained allows the extensive training of automatic classifiers that are based on several popular techniques, such as SVM, RNN, CNN and Hybrid Neural Networks. While the dataset includes only simulated activities by healthy volunteers, we believe to be virtually impossible to acquire such detailed recordings in real-world conditions. On the other hand, a comparative study of event detection methods on the dataset presented and on other real-world datasets (such as FARSEEING [3]) would be definitely advisable.

REFERENCES

[1] Musci M, et al. *Arxiv preprint 2018;http://arxiv.org/abs/1804.04976.*

[2] Xu T, et al. *Applied Science* 2018;8(3):418-429.

[3] Klenk J, et al. *Eur Rev Aging Phys Act 2016;13:8*

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MULTI-SENSOR INTEGRATION AND DATA FUSION FOR ENHANCING GAIT ASSESSMENT IN AND OUT OF THE LABORATORY

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INTRODUCTION

Recently, there has been a growing interest in methods for monitoring individual motor performance during daily-life activities. To this end, inertial measurement unit (IMU) turned out to be the most relevant technological solution. From direct measures of angular velocity and proper acceleration of sensed body segments, a broad set of spatio-temporal gait variables can be derived through signal morphology analysis, biomechanical models and machine learning techniques. However, the validity of IMU-based methods depends on several factors, including motor impairment severity, environmental context, IMU location. Accurate displacement estimations can be particularly critical. Full acceptance of IMU-based methods for «real world» mobility assessment in clinical programmes needs a rigorous validation and this, in turn, advocates for the development of suitable gold standards. This work deals with the design of a wearable multi-sensor system (INDIP) that, by integrating different sensing technologies, aims at providing the best possible reference for digital gait assessment in real world scenarios.

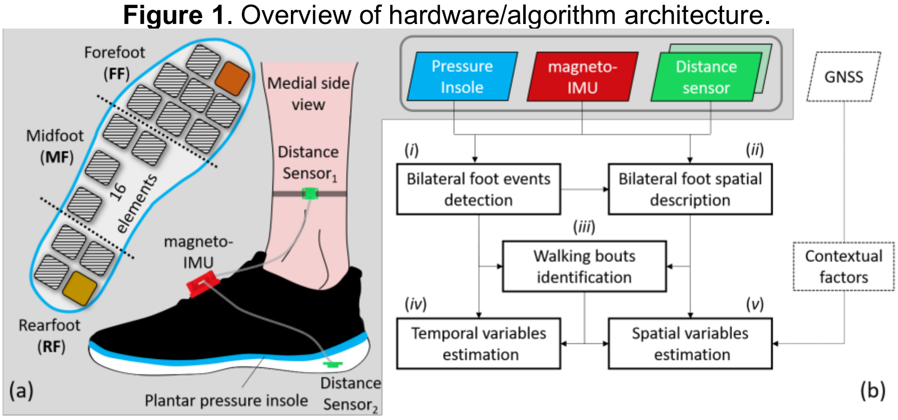
METHODS

The INDIP system includes a magneto-IMU, 2 distance sensors, and a plantar pressure insole (Fig.1a). Data are acquired by an ultra-low-power microcontroller and stored in an onboard flash storage for up to 4hrs of data logging. The system allows third-party devices to be synchronized via an external trigger. Multiple INDIP systems can be synchronized via a BLE protocol. The workflow for the data processing (Fig.1b) includes: *(i)* bilateral description of temporal events at foot level - this operation primarily relies on pressure data and secondarily on inertial and distance data; *(ii)* description of the foot position and orientation. This operation mainly relies on inertial data. Gait periodicity is exploited to implement zero velocity update techniques and self-tuning sensor fusion algorithms for the reduction of the integration drift errors [1]; *(iii)* walking bouts identification based on information provided in *(i)*−*(ii)* and according to standardized operational definitions; *(iv)*−*(v)* estimation of spatio-temporal gait variables for different walking bouts lengths.

RESULTS

Preliminary results based on IMU signals allowed the recognition of strides, walking bouts definition, and discrimination between straight and curvilinear portions. Foot clearance and inter-shank distance were obtained from distance sensor 1 and 2, respectively.

Figure 1. Overview of hardware/algorithm architecture.



DISCUSSION

Multi-sensor selection allowed to take full advantage of complementary characteristics of each sensing technology, providing a richer set of information to enhance gait assessment. For instance, by exploiting the 16-element pressure readings, it is possible to differentiate initial and final contacts for the different foot subareas (IC_{RF}, IC_{FF}, FC_{RF}, FC_{FF}). This allows to achieve a finer gait cycle segmentation compared to IMU-based methods only [1]. Thanks to the use of the distance sensors, the foot displacements estimated from the inertial data can be supplemented with information on foot clearance and inter-shank distance. These data can prove useful when analyzing highly abnormal gait patterns (e.g. foot-dragging walks, freezing). As supervised single-sensor machine learning methods require good labelled data, the INDIP system can also be used for generating reliable training data set. Finally, geolocation techniques can be easily integrated via BLE to correlate gait variables with contextual factors (Fig.1a).

REFERENCES

[1] Trojaniello D, et al. JNER 2014, Vol 11:152.
[2] Bertuletti S, et al. JoB 2019, Vol 84:274−277.

Sessione 2 – PORTARE L'ANALISI DEL MOVIMENTO FUORI DAL LABORATORIO

DOES CURVED WALKING SHARPEN GAIT DISORDERS? AN INSTRUMENTED APPROACH USING INERTIAL SENSORS

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INTRODUCTION

In everyday life, we are faced very often with changes in path directions and turning whilst walking. The ability to successfully perform these changes/turning is fundamental for a safe locomotion [1] and is strictly related to a decreased risk of falling [2]. This is particularly true for people with gait disorders, such as those who suffered of a severe traumatic brain injury (sTBI). Although the adoption of clinical tests based on curved paths has been proposed, few information is available about the quantitative differences between straight and curved walking, specifically when gait stability, symmetry, and smoothness are concerned. The aim of this study was to objectively quantify these differences in both healthy and sTBI populations, using an instrumented approach based on inertial sensors.

METHODS

Twenty healthy people (CG) (34.6±9.9 yrs; 15 males) and 14 people who suffered of a sTBI (35.0±12.6 yrs, 10 males) performed a 10-Meter Walking Test and a Figure-of-8 Walking Test while wearing four inertial sensors: 2 positioned on both distal tibiae and used for step segmentation, and 2 located at the pelvis (P) and sternum (S) levels. The following parameters related to gait stability, symmetry, and smoothness were obtained for the antero-posterior (AP) and medio-lateral (ML) directions: *i)* root mean square (RMS) values of the measured acceleration at P and S levels; *ii)* variation of RMS accelerations between P and S (attenuation coefficient, AC) [3]; *iii)* improved Harmonic Ratio (iHR) [4]; and *iv)* Spectral Arc Length (SPARC) [5], both calculated at P level. To evaluate differences between linear and curved walking in each group and between the two groups for each walking modality, Wilcoxon and Mann-Whitney tests, respectively, were performed for all the above-mentioned parameters (α=0.05).

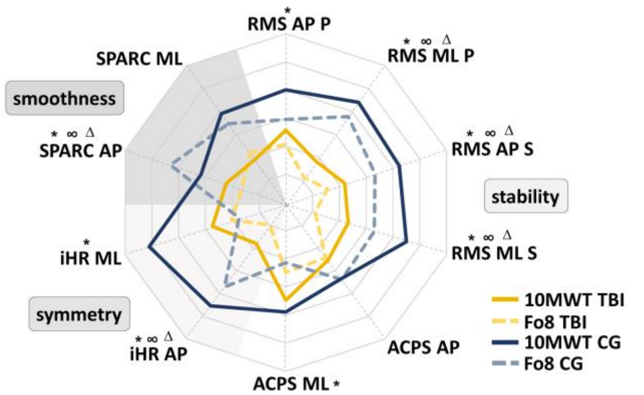

Figure 1. Stability, symmetry, and smoothness in CG and sTBI. Variability is not reported for the sake of readability. Significant differences: *CG: Fo8-10MWT; ∞Fo8: TBI-CG; ∆10MWT: TBI-CG.

RESULTS

CG showed significant differences between linear and curved walking, whereas no difference was displayed for sTBI, whose variability, however, was remarkable (as expected in this population). CG and sTBI presented statistical differences in terms of stability, symmetry, and smoothness for both walking modalities. Detailed information (including statistical differences) is displayed in Fig. 1, where, to ease reading, the additive inverse of RMS values was calculated to associate an increase with a clinical improvement and indices were normalized (z-score).

DISCUSSION

The results of the present study confirm that curved paths do put at strain our motor control more than straight paths. This is evident both in CG and sTBI (although not significant) in all investigated domains, i.e. stability, symmetry and smoothness. This is probably related to the higher voluntary (goal-directed) motor control demand required when walking in curved *vs* straight paths, in order to manage body rotations [1]. Although a larger sample size is needed to further confirm these findings, they suggest that the use of straight walking alone to assess gait disorders is discouraged, in favor of the adoption of complementary tests based on curved paths, such as the Figure-of-8 Walking Test.

REFERENCES

[1] Courtine G and Schieppati M. *Eur. J. Neurosci* 2003;18:177-190.
[2] Nevitt MC, et al. *J Gerontol* 1991;46(5):M164M-170.
[3] Mazzà C, et al. *J Neuroeng Rehabil* 2009;5:30.
[4] Pasciuto I, et al. *J Biomech* 2017;53:84-89.
[5] Beck Y, et al. *J Neuroeng Rehabil* 2018;15-49.

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MONITORING THE DEVELOPMENT OF ANTICIPATORY POSTURAL ADJUSTMENTS PRIOR GAIT INITIATION IN CHILDREN USING INERTIAL SENSORS.

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INTRODUCTION

The correct development of anticipatory postural adjustments (APA) during movement is fundamental for the overall motor development of a child. The assessment of APA prior to gait initiation could provide information to determine whether a child's motor development deviates from a typical trajectory and to plan possible effective interventions [1,2]. APA in children have been studied in traditional laboratory settings using force plates and/or electromyography [3-5], on small groups of participants (<10 per age) [1-5]. Despite the relevance of the topic, literature shows contrasting results (e.g. on which plane (frontal or sagittal) anticipatory behavior develops) [3,5], probably due to the small sample sizes considered. Wearable inertial sensors have been shown to be effective for evaluating APA prior gait initiation in elderlies and pathological populations [6]. Given sensor portability, their use have been proposed for the monitoring of motor control development in children, allowing the definition of motor trajectories reference values [7]. The aim of the present work was to evaluate the applicability of a sensor-based algorithm [6] for the assessment of APA during gait initiation in typically developing children.

METHODS

60 typically developing subjects (age groups: 6-, 8-, 10-, and 25 years, 6YC, 8YC, 10YC and 25YA) participated in the study. They were standing upright and were asked to start walking at their own speed. 3D acceleration and angular velocity of lower trunk and shanks were collected (Opals, APDM, sampling frequency 128Hz). Identification and characterization of APAs were computed following the method proposed in [6] (same sensors placement and orientation). APA measures computed from the lumbar accelerations were [6]: 1) peak acceleration toward the stance foot from baseline (PeakML), 2) forward trunk peak acceleration from baseline (PeakAP), and 3) APA duration. Measures describing first step and velocity computed from the shank angular velocity were [6]: 1) 1st Step Duration (defined as the time-to-peak angular velocity from APA end to heel-strike), and 2) the range of motion (RoM) of the swing phase (defined as the integrated angular velocity of the shank from APA end to heel-strike, 1st Step RoM). Effect of age was evaluated (Kruskal-Wallis, significance level 5%).

RESULTS

Percentage of participants in which APA periods were identified increased from 40% to 92% from the youngest group to 25YA. APA duration and 1st Step Duration increased significantly with age, while no significant trend was found in the other estimated parameters. All of the children presenting APA, showed a positive PeakML as expected; one 6YC (out of 5 presenting APA) and three 8YC (out of 9 presenting APA) did not show the expected positive PeakAP.

DISCUSSION

Preliminary results allowed characterizing APA prior to gait initiation in developing children, suggesting that ML adjustments are present in most of the children older than 8, while only 40% of the 6YC participants manifested this anticipatory adjustment. Among these children, some of the 6YC and 8YC did not show the anticipatory response in AP direction, while all of the 10YC and 25YA showed a positive value of PeakAP. These results appear in agreement with [3], which suggests that in children there is a prominence of the preparatory adjustments in the ML direction and a reduced magnitude of the responses in the AP direction. In order to confirm these preliminary findings, sample size will be increased, including younger and older children. Task repetitions will be considered to investigate if and how much APAs are structured and repeatable in developing children. Possible modifications of the algorithm for APA characterization will be necessary in order to better define APA period thresholds in ML and AP direction, allowing defining reference values for motor development monitoring.

REFERENCES

[1] Isaias IU, et al. *PLoS One*. 2014; 9(4)
[2] Fournier KA, et al. *Gait Posture.* 2010 May; 32(1): 6–9.
[3] Malouin F, Richards CL, *Gait Posture*. 2000 Jun;11(3):239-53
[4] Assaiante C, et al. *J Mot Behav*. 2000 Sep;32(3):211-26
[5] Ledebt A, et al. *Exp Brain Res*. 1998 May;120(1):9-17.
[6] Mancini M, et al. *Gait Posture*. 2016 Jan; 43: 125–131
[7] Bisi MC, et al. *Gait Posture*. 2019 Feb;68:232-237

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TOWARDS AN AUTOMATIC PARAMETER SETTING FOR MIMU SENSOR FUSION ALGORITHMS

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INTRODUCTION

Magnetic and Inertial Measurement Units (MIMU) are widely used in human movement analysis. MIMU orientation can be determined by combining accelerometer, gyroscope, and magnetometer data in a sensor fusion framework. Any algorithm for orientation estimation requires to define a given number of input parameters. It has been shown that any algorithm performance greatly varies depending on the selection of the parameter values according to both hardware and motion characteristics [1]. It is common practice to choose parameters values as set by the authors in their original implementations or by following a *trial and error* approach [2]. Unfortunately, the latter solutions are time-demanding, require a good level of expertise and do not guarantee for generalization. The aim of this work was to propose a method for sub-optimal parameter values identification based on specific hardware characteristics, different angular rates and types of motion without requiring reference data. The method validity was assessed on a popular complementary filter [2] using data recorded from a motion capture optical system (SP) as reference.

METHODS

The proposed method relies on the hypothesis that the value of the filter parameters minimizing the relative orientation of two MIMUs attached on the same rigid body, can be considered sub-optimal. The method validity was tested on Madgiwck's filter (MAD, [2]) which requires only one parameter to be set (β). Two pairs of MIMUs (Xsens-MTx and APDM-Opal) were aligned on a board equipped with four reflective markers. Reference orientation was obtained from marker trajectories acquired using a 12-camera SP (Vicon T20). A dynamic trial was recorded while an operator continuously changed the board orientation from 0° to 180° and back for five repetitions (2D motion) and then by performing a multi-axis rotation (3D motion). This protocol was executed at three rotation rates (rms 120-260-380 °/s). For each factor (hardware, angular rate, and type of motion), the orientation of each pair of MIMUs was computed for 76 values of β and then compared with SP to obtain the absolute orientation errors. Then, we searched for β* which minimized the relative orientation difference and for the interval of β values which corresponded to the absolute errors within the minimum (*E_min*) + 0,5°.

RESULTS

The values of β interval, *E_min* and β* are listed in Table 1 for both 2D and 3D results. The errors corresponding to β* (*E**) and to the default β=0.1 (*E_def*) set by Madgwick *et al.* in their original Matlab implementation [1-2] are also reported.

Table 1. Results for each condition analyzed (S=slow, M=medium, F=fast, XS=Xsens, AP=APDM).

		2D					3D				
		β interval	E_min	β*	E*	E_def	β interval	E_min	β*	E*	E_def
XS	**S**	0 – 0.0015	2.1°	0.0009	2.2°	4.2°	0 – 0.0498	2.3°	0.0050	2.3°	3.2°
	M	0 – 0.0018	2.0°	0	2.0°	5.0°	0 – 0.0550	2.1°	0.0074	2.1°	3.1°
	F	0 – 0.0020	3.0°	0	3.0°	6.1°	0 – 0.0743	4.9°	0.0273	5.0°	5.7°
AP	**S**	0.0082 – 0.1353	3.4°	0.0821	3.5°	3.6°	0.0101 – 0.0907	2.3°	0.1108	2.9°	2.8°
	M	0.0050 – 0.1827	5.5°	0.0302	5.5°	5.7°	0.0450 – 0.1827	3.5°	0.0608	3.6°	3.5°
	F	0 – 0.0498	6.8°	0.0041	6.9°	7.9°	0.0334 – 0.1496	7.3°	0.2231	8.8°	7.3°

DISCUSSION

Table 1 shows that the intervals of *β* where the errors are minimum were different depending on angular rate values, planarity of motion, and the MIMU model employed. These findings suggest that a fixed value of *β* could be not suitable for all experimental conditions. Moreover, the errors obtained using *β** computed with the novel proposed algorithm were close to *E_min* and the higher difference reached 1.5° for APDM-Fast-3D. For Xsens the errors obtained using *β** were lower than *E_def* in all cases.

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REFERENCES

[1] Bergamini, et al. *Sensors* 2014; 10: 18625 18649.

[2] Madgwick S. O. H. et al. 2011; ICORR, 2011.

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STUDY OF AGREEMENT BETWEEN TWO WEREABLE INERTIAL SYSTEMS FOR GAIT ANALYSIS BASED ON A DIFFERENT SENSOR PLACEMENT: G-WALK SYSTEM AND OPAL SYSTEM

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INTRODUCTION

The evaluation of rehabilitation outcomes in terms of space-time kinematic parameters is of primary importance in clinical practice about patients with neuro-motor disabilities. Although the gold standard in the gait analysis is still represented by stereophotogrammetric technology, inertial devices are having a very increasingly use in clinical practice. Despite the growing use of the latter, there is still a lack of knowledge about the agreement between systems based also on different sensor placement.

METHODS

The study has been carried out on a population of 43 patients with neuro-motor disabilities (60% males) aging from 18 to 78 years old admitted for rehabilitation treatments in the Neurology Unit of [2]. All subjects underwent a gait analysis session instrumented by both systems (Opal by APDM and G-WALK by BTS Bioengineering): 2 Opal sensor placed on each shin by velcro straps and 1 G-Sensor placed in the pocket of a belt in a lumbosacral region in according with the related handbooks. The gait analysis protocol consisted in a 10 meters walk along a straight path. For each subject the following value about the main kinematic gait parameters has been automatically calculated by the two systems: Cadence (steps/min), Gait Cycle Time (s), Stride Length (m). The agreement has been investigated by Bland-Altman technique, integrating the latter studying the absence of a significant statistical error, depending if the 95% confidence limit of the bias contain or not 0 value [1]. All test has been performed using GrapPhad Prism Software version 7.0 for Windows.

RESULTS

Table 1 describe results of Bland-Altman analysis where: LBb is the 95% lower bound bias, UBb is the 95% upper bound bias, LB is the Bland-Altman lower bound and UB is the Bland-Altman upper bound, respectively associated for each parameter with plots in Figure 1.

Table 1. Bland-Altman Analysis between parameter values calculated by the two inertial systems

Parameters	bias	LBb	UBb	LB	UB
Cadence (steps/min)	1.61	0.47	2.75	-5.58	8.80
Gait Cycle Time (s)	0.00	-0.01	0.01	-0.04	0.04
Stride Length (m)	-0.24	-0.30	-0.18	-0.61	0.12

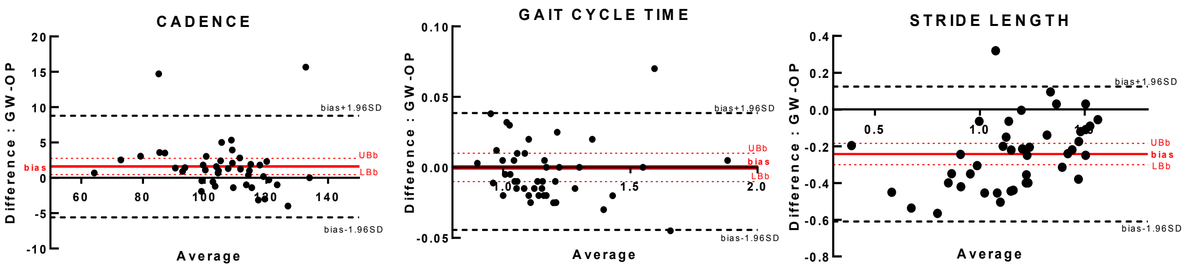

Figure 1. Bland-Altman plot of all parameters

DISCUSSION

Results described in Tab. 1 and also based on visual inspection of Bland-Altman plot (Fig. 1), show that parameter CA exhibits a moderate agreement between the two methods, mainly due to a constant systematic error, SL a poor agreement because of a constant and proportional systematic error, while CGT had the best agreement. Study results suggest that there is not a completely overlapping estimation of all parameters and that this must be taken into account in a medical facility.

REFERENCES

[1] S. Sotgia et al, Clin cheb Lab Med, 46, pp. 1046-9, 2008.

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CHOOSING AN APPROPRIATE SENSOR FOR MOVEMENT ANALYSIS: THE CASE STUDY OF CLIPPING IN FALL DETECTION

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INTRODUCTION

The analysis of movement with wearable sensors can be performed with sensors of varying characteristics (e.g., sampling frequency, range). The choice of the appropriate sensor should follow the requirements defined by the specific phenomenon analyzed. We will present the case study of fall detection [1], where inertial sensors are generally used. Inadequate sensor ranges could indeed lead to clipping of the recorded signals. We will evaluate the impact of this clipping effect in fall detection systems, suggest optimal (evidence-based) range values for this application, and provide possible signal reconstruction methods to deal with this issue.

METHODS

We analyzed activity monitoring data, including falls, from the FARSEEING dataset [2], for a total of 143 falls and 180 hours of activities of daily living. Activity monitoring was achieved via the use of a body-worn sensor system composed of either a smartphone or inertial sensor positioned on the lower back, with ± 2 g or ± 6 g acceleration range.

RESULTS

The clipping effect was observed in 39/143 falls. The number and percentage of saturated recordings per sensor type is reported in Table 1.

Table 1. Clipping effect impact.

Sensor	Manufacturer	Specified Range	Falls Acquired with this sensor	Number (Percent) with clipping
Galaxy SII	Samsung	±2g	7	0 (0.00)
Galaxy SIII	Samsung	±2g	93	7 (7.53)
Dynaport Minimod	Mc Roberts	±2g / ±6g	16	13 (81.25)
Dynaport Hybrid	Mc Roberts	±6g	15	9 (60.00)
uSense	Farseeing	±2g	12	11 (91.67)
TOTAL NUMBER OF RECORDINGS			**143**	**39 (27.47)**

DISCUSSION

We discovered a high prevalence of the clipping effect (in almost 30% of falls), especially with the ± 2 g range but also with the ± 6 g range. The impact of this loss of information in efficacy of fall detection algorithms was evaluated. Signal reconstruction (via Piecewise cubic spline interpolation) was applied to the clipped signals and was found to be promising to limit the effects of clipping (and is possibly usable in other similar applications). Based on this evidence, we suggest that future studies should use a sensor range greater than ± 6 g. Regarding data that was already recorded, the proposed interpolation could be used to limit the clipping issue.

REFERENCES

[1] Palmerini L et al., *Sensors,* 2015: Vol. 15(5).

[2] Klenk J et al., *European Review of Aging and Physical Activity*, 2016: Vol. 13(8).

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BODY CENTER OF MASS TRAJECTORY AND MECHANICAL ENERGY USING INERTIAL SENSORS: A FEASIBLE STRIDE?

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INTRODUCTION

The estimation of the human Body Center of Mass (BCoM) trajectory is crucial to understand the role of both biomechanical and physiological variables, such as mechanical work done and energy saving strategies [1]. Today, 3D BCoM trajectory is generally obtained using force platforms (FPLAT), representing the gold standard, or motion capture (MOCAP) [2]. These instruments, however, constrain the analysis to the laboratory and do not allow for the assessment of the above-mentioned quantities during real life situations. Wearable magneto-inertial technology (MIMU), which is currently pervading our daily life, may serve to fill this gap. Little is known, however, about the actual accuracy of MIMU-based technology in estimating the BCoM trajectory and derived quantities. The aim of this study was to assess this accuracy, with respect to both force platform- and motion capture-based estimation.

METHODS

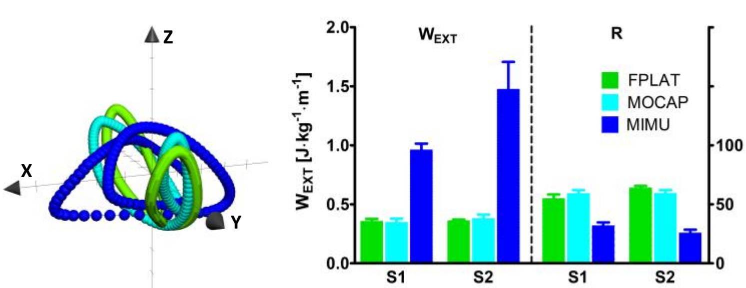
Two healthy participants (1 male; mass: 75 and 56 kg; height: 1.75 and 1.71 m) gave their informed consent to participate in the study, which is part of a project involving 15 participants and more than 360 acquired strides. Each participant was equipped with 17 MIMUs (XSens, MVN Animate [3]) and 18 retroreflective markers [2] and was asked to walk at his/her comfortable self-selected speed, ten times back and forth a 10m-long laboratory along a straight path embedding three force platforms (0.6x0.6 m AMTI). Data from each body mounted MIMU (3D accelerations, angular velocities and magnetic field vector, 60 Hz) were acquired together with the 3D trajectories of each marker (Vicon MX, 100 Hz) and ground reaction forces (1000 Hz). All instruments were synchronized through a kicking motion and data resampled to the same sampling frequency (100 Hz). Strides correctly performed on force platforms were segmented and the 3D BCoM trajectory was obtained for each stride from ground reaction forces [2], marker trajectories [2], and MIMU data [3]. From BCoM trajectories, the positive external mechanical work (W_{EXT}, the summation of all increases in potential + kinetic energy) and the energy recovery (R, the ability to exchange potential and kinetic energy) were then obtained [1]. To assess the accuracy of the 3D BCoM trajectory MIMU-based estimates, the 3D RMS between MIMU- and both FPLAT- and MOCAP-based estimates was calculated. Similarly, FPLAT-MIMU and MOCAP-MIMU differences were computed for both W_{EXT} and R.

RESULTS

A total of 12 (6+6) strides were analyzed at mean speed of 1.0 and 1.2 $m \cdot s^{-1}$ for S1 and S2. Average 3D RMS between MIMU- and FPLAT- as well as MIMU- and MOCAP-based BCoM trajectory were respectively 0.021±0.003 m and 0.009±0.005 m (Fig. 1a). Results about W_{EXT} and R values are depicted in Fig. 1b.

Figure 1. ***a.*** 3D BCoM trajectory during one randomly chosen stride (FPLAT: green, MOCAP: light blue; MIMU: blue; X: ant-post axis). ***b.*** W_{EXT} and R (mean and standard deviation) obtained with the nstruments for both participants (S1 and S2).

a. ***b.***



DISCUSSION

The results of the present study indicate that errors in estimating the 3D BCoM trajectory using a full-body MIMU-based approach, relying on musculoskeletal model, may reach 50% and 25% (with respect to the BCoM total range of movement) when compared to FPLAT- and MOCAP-based estimates, with an overall pattern that is different from the other methods. These errors propagate to W_{EXT} and R estimation, the former found to be 2.5 times greater that the gold standard estimates. Although a larger sample size is needed to confirm these preliminary results, they strongly suggest that the use of MIMU-based technology for the estimation of the BCoM energetics is not mature yet.

REFERENCES

[1] Cavagna GA and Kaneko M *J Physiol* 1977;268:467-481.
[2] Pavei G, et al. *Front Physiol* 2017;8:119.
[3] Karatsidis A, et al. *Med Eng Phys* 2019;65:68-77.

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TELE-REHABILITATION SYSTEM VALIDATION FOR SHOULDER REHABILITATION

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INTRODUCTION

The increase of rehabilitation demand, especially due to ageing population, wobbles the sustainability of health care services. This situation urges the need of new rehabilitation models to reduce costs and waiting lists while maintaining high-quality rehabilitation therapies [1]. In this context arises several tele-rehabilitation systems which can control rehabilitation processes remotely. One of the keys to ensure high adherence of patients in a rehabilitation process is to give real-time feedback while performing the exercise [2]. The main objective of this study is the validation of the real-time feedback algorithm incorporated in ReHub® platform. A digital tele-rehabilitation solution, developed by DyCare®, based on the use of a single inertial sensor to offer personalized and effective remote rehabilitation therapies.

METHODS

Nine healthy subjects were measured while performing 13 times each of the 5 upper-limb exercises selected. The first trial is used to build the patient movement pattern and the other 12 trials are divided as follows: 3 well-performed sets, 3 sets performed with small range of movement and 6 sets performed including compensations (3 sets for each compensation defined). Each trial is composed of 7-10 repetitions. The angles of the main movement axis were obtained from the accelerometer and a gyroscope.

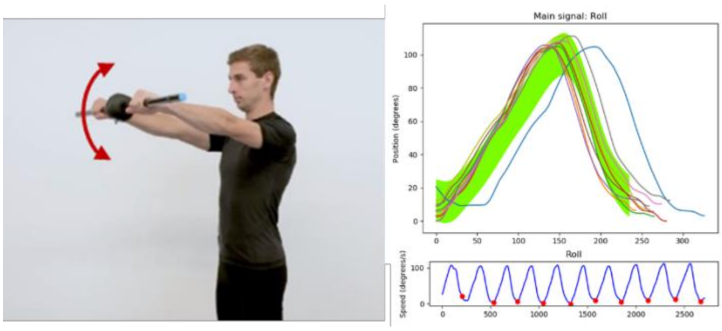

Figure 2. Example of exercise comparison with the reference

Then, the signals of interest (Euler angles of the main movement axis and gyroscopes) are analyzed using the real-time algorithm developed within DyCare® which is based on the comparison of each trial cycle with the correspondent reference cycle pattern (Figure 2).

To determine if a particular performance (performing well, errors related with range of movement, body compensation or force) is detected by the algorithm, at least the 80% of all the repetitions performed by all the volunteers must give as output the expected feedback.

RESULTS

Considering all the exercises together it was found that when the exercise is well performed, it is detected in the 89±2% of the cases. Small range of movement errors are detected in 90±7% of the cases, the compensations which include performing moments outside the main plane of the exercise are detected in 95±8% of the cases and force errors are detected in the 97±3% of the cases.

DISCUSSION

From the results achieved, it can be noted that when using a single inertial sensor, the capability of error detection is limited as it allows only to detect compensation errors involving movements outside the main plane of the exercise. Considering the simplicity of the setup, an accuracy of 93±4% is achieved which allow a first evaluation of patient performance. Therefore, the present digital solution would be useful to increase therapy adherence and efficiency. Moreover, a solution as ReHub® will greatly reduce the economic and social impacts of patients who needs rehabilitation.

Regarding compensation, future work will be addressed towards identifying the type of compensation.

REFERENCES

[1] Zampolini, M., et al. (2008). 44(2), 125-134.

[2] Bechly, K. E et al. (2013). Gait & posture, 37(3), 391-396.

ACKNOWLEDGMENTS

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TO LIVE TOGETHER IS TO MOVE TOGETHER: MARRIAGE AS TESTING PARADIGM FOR A SOCIAL ACTIGRAPHY

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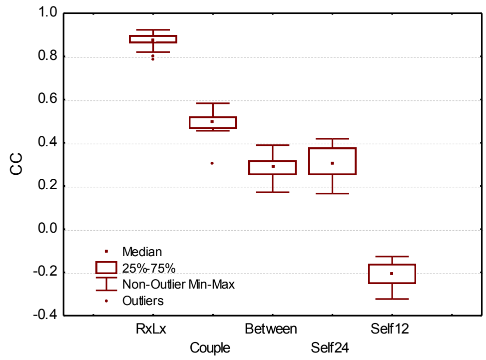
INTRODUCTION

Actigraphy, the tracking of motor activity by a wearable sensor, can provide valuable information for the health and lifestyle assessment of individuals [1]. Since humans are inherently social beings, it can be expected that the activities of people sharing time together can be in some ways entangled. The present study implements a "social" actigraphy method, able to quantify aspects of social interactions.

METHODS

Eight married couples participated in the study (16 healthy individuals, all retired from work, age range 60-80 years, no ongoing divorce requests, no son or daughter still living with them). Both participants from a couple wore a Geneactiv sensor (Activinsights.co.uk), a wrist-like triaxial accelerometer sampling at 100 Hz, for seven days. Synchronized raw data allowed to compute individual motor activity (MA) profiles split in 1-minute epochs according to [2]. A cross-correlation analysis of two concurrent MA profiles results in a CC coefficient (CC=1 for perfect association, CC=-1 for a counter-phase association; CC=0 for unrelated profiles). Correlation analysis was performed between married subjects (labelled "*Couples*"), between unrelated subjects ("*Between*"), within individuals with simulated 12 hours ("*Self12*") and 24 hours ("*Self24*") time shift. Additional data from 26 healthy adult subjects (age range 18-55) wearing a sensor at both wrist for 24 hours allowed for compute the CC between the right and left upper arm MA profiles ("*RxLx*").



RESULTS

Results are summarised in the boxplot. An analysis of variance and related post-hoc analysis evidenced significant differences between all groups except for between-subjects associations and within-subjects ones (*Self24*).

DISCUSSION

The results evidenced that a married couple tends to associate daily motor activity levels to a larger extent compared to individual between-days variability (*Self24*) and between-subjects one (*Between*), which, on the contrary, are comparable . Additional analysis confirm that the right and left upper limbs of an individual show the strongest association between activity levels (*RxLx*) and any healthy person evidences a substantial absence of relation between day and night activities (*Self12*). The whole body of evidence is coherent with expectations and provide reference values for future applications. Since the proposed method is able to quantify a n index related to social interactions, it is reasonable to apply such method in future to the study of social interactions in relevant dyads (caregiver/assisted, adult/child, etc.). Any extension of the method to social grouping including more than two individuals is straightforward and even pets or domestic animals, who play relevant roles in the social life of homo sapiens, can be considered and equipped with sensors.

REFERENCES

[1] Rabuffetti M et al. *Physiol Meas* 2016; 37(10)

[2] Rabuffetti M et al. *Sensors* 2019;19(3)

Sessione 3 – L'ANALISI DEL MOVIMENTO IN LABORATORIO: APPROFONDIMENTI METODOLOGICI

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CAN LABORATORY BASED ACL SCREENING EFFICIENTLY PORTRAY ON THE FIELD KNEE LOADING? A PILOT STUDY

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INTRODUCTION

Screening methods for anterior cruciate ligament (ACL) injury risk should be linked to the mechanical etiology of ACL injuries in order to effectively identify 'at-risk' athletes [1]. In literature evidence suggests that ACL injury risk is multifactorial and involves biomechanical, anatomical and neuromuscular factors [2]. The present study aims to compare laboratory based tests with on field assessment in post ACL injury subjects. We hypothesized that laboratory tests could efficiently portray knee loading condition in order to manage athletes' return to play.

METHODS

After signing informed consent, 5 healthy (mean±SD; age 27.40±9.86 years; BMI 24.80±2.30 kg/m2), and 2 ACL-injured (age 19±2.82 years; BMI 26.65±2.04 kg/m2) subjects were analyzed in laboratory conditions: one before ACL surgery and the other 6 months after surgery. All the subjects performed 3 single leg drop landing tasks from a 32 cm height [3]. Kinetics and kinematics were acquired by means of a stereophotogrammetric system (6 cameras, BTS, 60-120 Hz) and a force plate (Bertec, 960Hz). Reflective markers were applied as in [4] and joint angles and moments were determined [7]. 8 healthy (age 23.13±4.09 years; BMI 27.63±5.75 kg/m2) and 4 post ACL injury athletes, already returned to trainings after the rehabilitation period consequent ACL surgery (age 24.25±4.35 years; BMI 28.89±5.58 kg/m2), were evaluated on field: two right and left side cuts, three jumping headers (footballers) and two side-on tackles (rugby players) were acquired. Four cameras (GoPro Hero 3, 30Hz) and pressure insoles (PedarX, Novel, 100Hz) were adopted. Anatomical landmarks were digitalized, bilaterally, directly on the motion sequences [5] and a simplified version of [4] was adopted; joint angles and moments were determined [6,7]. Comparison between healthy and injured subjects across the different tasks was performed through Wilcoxon rank sum test (α=0.05).

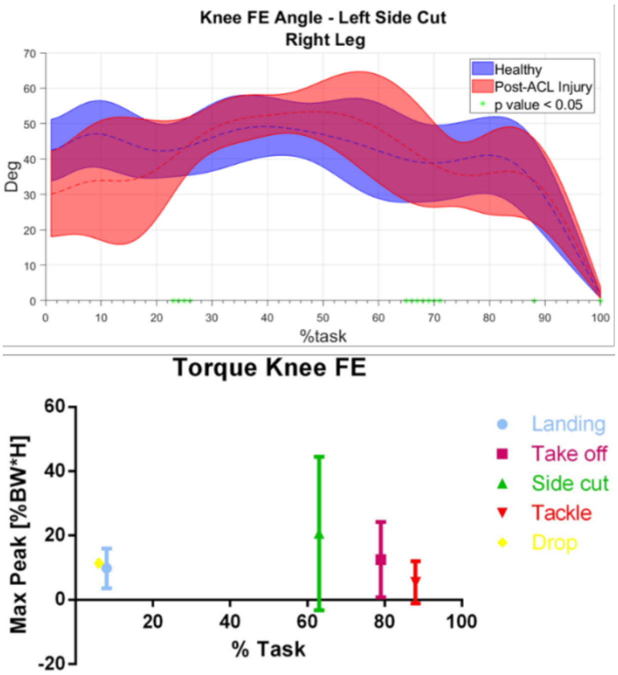

Figure 3: Top: Knee flexion-extension angle during side cut (mean±SD); Bottom: Knee valgus torque at different tasks (mean±SD)

RESULTS

Results are shown in Figure 1. Both laboratory and on-field tests displayed significant differences between the healthy and the injured subjects; however, the side cut revealed the higher knee joint angles and moments.

DISCUSSION

Although laboratory based tests are characterized by a higher repeatability, on field tests has the peculiarity to provide a more realistic evaluations of athlete's competencies. In particular the side cut resulted in the more demanding task in term of knee joint biomechanics. Future studies with a wider cohort are needed to support these preliminary results.

REFERENCES

[1] Fox A, et al. *Sports Med* 2016; Vol. 46(5): 715-35.
[2] Shin CS, et al. *J of Biomech* 2009; Vol. 42(3): 280-5.
[3] Medina JM, et al. *J Electromyog Kines* 2017; Vol. 18(4):591-7.
[4] Scarton A, et al. *Gait & Posture* 2013; Vol. 58:194-200.
[5] Magalhães F, et al. *J Sports Sc & Med* 2013; Vol. 12(4):660-7.
[6] ACL Quick Check® patent: https://bb-sof.com/
[7] Leardini A, et al. *Gait & Posture* 2007; Vol. 26(4): 560-7.

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XX Congresso SIAMOC

SPORT-INDUCED FATIGUE ASSESSMENT THROUGH GAIT PARAMETERS VARIATIONS

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INTRODUCTION

Sport training sessions impose physiological stress that could result in transient physiological, metabolic and kinematic changes. Fatigue is thus expected to lead to biomechanical compensation behaviors, altering normal subject motor patterns [1]. The nature of these changes depends on the type, duration and intensity of exercise. Furthermore, fatigue is mediate by several individual factors such as the presence of pathology, age, physical activity level and the type of activity performed [2]. Sport-induced fatigue is widely studied, especially to evaluate athletes' performance and understand the metabolic cost of physical exercises [1]. It is typically assessed through metabolic parameters, but the objective evaluation also involves kinematic parameters extracted using motion capture solutions [2]. The main advantage in doing so lies in the possibility to directly evaluate the kinematic alterations related to fatigue levels during sport practice. This work represents a preliminary study aiming to assess the feasibility of using gait parameters to automatically recognize the fatigue condition in football athletes.

METHODS

Twelve participants (age: 23±3 years, w: 75.9±9.3 kg, h: 177.8±8.0 cm, years of practice > 5) participated in the study after signing written informed consent. Each participant was equipped with 20 reflective markers placed according to the *Plug-in-Gait* lower limb marker set. Marker trajectories were collected at 100 Hz with a stereo-photogrammetric system (Vicon MX, UK). Participants were asked to perform two over-ground walking trials, before and after a yo-yo intermittent recovery test [3] that was administered to induce fatigue. Subjects conducted the exercise until their maximal effort. Then stride length, stride length variability, stride time, stride time variability, step width, step width variability and gait speed during the walking trials were measured. Computed parameters obtained before and after the fatiguing test were later compared in post-processing to assess how fatigue affected them. Wilcoxon–Mann–Whitney test was performed to assess the statistical significance of differences between the two conditions (e.g. before and after fatiguing test).

RESULTS

The only parameter that appeared to be significantly affected by fatigue was the stride time variability (Table 1).

More precisely stride time variability increased due to fatigue in all tested athletes but one. The magnitude of this increase resulted remarkably variable between subjects. Despite differences were found for other parameters, they did not reach statistical significance.

Table 1. Results in terms of percentage of deviation, reported as mean (standard deviation), between gait parameters values before and after the fatiguing tests.

	Pre-post fatigue change, %, mean (std dev)	*p-value*
Stride time	- 1.97 (4.93)	0.817
Stride time variability	+ 181.82 (216.18)	0.035
Stride length	+ 3.32 (4.55)	0.507
Stride length variability	+ 56.16 (103.47)	0.312
Step width	- 2.47 (8.32)	0.622
Step width variability	+ 11.82 (31.56)	0.625
Gait speed	+ 4.87 (9.19)	0.624

DISCUSSION

As reported by other authors, fatigue effects are difficult to detect in the analysis of gait parameters; mostly, previous studies did not report significant differences between trials before and after the fatiguing tests, [2]. Despite this, stride time variability resulted to be an eligible parameter to detect fatigue also in the present study, with higher values shown for walking trials after the fatiguing tests ($p < 0.05$). The high variance of the magnitude of this variation may depend on individual factors, such as age and physical activity level. Our findings suggest that stride time variability is a promising candidate parameter for fatigue detection. Obviously, the present work needs to be further consolidated, with possibly the extension to other fatigue related parameters using inertial wearable sensors to enable in-field objective assessment.

REFERENCES

[1] M. Lambert, J. Borresen. *International Journal of Sports Science & Coaching* 2006;1(4)
[2] F. A. Barbieri, J. H. van Diëen, *Journal of Back and Muscoloskeletal Rehab* 2013; 26(2013) 125-131
[3] https://it.wikipedia.org/wiki/Yo-Yo_Test#Yo-Yo_Intermittent_Endurance_Test

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THE ROLE OF TRUNK ON HUMAN LOCOMOTION: DAMPER, GENERATOR OR PERTURBATOR?

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INTRODUCTION

It is common opinion that the trunk is important in movement control and postural balance during functional activities [1], however its functional biomechanical role in human locomotion has been poorly investigated so far. The purpose of the present study was to investigate the trunk motion behavior in a large number of patients with gait disorders and healthy subjects in order to acquire information on its role as damper, generator or perturbator during walking, considering the impact of the specific diseases, the primary trunk involvement or trunk compensatory mechanisms adopted by patients.

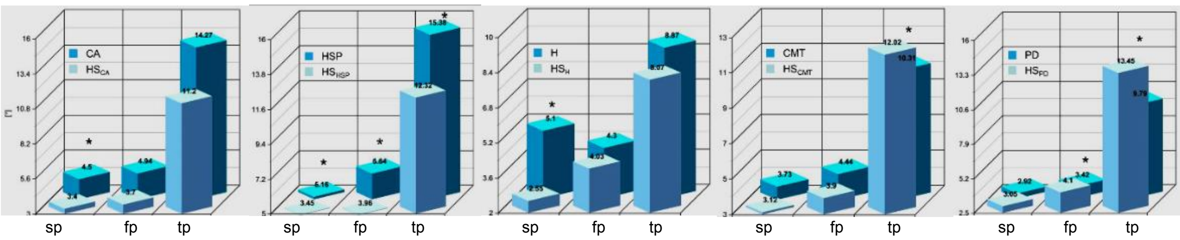
METHODS

A total of 192 patients affected by different types of neurological diseases (28 with cerebellar ataxia (CA); 49 with hereditary spastic paraparesis (HSP); 23 with hemiparesis (H); 12 with Charcot-Marie-Tooth (CMT); and 80 with Parkinson's disease (PD)) were included in this study. 60 healthy controls (HS) were recruited. Patients and controls were asked to walk barefoot at comfortable self-selected speeds along a walkway with 22 reflective spherical markers attached on the anatomical landmarks [2], including both trunk and lower limb. Time-distance, joint and trunk kinematics and energetic data were recorded using an optoelectronic motion analysis system. All the gait parameters of patients were compared with those of the respective control group, matched for gait speed.

RESULTS

Significantly higher values of the trunk RoM were found in one, two or all the three spatial planes in CA, H, HSP and CMT patients compared to controls at matched speed. Conversely, significantly lower values were found in PD patients than controls. No significant differences in energetic parameters (p>0.05) were found. Significant correlations between trunk rotation and both time distance parameters and RoMs were observed in all patients.

Figure 1. Trunk RoMs in the sagittal (sp), frontal (fp) and transverse (tp) plane for each group of patients. *Significant differences between patients and healthy subjects (p<0.05).



DISCUSSION

Abnormal trunk movements were present in all patients irrespective to the trunk involvement due to the specific neurological disease. Interestingly, we found that the trunk rotation was positively correlated with the gait performance parameters (e.g. gait speed, step length, joint RoMs) in both the investigated diseases and healthy controls, irrespective of whether the trunk motion was increased or reduced. Furthermore, we found a specific abnormal trunk motion pattern for each neurological disease reflecting either a primary deficit or a compensatory mechanism. Particularly, beyond its well known role as damper, the trunk may be used as generator of movement to improve gait performance in some patients (e.g. in HSP, H and CMT), which it is not possible for other patients (e.g. in PD) because of a primary trunk involvement. Conversely, in CA patients, despite of their efforts to maintain stability, there is a sort of vicious circle that transforms the upper body into a generator of perturbations due to the inter-segmental coordination deficit. The abnormal trunk control in patients with neurological gait disorders unveils the function of the trunk in human locomotion as damper, generator or perturbator. These findings may help the clinicians to tailor the rehabilitation and management strategies for improving gait function and trunk control in neurological diseases.

REFERENCES

[1] Kim JH, Lee SM, Jeon SH. *Journal of Physical Therapy Science* 2015, 27(9): 2955-2958.
[2] Davis III RB, Õunpuu S, Tyburski D, Gage JR. *Human Movement Science* 1991,10: 575–587.

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A WAVELET-COHERENCE ANALYSIS FOR THE IDENTIFICATION OF MUSCULAR CO-CONTRACTION DURING WAKING

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INTRODUCTION

Muscular co-contraction is defined as the activity of agonist and antagonist muscles around a joint, enhancing joint stability and balance [1]. The quantitative assessment of muscle co-contractions would be meaningful for deepening the comprehension of this physiological mechanism. The purpose of the present study is the quantification of muscle co-contraction using a Wavelet-transform-based coherence analysis of surface electromyographic (sEMG) signal during straight walking.

METHODS

sEMG from tibialis anterior (TA) and gastrocnemius lateralis (GL) and basographic signals were acquired in 5 healthy subjects (3 females and 2 males) during straight walking. Basographic signals were analyzed to quantify foot-floor contact. Details can be found in [2]. sEMG signals were processed using Wavelet Transform. Daubechies (order 4 with 6 levels of decomposition) was chosen as mother wavelet. A denoising algorithm based on a soft thresholding was applied for removing noise from raw signals. Wavelet Transform Coherence (WTC) function, an acknowledged localized statistical assessment of cross-correlation between signals [3], was extracted from denoised sEMG signals. This study proposes WTC cross-correlation as the assessment of muscular co-contraction.

RESULTS

The representation of WCT between sEMG signals from TA and GL is reported in Figure 1, for a representative stride. The white dashed line represents the cone of influence, i.e. the region of the wavelet spectrum where is maximum the autocorrelation of wavelet power at each scale. Within this region, GL/TA co-contractions were identified by red boxes. In time domain, GL/TA co-contractions were detected during heel strike (0-10% of gait cycle) and during push-off (59-72% of gait cycle), matching with literature [2]. WTC approach was able to provide also the frequency band of information content for muscle co-contractions: 32-65 Hz for heel-strike co-contraction and 16-32 Hz for push-off co-contraction.

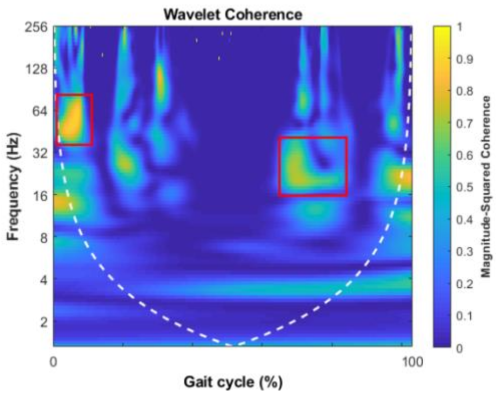

Figure 1. Wavelet Coherence between sEMG signal from TA and GL muscles. Muscle co-contractions are highlighted by red boxes.

DISCUSSION

The present study supports the suitability of WT approach for both sEMG denoising and quantitative assessment of muscle concomitant recruitment during walking. In particular, this study proposed WT coherence function as a reliable technique for the assessment of muscle co-contraction in time-frequency domain.

REFERENCES

[1] Olney SJ. Biomechanics, international series on biomechanics, Human Kinetics Publishers, Champaign (IL), 1985.
[2] Di Nardo F, et al. *J Electromyogr Kinesiol* 2015; 25:347–354.
[3] Sukiennik P, et al. *Journal of Neuroscience Methods* 2015; 24713-22.

QUADRICEPS FEMORIS DYNAMIC ELECTROMYOGRAPHY DURING WALKING AT DIFFERENT SPEEDS: NORMATIVE DATA

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INTRODUCTION

Stiff Knee (SKG) is a common gait deviation in patients with upper motoneuron lesion. Inappropriate quadriceps femoris (QF) swing-phase activity is one cause of SKG. There is conflicting evidence, and few data, in the literature about the precise activation pattern in dynamic electromyography (EMG) of rectus femoris (RF) and vastus intermedius (VI) muscles during gait in healthy subjects [1,2]. The aim of the study was to define the normal EMG pattern of QF, with special reference to RF and VI muscles activation, in a population of healthy subjects during walking at three different speeds in two laboratories.

METHODS

Seventeen healthy adults were recruited. Each subject underwent EMG, recording QF timing of activation during walking at spontaneous, slow and very slow speed.

The muscles of dominant lower limb studied were: vastus lateralis (VL) and vastus medialis (VM) recorded with surface electrodes, RF and VI recorded with fine wire electrodes.

The data were recorded for each speed using an Emg ZeroWire of Cometa and a BTS FreeEMG and the EMG signal was processed with an Emg EasyReport 6.02 software. The procedure to identify the target muscles and obtain a good reliability between the two laboratories was based on A. Perotto's guide [3]; a US guide was also used. For EMG signal normalization, a trial was used consisting of three QF maximal isometric contractions repeated with a duration of 5 seconds each. RF and VI signals were detected within the muscle; hence, no tissue filtering was present as in surface EMG and no amplitude normalization was required. EMG data were high-pass filtered to remove motion artifacts, and further wavelet-filtered to enhance muscular components. Next, the median envelope was computed over 10 to 15 strides per subject. Finally, the ensemble average among subjects was computed, leading to the median profile with its confidence bands.

RESULTS

In all the subjects examined we observed that, during walking at spontaneous speed, VI, VM and VL were active in Terminal Swing and at Initial Contact until the end of the Loading Response phase. It was possible to observe a low activity in VI during Pre and Initial Swing at spontaneous speed. RF revealed a significant EMG activation timing variability during walking at spontaneous speed. RF was inconstantly active in PreSwing, Initial Swing and Loading Response. At slow and very slow walking speed VI, VM and VL presented a lower signal amplitude with the same EMG activation timing recorded at spontaneous speed. RF presented a progressive EMG amplitude decrease during slow walking and no significant EMG activity during very slow walking.

DISCUSSION

In relation to VI, VM and VL, we observed the same timing activation that has already been described in the literature, however in some subjects the presence of VI activity could also be seen during Pre-Initial Swing.

RF muscle confirmed inconstant activity in PreSwing and Initial Swing at spontaneous walking speed. The results confirmed the importance of using an adequate procedure in detection EMG signal from knee extensor muscles in order to limit false interpretations.

REFERENCES

[1] Nene A, et al. *Gait Posture* 2004;20(1):1-13.
[2] Perry J., Gait Analysis, Normal and Pathological Function. Slack Inc., Thorofare (NJ), 1992
[3] Perotto A., Delagi EF. Anatomical guide for the electromyographer, Charles C Thomas Publisher, Springfield, 3rd Ed, 1994

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SPLIT-BELT WALKING DOES NOT REPRODUCE HEMIPARETIC CLAUDICATION: A STUDY ON THE POWER OUTPUT AT THE ANKLE AND AT THE BODY CENTRE OF MASS

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INTRODUCTION

Walking on a split-belt treadmill (with each of two belts running at a different velocity) has been claimed, based on kinematic findings, to mimic pathologic claudication by imposing a shorter stance ("escape" limp) on the faster belt. However, the anterior step decreases, contrary to what is usually observed in hemiparesis. This paradigm has been claimed to be a useful therapeutic exercise. Nevertheless, it leads to contradictory findings: spatial symmetry can be forced by placing the hemiparetic lower limb on the faster belt, but this entails exaggeration of the temporal asymmetry (vice-versa if belts are exchanged). Some light can be shed onto this contradiction if one considers the dynamics of gait. In the present study, the muscle power subtending the sagittal rotation of the joints of the lower limbs and the translation of the body Centre of Mass (CoM) were analyzed.

METHODS

Ten healthy adults (5 women), mean age (SD) 26 (2.81) years, height (SD) 1.71 (0.12) m, body mass (SD) 63.67 (11.13) kg walked on a split-belt treadmill mounted on force sensors providing 3D ground reaction forces. The belts ran either at the same ('tied' condition, TC) or at different velocities ('split' condition, SC) [2]. Lower limb joint rotations were recorded through a wireless optoelectronic system. The spatiotemporal synchronization of sagittal ground reactions and joint rotations allowed measuring the muscle power in the sagittal plane at the ankle, which provides about 70% of the muscle power needed to keep the body in motion during normal waking [3]. Subjects walked in TC at 0.6 m s^{-1} and in SC at 0.4 vs. 0.8 m s^{-1}, with the dominant lower limb placed on the faster belt. By summing vectorially the ground reactions from both belts, the 3D mechanical energy changes of the body CoM could be computed, according to the "double integration" method (Cavagna's algorithms, [3]). The total mechanical energy (E_{tot}) and the efficiency of its pendulum-like transfer (saving of muscle work, percentage of energy Recovery, %R), were analyzed. A 30-180-30 s tied/split/tied walking sequence was requested.

RESULTS

In the SC, it has already been demonstrated that healthy adults show a marked asymmetry in the peak joint power provided by the trailing ankle at push-off: this was 2.5 times higher compared with the slower side, and 1.2 times higher compared to the one observed at the intermediate speed in TC [4]. In the present study, the analysis of the CoM unexpectedly revealed an increased efficiency of the pendulum mechanism during the whole stride (hence, per unit distance). %R was 58% in SC and 40% in TC. The reasons still need to be clarified.

DISCUSSION

Walking on a split-belt does not reproduce pathologic claudication but is an original form of gait instead. %R is higher than that recorded during TC at intermediate velocity. The step performed on the faster belt mimics the paretic step temporally but neither spatially nor, which is the original finding here, dynamically. Split-belt walking cannot be proposed as an established therapeutic paradigm until the choice for forcing dynamic (at joint and/or CoM level) vs. temporal vs. spatial symmetry is motivated.

REFERENCES

[1] Helm EE, Reisman DS. *Phys Med Rehabil Clin N Am*, 2015;26(4):703–13.
[2] Tesio L, et al. *Am J Phys Med Rehabil*. 2008;87(7):515–26.
[3] Cavagna GA, et al. *J Appl Physiol.* 1983; 55(2):607-613
[4] Tesio L, et al. *Int J Rehabil Res*. 2018;41(4):304–315.

Sessione Poster Metodologici

COMPARISON OF AN INNOVATIVE INERTIAL SYSTEM AT HIGH SAMPLE RATE WITH THE GOLD STANDARD OPTOELECTRONIC SYSTEM IN GAIT ANALYSIS TEST

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INTRODUCTION

Gait analysis can be performed by means of optoelectronic system. Because of the top-accuracy they represent the gold standard. However, cameras need a pre-arranged environment, a long set-up procedure and can be very expensive. In order to overcome some of those drawbacks, wearable devices based on inertial measurement units (IMUs) have been taking hold. IMUs are poorly invasive, adoptable in any environment, have a fast set-up procedure [1] and are relatively cheap. We present a novel IMU technology Movit System G1 (by Captiks Srl, Rome, Italy), and its validation in terms of accuracy, with respect to a gold-standard camera based system for gait analysis purposes.

METHODS

Four healthy subjects, two males and two females, with different anthropometric characteristics were enrolled in this study, at the "Movement and Posture Analysis" laboratory, Santo Stefano Institute (Porto Potenza Picena, Italy). The gold-standard system was made of six infrared cameras with refresh rate of 100 Hz. The under-test system was made of 7 IMUs (Movit G1) with sample rate at 200 Hz, 3D accelerometers and 3D gyroscope full-scale range of ±2g and ±2000 dps, respectively. They were positioned on pelvis, thighs, shanks and feet. The passive markers were positioned on specific body landmarks according to the Davis protocol. The subjects, wearing both the systems and starting from standing position, performed a bilateral knee flexion (useful to set a motor triggering for synchronization purpose) and then walked for 6 meters at a subject-comfortable speed. They repeated this test 10 times. Our measurements aimed at considering the temporal parameters of Stride time, Step time and Cadence and the range of motion (ROM) of the pelvis along the three plane, of the hip, knee and ankle on the sagittal plane. ROM was calculated after offset removal measured during the standing position.

RESULTS

In order to assess the accuracy of the system, for each test repetition we calculated the root mean square error (RMSE) and the Pearson correlation coefficient, of the joints' ROM (Table 1).

Table 1. Mean and Standard Deviation of RMSE and Pearson correlation coefficient of ROMs

ROM	RMSE(°)	PEARSON COEFF
PELVIS TILT	1.75 ± 0.66	0.75 ± 0.23
PELVIS LATERAL BENDING	1.15 ± 0.23	0.93 ± 0.03
PELVIS ROTATION	1.28 ± 0.37	0.94 ± 0.03
HIP FLEXION-EXTENSION	3.14 ± 0.59	0.99 ± 0.00
KNEE FLEXION-EXTENSION	3.06 ± 0.58	0.99 ± 0.00
ANKLE FLEXION-EXTENSION	2.86 ± 1.08	0.95 ± 0.04

The absolute error (ε) and the absolute percentage error ($\varepsilon_{\%}$) have been calculated for Stride Time, Step Time and Cadence for each test, reporting mean and standard deviation values of ε= 0.01±0.01(s), 0.01±0.01(s), 0.91±0.81(step/min) and $\varepsilon_{\%}$ = 0.99±0.88, 1.62±1.59%, 0.98±0.86%, respectively.

DISCUSSION

As a conclusion, the Movit system G1 highly performed in terms of measurement accuracy. In fact, according to our results, comparing this IMU-based system to the Vicon gold-standard camera-based system, the ROM error was found always smaller than 5°, which is considered as an excellent result according to [2]. In addition, the Pearson coefficient was higher than 0.9 for all ROMs, that is, an excellent result, except for pelvis tilt, that is, a good acceptability [2]. All the percentage errors, $\varepsilon_{\%}$, are less than 5%, which demonstrate an excellent accuracy [3]. Further work will be devoted to examining ROMs in the frontal and transversal planes.

REFERENCES

[1] Cuesta-Vargas AI, et al. *Physical Therapy Reviews* 2010;15 (6):462-473.
[2] Poitras I, et al. *Sensors* 2019;19(7): 1555.
[3] Fusca M, et al, *Appl. Sci*. 2018; 8(7): 1167.

GAIT TEMPORAL PARAMETERS ANALYSIS OF TURNING TASKS USING MIMUS IN PARKINSON'S DISEASE PATIENTS

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INTRODUCTION

Turning (T) represents a challenging task in Parkinson's Disease (PD) patients. Clinical examinations such as Time-Up-and-Go (TUG) test include U-turns to evaluate subject's performance during T task. In order to collect meaningful parameters in an unobtrusive and low-cost way, magneto-inertial measurements units (MIMUs) have been employed to analyze the T task [1,2]. The majority of the studies focuses their attention on the estimation of T duration, peak velocity, jerk, and number of steps [1,2]. Indeed the analysis of gait spatio-temporal parameters is commonly limited to the straight-line (SL) gait condition whist it could add meaningful information also in T task evaluation [3,4]. The aim of this study was to apply a previously presented method for the estimate of temporal parameters [5], already validated in SL gait condition, during a turning (T) task on a small group of PD patients.

METHODS

The study included 5 PD subjects (66.4±5 y.o., Hoehn&Yahr=2.3±0.4). Data from three MIMUs (Shimmer™ 3) one positioned over the lumbar spine and two attached to the subject's ankles (20mm above the malleolus) were acquired simultaneously with data from a stereo-photogrammetric system (gold standard, GS). Each subject performed two TUGs, at comfortable (C) and fast (F) speed. First, turning onset (T_{ON}) and offset (T_{OFF}) from lumbar mounted MIMU were identified using [1]. Then, the method proposed in [5] was used to identify the gait events (GEs) and to estimate relevant temporal parameters in both SL and T walking bouts. For each left and right gait cycle, the difference between MIMUs estimates and GS values was calculated (error). Error mean (me) value and its standard deviation (sd), as well as the mean absolute error (MAE), were computed separately for SL and T cycles.

RESULTS

83 gait cycles (SL=46, T=37) were analyzed, and no extra or missing GE were found. A total of 10 turnings were correctly identified. The errors in determining the selected temporal parameters are reported in Table1. Errors were comparable between the two gait conditions, SL and T.

Table 1. Errors in determining the gait temporal parameters in SL and T cycles

		Stride time [ms]		**Stance time [ms]**		**Swing time [ms]**		**Step time [ms]**	
		SL	***T***	***SL***	***T***	***SL***	***T***	***SL***	***T***
me (sd)	***C***	3 (7)	0 (4)	1 (5)	2 (4)	0 (5)	-3 (6)	1 (7)	0 (7)
	F	3 (7)	0 (5)	1 (5)	2 (7)	1 (5)	-4 (8)	0 (7)	-5 (5)
MAE	***C***	5	2	4	4	4	5	7	6
	F	6	4	4	5	4	7	6	5

DISCUSSION

Gait temporal parameters differences registered between SL and T gait conditions, both in C and F gait speed tasks, have been found comparable. Slightly higher MAE values have been observed during the T task when performed at F speed. Nevertheless, being the results in line with those obtained in [5], the applied method results to be reliable for determining the temporal parameters during T task both at comfortable and higher speed. To confirm such validation, a larger number of participants and turning types should be tested. Moreover, the estimation of gait spatial parameters using the method proposed in [5] should be addressed and deeply explored during the T task.

REFERENCES

[1] El-Gohary M. et al. *Sensors* 2014; 14:356-369
[2] Salarian A. et al. *Conf Proc IEEE Eng Med Biol Soc*. 2009; 224-7.
[3] Mariani B. et al. *IEEE Transactions on Biomedical Engineering* 2013; 60(1):155-158
[4] Mellone S. et al. *Journal of NeuroEngineering and Rehabilitation* 2016; 13:39
[5] Trojaniello D. et al. *Journal of NeuroEngineering and Rehabilitation* 2014; 11(1):152

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TREATING GAIT IMPAIRMENTS OF PERSONS WITH PARKINSON'S DISEASE WITH CLOSED-LOOP BIOFEEDBACK IN DAILY LIFE

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INTRODUCTION

Parkinson's disease (PD) causes severe gait deficits with negative consequences on Quality of Life. Recent studies have shown that gait training is an effective rehabilitation tool [1]. The Gait Tutor system (mHealth Technologies, IT) implements in a smartphone a virtual trainer based on real-time spatio-temporal parameters monitored via shoe-worn inertial sensors. It aims at tutoring the user to maintain a coordinated and effective gait through vocal instructions generated in a closed-loop modality [2]. Lifespace describes where a person lives and reflects mobility and well-being. Lifespace can nowadays be measured via GPS [3]. Aim of this study is to investigate whether a system like Gait Tutor is able to improve lifespace and overall independence by training self-awareness of performance and self-correction of pathological gait patterns.

METHODS

Ten male persons with PD undertook smartphone-delivered automated feedback during a period of 5 to 6 weeks (age: 65 ± 9 yo, Hoehn & Yahr 2.3 ± 0.4). The system offered praising/corrective verbal feedback, encouraging to keep pre-set gait parameters within a therapeutic window, that is within a lower and upper tolerance level, during walking in a real-world environment. A tutor or reward message was played when the ongoing monitored gait parameter was respectively outside or inside the therapeutic window. The upper and lower tolerances were dynamically adjusted by the system trying to offer a challenging exercise. Lifespace was quantified with typical metric of posturography, such as range and sway path, computed on GPS signal recorded from smartphone.

RESULTS

Overall 210 trials with both inertial sensors and GPS data were recorded. Trials where the GPS was incorrectly received were removed. Figure 1 reports some of the parameters obtained by combining gait and GPS data. In particular, moving from the first to the sixth week, distance walked and number of steps increased. As well, the number of messages and the area of therapeutic window increased.

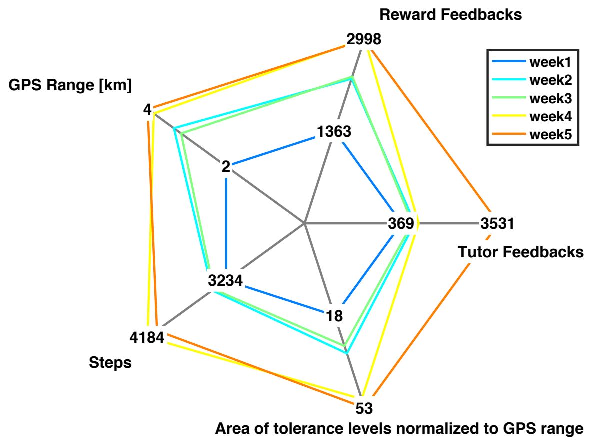

Figure 1: Radar plot of the gait and GPS data recorded during the training protocol. The total number of steps, the distance covered during the workout measured by GPS, the number of vocal messages (corrective or rewarding) normalized by the distance covered and the area of the therapeutic window are reported.

DISCUSSION

Continuous training may increase rehabilitation efficacy in PD [1]. Beyond unsupervised endurance training, Gait Tutor was independently and increasingly used by patients along weeks and allowed to collect precious information on persons lifespace and gait pattern. Given the stand-alone provision of motor exercises, it appears to be well suited for independent gait training in a real-world setting.

REFERENCES

[1] Ginis P, et al. *Parkinsonism Relat Disord* 2016;22:28-34.
[2] Ferrari A, et al. *IEEE Trans Neural Syst Rehabil Eng*. 2016;24:764–73.
[3] Liddle J, et al. *JMIR Mhealth Uhealth*. 2014;2(1):e13

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GAIT TIMING ESTIMATION USING IMUS IN PARKINSON'S DISEASE: COMPARISON AMONG 17 DIFFERENT ALGORITHMS

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INTRODUCTION

The assessment of gait segmentation (gait events, GEs; gait temporal parameters, GPTs) is essential to quantitative motion analysis. A number of different algorithms have been proposed for the purpose as IMUs have become extensively used for ambulatory motion analysis [1]. These algorithms demonstrated to perform pretty well when applied to normal gait (gait of healthy subjects in unperturbed conditions), but any alteration in the gait pattern, either depending on the subject or on the environment can lead to a significant degradation of this performance [2-4]. Independently on characteristics of the specific algorithm, this results from the alteration in the timing and/or actual occurrence of features in the IMU signal associated to GEs. The present work aims to analyze the performance of 17 algorithms for gait segmentation as applied to Parkinson's disease patients (PDPs) gait.

METHODS

Twenty PDPs (12F,8M; 67.2±9.1y.o.; 1.65±0.12m; 67.3±13.1Kg; Hoehn-Yahr stage III, 10 with freezing) walked for 6 minutes back and forth along a 15m straight path. Measures of acceleration and angular velocity were collected using 5 tri-axial IMUs (OPAL, Apdm, sf=128Hz) located on the lower trunk, the shanks, and the feet. Walking tasks were also filmed using a GoPro (Hero4, USA, sf=240Hz). Three IMU impacts were video recorded and used for synchronization. For each participant, 48 steps were analysed. GEs identified from videos were assumed as reference. Seventeen algorithms for gait segmentation were implemented and classified based on: a) sensor position, b) target variable, and c) computational approach. GTPs were calculated from GEs. ICC of the mean stride patter over the trial was calculated. Sensitivity of each algorithms was calculated as the number of missed GEs (IMU) relative to the number of true GEs (video). Only PDPs reporting a minimum sensitivity of 81% for all algorithms [4] were included for further analysis. The influence of different implementation criterions was calculated using a linear mixed model [3].

RESULTS

Preliminary analysis was performed on 4 PDPs, of which 2 with freezing. Of these only one exhibited freezing during the trial and did not pass the sensitivity criterion. The gait pattern of this PDP also exhibited an ICC lower than 0.70. Detailed results for errors are reported in Table 1.

Table 1. 25% percentile, Med, 75% percentile of error for GEs and GTPs as related to a) IMUs position, b) target variable and c) computational approach. * p<0.05

GEs - GTPs		FC (s)	FO (s)	Stride time (s)	Step time (s)	Stance Time (s)	Swing Time (s)
a)	Trunk (T)	0.00;0.05;0.15	-0.15;-0.10;0.05	0.00;0.00;0.05	-0.05;0.00;0.05	-0.20;-0.05;0.30	-0.30;0.05;0.20
	Shanks (S)	0.00;0.05;0.10	-0.10;-0.05;0.00	0.00;0.00;0.00	-0.05;0.00;0.05	0.15;-0.10;-0.05	0.05;0.10;0.15
	Feet (F)	0.00;0.05;0.05	-0.05;0.00;0.00	0.00;0.00;0.00	-0.05;0.00;0.05	-0.10;-0.05;0.00	0.00;0.05;0.10
P value (T-S/S-F/T-F)		*/*/	*/*/			*/*/*	*/*/*
b)	Acceleration	0.00;0.05;0.15	-0.05;0.00;0.05	0.00;0.00;0.00	-0.05;0.00;0.05	-0.15;-0.10;0.00	0.00;0.10;0.15
	Angular Velocity	0.00;0.05;0.05	-0.05;-0.05;-0.05	0.00;0.00;0.00	0.00;0.00;0.01	0.15;-0.10;-0.05	0.05;0.10;0.15
P value		*	*				
c)	Peak Detection	0.00;0.05;0.10	-0.05;-0.05;0.00	0.00;0.00;0.00	-0.05;0.00;0.05	0.15;-0.10;-0.05	0.05;0.10;0.15
	Zero Crossing	-0.05;0.00;0.15	0.00;0.00;0.05	0.00;0.00;0.05	-0.05;0.00;0.05	0.00;0.05;0.30	-0.30;-0.05;0.00
P value		*	*			*	*

DISCUSSION

Feet-based algorithms seemed to be the most accurate (Med 0.05s and 0.00s for FC and FO, respectively) and repeatable (25th/75th percentile error 0.00/0.05s and -0.05/0.00s for FC and FO, respectively) in the estimation of GEs. Algorithms showed comparable accuracy and repeatability in the estimation of stride and step time, independently from the implementation characteristics. Conversely, stance and swing time resulted underestimated or overestimated, depending on the implementation rules.

REFERENCES

[1] Pacini et al., 2018; Gait & Posture 2018; 66: 76–82;
[2] Trojanello et al., Gait Posture. 40 (2014) 487–492;
[3] Mileti P. et al., Sensors 2018; 18(3): 919;
[4] Bertoli M. et al., BioMedical Engineering OnLine 2018;17:58

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ANKLE DORSIFLEXION MEASUREMENT METHOD BASED ON INERTIAL SENSORS. REPRODUCIBILITY STUDY.

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INTRODUCTION

Several ankle-related injuries are developed from a limited ankle dorsiflexion. A fast diagnosis of this condition is crucial to ensure a correct recovery process. However, determining the amount of dorsiflexion that implies that condition is not a simple issue [1]. Multiple tools such as goniometer, inclinometer or tape measure are commonly utilized to obtain an accurate measurement [2]. The main drawback is that such tools are dependent on the examiner expertise and, while the intra-rater reliability is acceptable, inter-rater reliability is rather deficient [3]. In this study, an ankle dorsiflexion measurement system based on inertial sensors (IMU) is presented. To assess the reproducibility of such method, intra-rater and inter-rater variabilities are studied.

METHODS

10 healthy subjects and 2 examiners participated in the study. Each examiner used 2 IMU sensors provided by DyCare® to measure 2 trials of active and passive movements, alternatively. The exam position was supine decubitus, using a pad below the knee and assessing the neutral initial position with a goniometer. The reference IMU was located at the shin while movement IMU was located at the instep bridge.

For each trial, a set of maximums and minimums were detected along 4/10 cycles (active/passive) to assess the ROM in each cycle. Regarding intra-rater and inter-rater reliability, Interclass Correlation Coefficients (ICC) of the average ROM were calculated for active and passive movements and right and left legs.

RESULTS

Table 1 shows the average ROM, its standard deviation (SD) and its coefficient of variation (CV). among 10 subjects measured using the protocol presented in this study. ICCs are reported to show the intra-rater and inter-rater reliabilities for each type of movement and leg. After averaging the results of both legs, the following values were obtained from active and passive movements respectively: a ROM of 67.46º with 6.92º of variability, and 65.76º with 11.75º of variability; a ICC of 0.753 and 0.946 for intra-rater reliability; a ICC of 0.79 and 0.854 are obtained for inter-rater variability.

		Active	Passive
Right	ROM Mean ± SD (º)	66.94 ± 7.59	65.87 ± 11.50
	ROM CV (%)	11.33	17.46
	Intra-rater reliability 1 (ICC)	0.798	0.929
	Intra-rater reliability 2 (ICC)	0.973	0.948
	Inter-rater reliability (ICC)	0.853	0.851
Left	Mean ± SD (º)	67.99 ± 6.25	65.65 ± 12.00
	CV (%)	9.51	18.28
	Intra-rater reliability 1 (ICC)	0.397	0.939
	Intra-rater reliability 2 (ICC)	0.845	0.97
	Inter-rater reliability (ICC)	0.727	0.858

Table 1. Mean, SD, CV and ICC for active and passive movements and righ and left ankle.

DISCUSSION

The measurement protocol presented in this study presents an excellent inter-rater and intra-rater reliability compared with other methods [4]. In addition, the symmetry present between left and right ankles, indicates reproducibility of the measurements. Further research will be addressed to include more trails and examiners as well as studying the influence of subject training in the intra-rater reliability

REFERENCES

[1] Gatt, A., et al. (2011). *Journal of the American Podiatric Medical Association*, *101*(1), 59-69.
[2] Konor, M. M., et al. (2012). *International journal of sports physical therapy*, *7*(3), 279.
[3] Kim, P. J., et al. (2011). *Journal of the American Podiatric Medical Association*, *101*(5), 407-414.

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DOES THE USE OF CRUTCHES INFLUENCES THE ABILITY OF A SINGLE COMMERCIAL INERTIAL MEASUREMENT UNIT TO PROPERLY ANALYZE SPATIO-TEMPORAL GAIT PARAMETERS?

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INTRODUCTION

Patients after total hip (THA) or knee (TKA) arthroplasty often show gait abnormalities whose comprehension is crucial in order to plan an appropriate rehabilitative treatment [1-2]. Wearable sensor devices can be a valid tool for gait assessment in clinical practice, being relatively inexpensive and easy to use [3-6]. At the present no study investigated if the use of crutches influences the ability of a single inertial measurement unit (IMU), placed on the lower trunk, to correctly record the spatio-temporal gait parameters in patients after a recent THA or TKA.

METHODS

To answer our question we enrolled 20 patients (14 males, 6 females, age of 68.9 ± 10.9 years) admitted to the Physical and Rehabilitative Medicine Unit of Campus Bio-Medico University after total hip or knee surgical replacement. All the patients walked with two crutches. A control group of 10 healthy subjects was enrolled (6 males, 4 females, age of 43.4 ± 9.45 years). Participants were recorded simultaneously with a single IMU (G-WALK – BTS Bioengineering) and with a motion capture system (SMART-D – BTS Bioengineering) during 5 consecutive gait trials along the same path. All the participants were invited to self-select a comfortable walking speed.

RESULTS

Intraclass correlation index of spatio-temporal parameters recorded with the IMU showed moderate to excellent reliability results as for healthy subjects (ICC range 0.626–0.897) as for patients (ICC range 0.596–0.951). Pearson's r coefficient of healthy subjects showed strong to very strong levels of correlations for some spatio-temporal parameters (speed, mean cadence, left and right stride length, and stride duration) (range 0.646–0.977) and very week to moderate levels of correlation for gait cycle phases (swing, stance, single support and double support) (range 0.390–0.633). Patients data analysis showed similar results for general spatio-temporal parameters (range 0.704–0.986) and slightly lower values for gait cycle phases (range 0.077–0.464).

DISCUSSION

Our results outline that a single IMU placed on the lower trunk is a reliable tool for detection of some spatio-temporal gait parameters even in presence of crutches. However, crutches seem to interfere with the detection of the gait cycle phases

REFERENCES

[1] Ewen AM, et al. *Gait and Posture* 2012;36(1):1–6.
[2] McClelland JA, et al. *The Knee* 2007;14:253–63.
[3] Zügner R, et al. *BMC Musculoskeletal Disorder* 2019;20(1):52-60.
[4] De Ridder R, et al. *Journal of Sport Rehabilitation* 2019;0(0)1–4.
[5] Esser P, et al. *Journal of Neuroscience Methods* 2012;205(1):177–81.
[6] Washabaugh EP, et al. *Gait and Posture* 2017;55:87–93.

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EVALUATION OF A SET OF GAIT STABILITY INDEXES DURING DIFFERENT WALKING PERTURBATION PARADIGMS IN HEALTHY SUBJECTS

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INTRODUCTION

Dynamic stability is a fundamental prerequisite to ensure safe and efficient locomotion, despite the presence of small kinematic disturbances or control errors [1,2]. A series of biomechanical stability measures have been proposed as tools to investigate dynamic balance in both healthy (young or old people) and patients with gait disorders, with the primary aim to prevent falls. However, since in the most studies, the stability indexes have been investigated individually during several locomotor tasks, it is not clear, those that are the most specifically related to locomotor task, to perturbative condition, and to walking features. At these aims, we investigated a set of instability indexes in a sample of healthy volunteers performing different gait perturbation paradigms.

METHODS

The gait of twenty healthy subjects (from 23 to 45 years old, mass 63.6 ±12.1 kg, height 1.70 ±0.1 m, BMI 22.1 ± 2.1) was recorded through an optoelectronic motion analysis system (SMART-D500, BTS, Milan). A 15-segments model was used for the CoM calculation. Participants were asked to walk: i) at three different gait speeds [self-selected speed (M), fast speed (F) and low speed (S)]; ii) with either opened (OE) or closed eyes (CE); iii) on a slippery surface (SS); iv) after a vestibular stimulation (VS). Six trials were recorded for each condition. The spatio-temporal parameters, joint kinematics, distance between CoP and CoM, distance between CoP and XcoM (b min), harmonic ratio of the trunk acceleration (HRx, HRy, HRz) and coefficient of variation of the joint kinematics (CV) were measured.

Bivariate correlation, multiple linear regression analysis and receiver operating characteristic (ROC) curves were all used to test the correlation, the predictive value and the responsive ability, respectively, of the stability indexes with the locomotor perturbative tasks and gait variables.

RESULTS

Overall, we found that the CV of the trunk, the step width and the XcoM either correlated to (Figure 1), or predicted, or was responsive to a specific gait perturbation task. Furthermore, step width showed to significantly increase proportionally to the task's challenge (Figure 1).

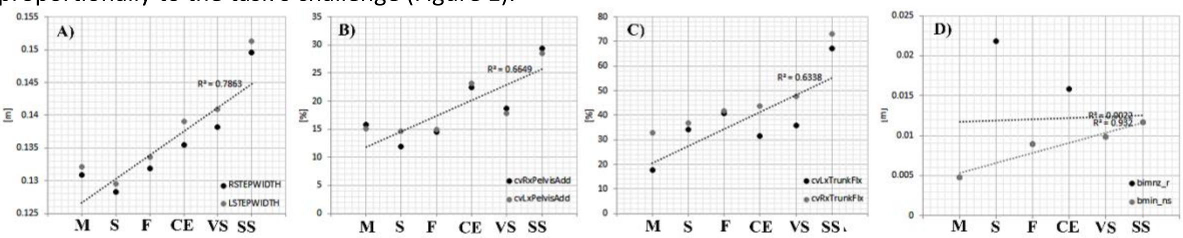

Figure 1. Mean values and correlation of the step width **A),** CV of the pelvis **B)** and trunk **C)** and b_{min} **D)**.

DISCUSSION

Investigating a set of stability indexes can help physicians to understand which aspect each index expresses within the complexity of the human gait stability. This approach would be useful to improve falls prediction when applied in gait disorders, and to increase our ability to group patients according to their clinical characteristics and gait features with the common aim of better rehabilitative programs.

REFERENCES

[1] Bruijn SM, et al. *J R Soc Interface* 2013;10(83):1-23.

[2] Simon AL, et al. *Gait & Posture* 2017;(55):37–42.

http://doi.org/10.6092/unibo/amsacta/6260

A COMPARATIVE ANALYSIS OF GAIT SYMMETRY INDICES IN PEOPLE WITH TRANSFEMORAL AMPUTATION

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INTRODUCTION

The quantification of features related to the symmetry of gait is of particular importance in several clinical contexts. Several indices were defined based on different signals and mathematical definitions [1]. Among them, the Harmonic Ratio (in its improved version, iHR [2]) and absolute symmetry indices derived from gait temporal or loading parameters (ASI, [3]) are very often used. However, no information is available about the mutual relationship among these indices, especially in populations with asymmetrical gait, such as people with transfemoral amputation (TF). The aim of this study was to fill this gap, by comparing the iHR and ASI indices in TF and in healthy controls.

METHODS

Five TF (age: 46.6±5.7 years; mass: 77.0±5.8 kg) and three healthy controls (HC; age: 24±2.0 years; mass: 51.6±2.9 kg) gave their informed consent to participate in the study. They walked a minimum of seven times at their self-selected speed along an 8-meter walkway, with a pair of pressure insoles (100 Hz, Novel) and two IMUs (100 Hz, xSens) located over their sacrum and on their sound shank (right shank for HC). For each trial, synchronization between the two systems was performed through a kicking motion of the sound (right) foot. Proper alignment of the pelvis IMU with the vertical (CC), anteroposterior (AP) and mediolateral (ML) anatomical axes of each participant was ensured through a verticalization procedure performed during a static phase before each trial [4]. A threshold of 20 N on the insoles' signals was used for stride segmentation and to compute stance phase durations (SPD). Frequency-, temporal- and loading-based symmetry indices were then quantified for each steady-state stride: iHR in all three directions using IMU-based pelvis accelerations, ASI using the SPD (ASI SPD), and ASI using the weight acceptance peak on the ground reaction force measured by the insoles (ASI GRF). Given the low sample size in this study, no statistical tests were performed. Instead, a visual comparison of the median scores was proposed through a spider plot. To allow for the comparison of the different indices, their zeta scores were computed, and an affine transformation was applied so that all scores ranged from 0 (total asymmetry) to 1 (total symmetry).

RESULTS

In Fig.1, the normalized values of all symmetry indices are displayed. Each line represents a participant. When all indices agree and have approximately the same values, the profile plot should describe a regular pentagon. Larger profile plots indicate higher symmetry. HC display rather repeatable profiles and overall agreement among the different indices, particularly among all iHR components and ASI SPD. Conversely, TF profile plots are highly variable, showing no general agreement among the different symmetry indices.

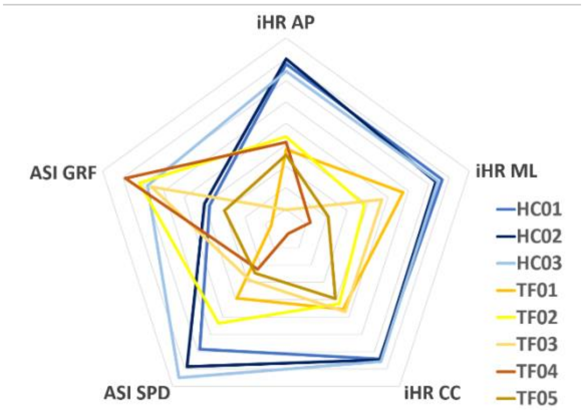

Figure 1. Symmetry indices for each participant.

DISCUSSION

The results of this preliminary study suggest that caution must be taken when generically referring to gait symmetry. The considered indices, based on the frequency content of pelvis accelerations, stance phase duration and vertical GRF, describe different aspects of gait symmetry and proved not to be necessarily related, particularly in TF. Indeed, TF patients seem to be characterized by different forms of gait asymmetry, involving either/both load or/and temporal aspects according to the adopted walking strategy. Further studies with larger sample size are needed to confirm these results. However, it is suggested that special attention is paid in providing and interpreting measures of gait symmetry, particularly when pathological populations are considered.

REFERENCES

[1] Patterson KK, et al. *Gait Posture* 2010;31:241-246.
[2] Pasciuto I, et al. *J Biomech* 2017;53:84-89.
[3] Nolan L, et al. *Gait Posture* 2003;17:142-151
[4] Bergamini E, et al. *Sensors* 2014;14:18625-18649.

ANTICIPATORY POSTURAL ADJUSTMENTS IN LATERAL STEPPING: COMPARISON BETWEEN BAREFOOT AND SHOD CONDITIONS

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INTRODUCTION

Postural control is the ability to maintain a desired position of body segments and/or whole body to ensure equilibrium in both static and dynamic conditions. To keep this control, hence reducing risk of falls, voluntary movements are normally preceded by the so called Anticipatory Postural Adjustments (APAs), which aim at reducing the forthcoming imbalance. Lateral stepping is a frequently repeated action performed during everyday activities and it plays an important role in changing base of support and avoiding obstacles [1]. It is known that footwear significantly modifies feet and ankle range of motion, with relevant alterations of rockers action and of inversion/eversion movements [2]. In addition, previous research highlighted also the pivotal role of sensory input in load accommodation and management. While the different role of both barefoot (BF) and shod (SH) conditions were analyzed in forward/backward stepping, no information is available for other movement directions. Therefore, the aim of this study was to investigate the differences in APAs during lateral stepping performed in both BF and SH conditions.

METHODS

Eight healthy young participants (age: 24.7± 4.8 years; mass: 65.3± 15.4 kg; stature: 171.1± 9.0 cm) were recruited for the study. All subjects were asked to wear training shoes. Instructions for participants were to stand as still as possible with their feet in a comfortable position (shoulder width apart), looking straight ahead, with the arms alongside the trunk, equally distributing the weight between their feet. Participants were verbally asked to start a voluntary lateral step with dominant leg and to finish action standing still. A total of five trials were completed and analyzed for each condition. Center-of-Pressure (CoP) trajectory was recorded using an in-ground 40*40 Bertec force platform. Data was recorded at a sampling frequency of 1 kHz and lowpass filtered at 10Hz. APAs medio-lateral (ML) and anterior-posterior (AP) amplitude and durations were calculated. Statistical analysis was performed through Paired T-tests (α=0.05).

RESULTS

Test showed there are no significant differences in AP and ML durations and in ML amplitude. Contrarily, AP amplitude is statistically different between conditions ($p < 0.02$) with higher displacements in SH compared to BF.

		Mean	*SD*	T	*p*
AP APA duration *(ms)*	BF	287.66	56.48	1.232	.258
	SH	263.43	77.97		
AP APA amplitude *(mm)*	BF	-6.24	1.93	3.163	.016
	SH	-12.55	5.27		
ML APA duration *(ms)*	BF	240.28	92.63	-.248	.812
	SH	248.29	54.34		
ML APA amplitude *(mm)*	BF	-14.38	5.82	.848	.425
	SH	-17.04	8.21		

Table 1. APAs parameters comparison between BF and SH conditions

DISCUSSION

A possible explanation is that due to the presence of training shoes, which are highly cushioned, subjects adapted to produce larger CoP displacements, as a consequence of increased acceleration of their center of mass towards the forefoot. Taken together these results on one hand agree with previous studies which have shown that footwear has some minor influence on dynamic postural control [3], whereas on the other suggests major changes in the antero-posterior compartment.

REFERENCES

[1] Maki BE, McIlroy WE. *Physical Therapy* 1997; 77(5):488-507
[2] Vieira MF et al. *PLoS One.* 2015; 10(8): e0135821.
[3] Nurse MA, Nigg BM, *Clin Biomech (Bristol, Avon) 2001; 16(9):719-27.*

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XX Congresso SIAMOC

QUANTITATIVE TESTING AFTER ACL SURGERY: A BIOMECHANICAL ASSESSMENT TOOL BEFORE ÉLITE ATHLETES RETURN TO COMPETITION.

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INTRODUCTION

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 aetiology [1]. Furthermore, ACL re-injury occurs in 6-13% of ACL-reconstructed knees [2]. The most likely mechanisms causing ACL injuries have been identified as excessive knee valgus rotation, knee internal rotation moments and large anterior tibial translation [1-2]. This study presents a quantitative testing tool for clinical decision-making after ACL surgery and athletes rehabilitation.

METHODS

9 élite athletes (mean±SD; age: 21.11±3.79, BMI: 27.54±5.41 kg/m^2) were evaluated after surgery (6-9 months), before returning to trainings, along with 10 healthy athletes (21.80±3.65, 22.41±1.39 kg/m^2). After signing informed consent, subjects performed 3 single leg drop landings (SLDL) from 32 cm height [3] and 3 single leg squats (SLS). Two force plates (Bertec, 960 Hz) and a stereophotogrammetric system (6 cameras, BTS Smart, 60 Hz) were used; markers were set as in [4]. A surface electromyography (sEMG) system (FreeEmg, BTS, 1000 Hz) collected the activity of Tibialis Anterior, Gastrocnemius Medialis, Vastus Lateralis, Rectus Femoris, Biceps Femoris and Semitendinosus. Ground reaction forces, hip, knee and ankle joint angles and moments were computed. sEMG activity was determined in term of onset, offset, duration and peak of the envelope [3].

RESULTS

Results showed a reduction in knee extensor and varus moment at initial SLDL after surgery (Fig.1); while a higher knee varus moment was observed during SLS, after surgery. The following differences were observed in term of kinematics: a reduced knee and ankle flexion angles at initial landing in SLDL; a higher hip, knee and ankle flexion angle in SLS; an excessive ankle eversion and external rotation in both SLDL and SLS; an excessive adduction, flexion and external rotation at the hip during SLDL and SLS. sEMG analysis showed an attempt to stabilize the knee joint through a co-activation of knee flexors-extensors muscles.

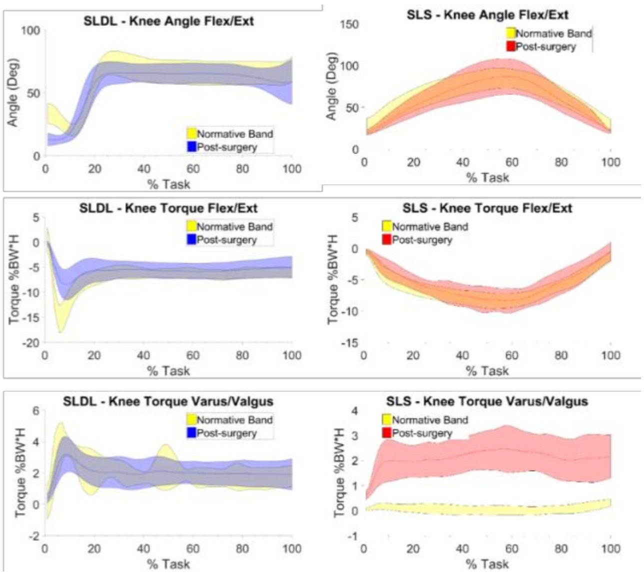

Figure 1: Knee angles and torques during SLDL and SLS (Post-surgery vs normative bands; mean±SD)

DISCUSSION

The adopted methodology has proven to be effective in detecting knee kinematics and kinetics alteration after surgery. This approach could be adopted for individualizing the clinical decision making for return to sports after ACL reconstruction, and for guiding the rehabilitation and preventive training programs.

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REFERENCES

[1] Shin CS, et al. *J Biomech*. 2009:Vol(42):280-285.
[2] Davies GJ, et al. *Curr Rev Musculoskelet Med. 2017*:Vol(10):307-314.
[3] Bonato P, et al. *IEEE Trans Biomed Eng. 1998*:Vol(45(3)):287-299.
[4] Sawacha Z, et al. *Clin Biomech. 2009:*Vol(24):722-728.

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BIOMECHANICAL ANALYSIS OF THE SIDE CUT IN BASKETBALL ATHLETES AS noncontact ACL injury screening.

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INTRODUCTION

The incidence of ACL is rising in noncontact injuries among professional basketball players, and authors agree that the majority of them occur during single leg weight bearing tasks as side-cuts and landings [1-2]. Neuromuscular risk factors have proven to provide important insight in determining athletes at risk of ACL injuries; however, the majority of the studies have been performed in laboratory conditions [2-3]. We investigated effects of performing a side-cut on lower extremity joints' kinematics and kinetics and the impact of the attending to a ball, by assessing athletes directly on the basket court. We hypothesized that attention to a ball would increase the neuromuscular risk factors.

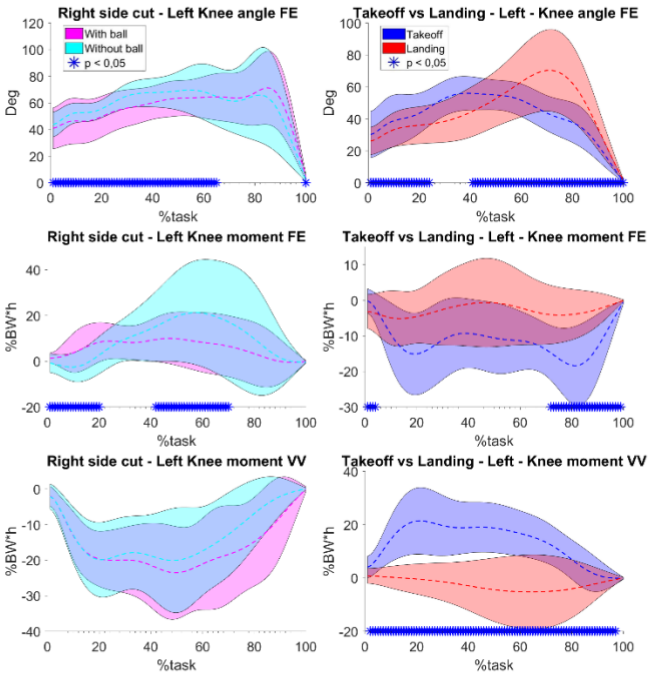

Figure 1 Side cut toward right with and w/o ball, shot jump take-off and landing kinetics and

METHODS

After signing the informed consent, 10 male professional basketball players (mean±SD; age: 21.89±1.69, BMI: 23.75±1.98 Kg/m^2) performed, bilaterally, 6 side-cuts, equally divided between attending (AB) or not (NAB) to a ball, and 3 jumping shots on the preferred leg. Data were acquired at their usual basketball court, by means of 4 cameras (GoPro Hero3) and pressure insoles (Novel Pedar); tape markers were applied as in [4], and their 3D trajectories reconstructed using a self-developed automatic tracking software [5]. Peak of Pressure, its occurrence within the task, the Centre of Pressure displacement, vertical ground reaction forces, 3D joints' rotations [4] and moments [6] were extracted. Paired T-Test ($p<0.05$) was adopted for data comparison.

RESULTS

Athletes exhibited a lower knee valgus moment while performing shot jump and landing then when performing the side cuts, in agreement with [3]. Furthermore, higher vertical ground reaction forces were detected in NAB (221.4(±73.2) %BW) than in AB condition (209.2(±41.4) %BW); higher knee flexion angle were also revealed in AB (65.5(±29.8)°) than in NAB condition (50.9(±22.8)°); lower knee valgus moments was observed in NAB (12.9(±31.9) %BW*H) than in AB condition (20.3(±19.1) %BW*H).

DISCUSSION

Our findings showed that athletes displayed higher knee flexion angles and knee abduction moments during side cut maneuvers, in particular while attending to a ball. The proposed approach could be used as a screening test for neuromuscular risk factors assessment and for planning preventive protocols.

REFERENCES

[1] Griffin LY et al. (2006). *Am J Sports Med*; **34**:1512-1532.
[2] Almonroeder TJ et al. (2015). *Int J Sports Phys Ther*; **10**: 918–928.
[3] Fedie R et al. (2010). *Sports Biomech;* **9**:165-77.
[4] Sawacha Z et al. (2009). *Clin Biomech*; **24**: 722-8.
[5] Volpe D et al. (2017). *Gait Posture*; **52**:87-94.
[6] ACL Quick Check® patent: https://www.bb-sof.com/

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SEX DIFFERENCES IN PROFESSIONAL FIELD HOCKEY PLAYERS DURING ON FIELD 20 M SPRINT RUN WITH PARTICULAR REFERENCE TO THE EFFECT OF HANDLING A STICK.

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INTRODUCTION

Field hockey players, depending on their designated position, cover a distance ranging from 9300 to 10870 meters [1]. In order to choose the appropriate exercise load for each player during the training sessions, the most frequent tests adopted are the 10m and 20m sprint tests. The latter is commonly carried out using chronometers or photoelectric cells to measure an athlete's ability to accelerate from 0-10m as quickly as possible. The use of an implement, as the hockey stick, modifies the overall athlete posture, resulting in an increased metabolic demand due to the low stance commonly assumed by the players [1]. Kinematics adaptations affect the athletes not only when handling a ball, but also their sprinting performance [2]. Furthermore, evidences suggested that females and males field hockey players differ mainly in term of the total distance covered per playing position for the duration of the game and their heart rate [3]. The aim of this study was twofold: first to investigate differences between female and male field hockey player's performance during the 20m sprint test, second to assess the impact of carrying the stick on athletes' performance. The assessment was carried on field, by opting for the lightest setup available, to provide coaching staff with an affordable performance evaluation tool.

METHODS

After signing informed consent, 9 females (mean±SD: age 21.56±4.67 years; BMI 22.01±0.99 Kg/m^2) and 8 males (age 21.82±2.89 years; BMI 23.91±1.56 Kg/m^2) professional élite hockey athletes were acquired while executing 3 consecutive 20m sprints in the following conditions: without carrying the stick (NS), carrying the stick with 1 hand (1HS), and with both hands (2HS). Kinematics data were collected by means of 4 cameras (GoPro HERO3, 30 Hz) and by placing a marker on L5 vertebrae; hence a self-developed automatic tracking [4] was used to compute 2D velocity and acceleration over time, and determine their peaks and occurrence within the task. Finally, Mann-Whitney U-test ($p<0.05$) was adopted to compare male and female groups for the collected variables.

RESULTS

Female athletes achieved the maximum speed earlier than male athletes and this difference became statistically significant when carrying the stick, in both the analyzed conditions. Despite this, when carrying a stick with both hands, male players registered significantly higher acceleration and speed peaks during the 20m sprint.

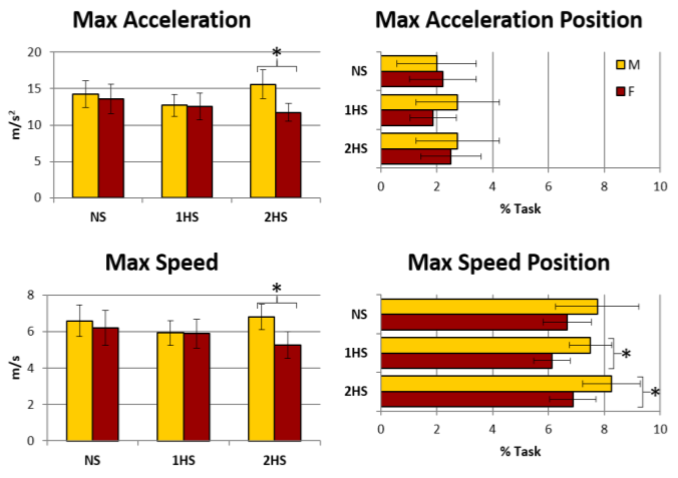

Figure 1: Acceleration and speed peaks, along with their position along the 20m sprint (mean±SD; *=p<0.05).

DISCUSSION

The presented experimental setup was able to detect differences between female and male élite athletes, during on field executed sport-specific tasks, thus allowing the coaching staff to quantitatively assess athletes' performance. The light and affordable setup facilitates athletes' assessment during training sessions, with no need to fix equipment on the players.

REFERENCES

[1] Podgórski T, Pawlak M. *Hum Mov.* 2011:Vol(12):108-123.

[2] Wdowski MM, et al. *Sports Biomech*. 2013:Vol(12):143-153.

[3] Cronin J, Sleivert G. *Sports Med*. 2005:Vol(35):213-234.

[4] Magalhaes FA, et al. *J Sport Sci Med*. 2013:Vol(12):660.

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XX Congresso SIAMOC

THE ROLE OF MUSCLE FORCES ON LOADING DURING THE SINGLE-LEG LANDING TASK ON ACL INJURED PRE- AND POST-SURGERY ATHLETES .

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INTRODUCTION

The anterior cruciate ligament (ACL) injuries have severe consequences for team and open-skills sport athletes, with higher risk in players with a previous rupture [1]. Kinematics and kinetics of the Single-Leg Landing task (SLL) was recently investigated by many researchers [1,2] for ACL injury prevention purposes. However, to date musculoskeletal modelling (MSM) method was little used to understand the role of biomechanics on loading during SLL in ACL injured subjects [2,3]. The aim of this study was to detect the presence of neuromuscular alterations in athletes with ACL injury before and after surgical ligament reconstruction through the assessment of their muscle forces during the SLL task.

METHODS

Thirteen male elite players (25.0±7.5 yr, 23.55± 2.1 BMI) without previous injuries (control group (CG) and four male elite rugby players (24.5±6.6 yr, 29.1± 4.0 BMI) with ACL injury were analyzed. Injured athletes were divided into before ACL reconstruction group (BAR) and after ACL reconstruction group (AAR). After signing appropriate informed consent, subjects performed a static trial and 3 SLL tasks bilaterally from a box 32-cm height onto a force plate. A 3D motion capture systems (BTS, 6 cameras, 60-120 Hz) synchronized with two force plate (Bertec FP4060, 960 Hz) and an 8-channel surface electromyography system (Free 1000 BTS, 1000 Hz) were adopted. Thirty reflective markers were applied according to a modify version of [4] as in [5], and the activity of rectus femoris (RF), biceps femoris (BF) caput lungus, tibialis anterior, gastrocnemius lateralis was recorded bilaterally. MOtoNMS [6] was adopted for converting 3D markers trajectories, GRFs and sEMG in OpenSim (model Gait 2392) [5]. By considered that the majority of noncontact ACL injuries occurs in the early phase of landing [1,2], the 2 seconds after the foot contact on the force plate were analyzed. For validation purposes the peak of the envelope occurrence within the task computed in OpenSim was compared with the one determined from the experimentally measured sEMG [5]; the Wilcoxon test ($p<0.05$) was used. Joint kinematics and kinetics, muscle forces were estimated and compared between BAR, AAR athletes and CG through the U-Mann-Whitney test ($p<0.05$).

RESULTS

The comparison between CG, BAR and AAR athletes underlined significant differences ($p<0.05$) in both the kinematics and kinetics variables. In term of muscle forces, the injured limbs displayed alterations at the level of the hip, knee and ankle joints (Figure 1).

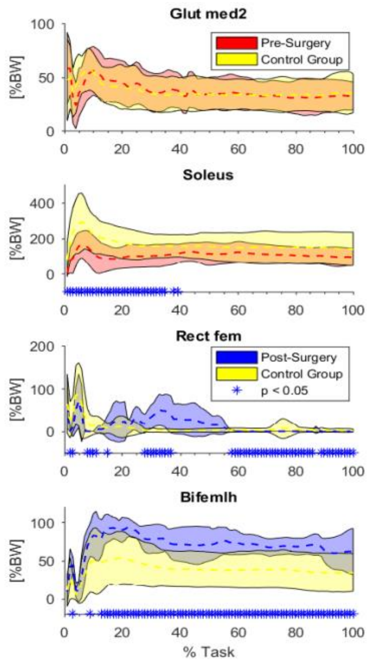

Figure 1. Gluteus medius, Soleus, RF, BF muscles forces compared respectively between the BAR (red), AAR (blue) and controls.

DISCUSSION

Results of the current research showed the presence of neuromuscular alterations associated with ACL injuries and the subsequent surgical ligament reconstruction. Future research should focus on improving the Opensim model by adopting a 3-dof knee model and by increasing the subjects population.

REFERENCES

[1] Hewett et al., Am J Sports Med 2005; 33: 492-501.
[2] W.A. Laughlin et al., *J Biomech.* 2011; 44: 1845-51.
[3] R. Bakker et al., *J Orthop. Res.* 2016; 34: 1636-44.
[4] Z. Sawacha et al., *Clin. Biomech.* 2009; 24:722-28.
[5] A. Scarton et al., *Gait Posture* 2017*;* 58:194-200.
[6] A. Mantoan et al., *Source Code Biol. Med.* 2015*;* 10: 12.

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3D-GAIT ANALYSIS AND COGNITIVE ASSESSMENT IN ADVANCED TAI-CHI PRACTITIONERS.

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INTRODUCTION

Tai Chi Chuan (TC) is a traditional Chinese body-mind exercise, characterized by slowness, muscle relaxation steady rhythm, brething control, mental focus and body weight shifting[1]. Previous studies have examined the efficacy of TC for healthy older adults, concentrating on motor function-related outcomes (flexibility, strength, mobility and balance) rather than gait-related parameters. Furthemore, it is unclear whether TC would improve cognitive functions. The aim of study was to evaluate the effects of TC on gait parameters and cognitive ability, in healthy adults practitioners respect to naivë healthy controls.

METHODS

14 advanced TC practitioners and 14 age-gender-BMI matched naivë healthy controls were enrolled. All subjects underwent to neuropsychological (NP) evaluation assessing cognitive functioning (visual spatial memory, verbal fluency, executive functions). Moreover the 3D-Gait analysis (3D-GA) assessment of walking, was performed by using a Stereophotogrammetric system (Qualysis,120 HZ)[2], after placing fifty-nine 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 [2],. The means and standard deviations of outcome measures were calculated, after correcting the value of each parameter for the body mass index (BMI).

RESULTS

Our results showed a better cognitive ability of TC then to naivë controls ($p<0.05$) highlighted by visual-spatial memory test evaluating though Corsi test. 3D-GA showed an increase of stance time ($p<0.05$), the decrease of double limb support time (DBL) ($p<0.01$) and the increase of relationship between DBL time and Single Limb Support time (SLS) (DBL/SLS) ($p<0.001$). We also found the increase of ankle plantar flexion during initial contact and load response ($p<0.05$), increase of ankle dorsal flexion during mid and terminal stance phases, increase of knee flexion during initial contact and load response ($p<0.05$).

DISCUSSION

The study shows that, TC practice improve the gait parameters and joints excursions. These results are supported by reduction of DBL time that indicate a better gait stability and a reduction of fall risks. Our results suggested that TC practice is a good strategy to improve the quality of life.

REFERENCES

[1] Wang H et al. Altern. Med. 2016; 2016: 1–6.

[2] Perry, J., Burnfield, J.M., 1993. Gait analysis: normal and pathological function. Dev. Med. Child Neurol. 35, 1122.

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A COMPARATIVE STUDY OF THREE SEGMENTATION ALGORITHMS FOR 2-DIMENSIONAL MARKERLESS GAIT ANALYSIS

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INTRODUCTION

Three-dimensional marker-based gait analysis by means of multiple cameras is often considered the gold standard for quantifying gait., Recent advancements in depth camera (RGB-D) technology and video processing have paved the way to the development of a new generation of low-cost movement analysis systems. The most critical step required to implement any "marker-less" method is the subject separation from the background (segmentation). Despite the plethora of methods and approaches proposed in computer vision, specific investigations aiming at identifying the most effective methods for clinical movement analysis applications are still missing. The aim of this study is to perform a direct comparison between a common segmentation algorithm, based on green background subtraction (GBS) used as the reference solution, and two different automatic thresholding methods [2,3], adapted to human segmentation, with which a threshold can be set by analyzing the image histogram.

METHODS

The algorithms were a) GBS [1], b) OTSU (a modified version from [2]), and c) SAL, a modified version from [3]. Experimental data were collected on a subject who walked at a self-selected speed on a 7-meter walkway wearing a T-shirt, underwear, and coloured ankle socks (pink and blue). The RGB-D camera (Kinect 2) was positioned laterally to the walkway, and a homogeneous green background was used. The image coordinate system of the video camera was aligned to the sagittal plane. In all three methods a white color filter to identify and segment the feet was implemented. The accuracy of the segmentation obtained from the three algorithms was evaluated by a comparison with a manual mask (gold standard) and the Jaccard similarity index (JI) was calculated in which JI = 1 represents the perfect matching.

RESULTS

For each algorithm the JI was calculated for the entire dataset (50 images) and the following scores were obtained: GBS 0.94±0.01, OTSU 0.93±0.01, SAL 0.95±0.01.

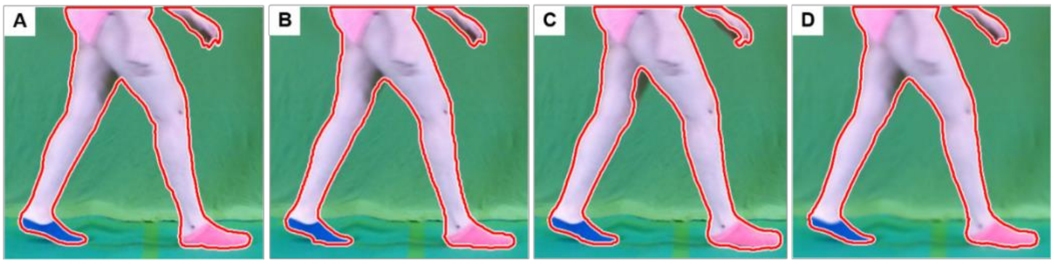

Figure 1. Segmentation masks (red lines): A) manual, B) GSB, C) OTSU, D) SAL.

DISCUSSION

GBS and SAL showed similar performances (0.94-0.95). Both GSB and SAL were successful in identifying also the areas of the considered leg even when it was overshadowed by the contralateral leg. They proved to be selective in segmenting the feet by excluding the shaded areas below them. The performance of SAL and GBS was poorer during the swing phase as the fix value of the time of exposure of the camera did not allow to better distinguish the silhouette of the leg and the foot. OTSU exhibited the worst performance (0.93) as it did not permit to identify a correct threshold also for the shady areas and its performance could deteriorate in low light conditions. In summary, the SAL method showed a similar performance compared to the GBS method with the advantage of avoiding the presence of the green background and selecting the appropriate threshold automatically.

REFERENCES

[1] Pantzar-Castilla et al. Acta Orthop 2018; 89 (6): 656–661
[2] Otsu, N. IEEE T Syst Man Cyb 1979; 9 (3): 62-66
[3] Salvi et al. BioMed Eng OnLine 2018

A 2D MARKERLESS GAIT ANALYSIS PROTOCOL FOR ESTIMATING THE SAGITTAL LOWER LIMB JOINT KINEMATICS OF CHILDREN WITH CEREBRAL PALSY

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INTRODUCTION

Quantitative gait analysis is a valuable tool to identify and monitor the locomotion deterioration of ambulatory children with cerebral palsy (CP) [1,2]. A low cost, easy to set up gait analysis system would be very beneficial to an extensive monitoring program. To this purpose a markerless (ML) protocol for clinical gait analysis, based on the use of a single RGB camera integrated with an infrared depth sensor, was developed and validated on gait data collected on children with CP. The accuracy of the estimated lower limb sagittal joint kinematics was assessed against that of a conventional marker-based protocol.

METHODS

The proposed protocol was tested on 18 children with CP. The sensing device was a Kinect 2, used to capture both the RGB video and the depth data (RGB-D). A segmental 2D model of the foreground lower limb was extracted from the raw data and it was used to estimate the sagittal joint kinematic of hip, knee and ankle joints. The ML protocol was validated by comparing the resulting kinematics to that obtained with a marker-based stereo-photogrammetric system. The offset between the two estimates was determined. The Root Mean Square Deviation (RMSD) of the two kinematics was determined before and after removing the offset between the two estimates.

RESULTS

The mean RMSD values were about 9° for the hip, 7° for the knee and 8° for the ankle. After the offset was removed, all mean RMSD values were between 3 and 5 degrees (Table 1) with slight differences between left and right side and amongst joints. The correlation between the joint kinematics patterns obtained with the two methods was close to 1 (0.9±0.08) for all joints and both sides.

Table 1. Root Mean Square Deviation (RMSD) of the sagittal joint kinematics after removing the offset.

Joint kinematics RMSD [deg]	Ankle		Knee		Hip	
	Right	Left	Right	Left	Right	Left
mean±st.d.	5.1±1.9	4.6±1.2	3.6±1.1	3.6±0.9	3.7±1.1	3.7±0.9
Maximum	10.5	7.3	6	5.4	6.6	5.9
Minimum	2.7	3	2.1	2.4	2.2	2.3

DISCUSSION

Once the offset was removed, the joint kinematics patterns obtained from the proposed ML protocol applied to the RGB-D sensor and those obtained from a conventional protocol applied to stereo-photogrammetric data showed a good agreement. This indicates that the novel protocol can estimate the joint kinematics patterns and ranges very faithfully. On the other hand, the presence of a non-negligible offset, which was expected due to the differences in the definition of the anatomical reference frames of the body segments, requires caution in comparing data from different protocols. The use of a reference posture could minimize the drawbacks associated to joint angular offsets. Additional improvements to the proposed method are expected by using the latest RGB-D sensors which allow for a full control of the camera settings (white balance, exposure time, etc.) and by developing more efficient algorithms for extracting the image portion of interest (the foreground lower limb) from which the joint kinematics is estimated.

REFERENCES

[1] Bell et al. *J Pediatr Orthop* 2002; 22 (5): 677-82.
[2] Butler et al. *J Med Case Rep* 2016; 10: 157.

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THE TEXT NECK AND THE SMARTPHONE: THE DESIGN OF A HEAD MOUNTED DEVICE FOR THE ASSESSMENT OF THE PREVENTION APPS

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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]. 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*.

METHODS

The general idea was to design a tool for the assessment of the neck angular improvement while using smartphones Apps with biofeedback embedded acting as a tutor to prevent the text neck. The tool was based on IMUs with accelerometers and a properly designed protocol based on the activity with the smartphone. The device used to validate the App was based on an Inertial Measurement Unit with accelerometers [1-2]. It consists on two components. The first component is arranged in a helmet in order to monitor in nautical angles the head-pitch and head-roll. The second component has been designed to be affixed in the back to monitor the back angles and to finally provide information useful to detect the relative neck-back angle.

PROTOCOL AND RESULTS

Figure 1 shows the helmet. The protocol consists on a subject monitoring while using 1 hour of smartphone while sitting on an ergonomic chair assuring a vertical back position in two conditions:

C1) Without the App for text neck activated.

C2) With the App for the text neck activated.

Each trial associated to each condition should be repeated 5 times in different days.

Figure 1 Head mounted device

The timing of the system was aligned with the time of the smartphone; the screen lock was settled to 0s to don't allow pauses. The only instruction was to use the smartphone in texting activity (the more critical according [1]) as chatting in the social-networks. The use of the ergonomic chair avoided the use of the second component of the device.

An application in a case study on *HeadUp-Protect your neck!* indicated that the reduced angular inclination on a 18 years old subject in C2 was equal to 31% in mean value (STD ± 8%) for the roll angle, 40 % in mean value (STD ± 11 %) for the pitch angle.

DISCUSSION AND CONCLUSION

A device has been proposed to assess the neck angular improvement while using smartphones Apps with biofeedback embedded to prevent the text neck. A preliminary trial indicated the usefulness of the App to prevent the text neck. We are now planning the enlargement of the study to a wide sample

REFERENCES

[1] Giansanti D., *Istisan* Report 18/21, ISS, 2018, Rome.

[2] Giansanti D. et al., Notiziario ISS, Vol 31, n. 7-8, 2018, Rome

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DESIGN AND TEST OF A SENSORIZED PACIFIER

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INTRODUCTION

Breastfeeding (BF) is considered fundamental for infant feeding and has basic role in nutrition, immunological protection and creation and growth of the infant's orofacial functions and structures
[1-3]. Infants in order to perform a correct BF must have suitable oral capacity with suitable strength and therefore dynamic and kinematic functionalities. An infant demonstrates these capacities through two distinct patterns: non-nutritive sucking (NNS), for example when the infant sucks a finger or a pacifier which occurs in the absence eating, and nutritive sucking (NS), which occurs during BF or when eating from a baby bottle. Both NS and NNS patterns are fundamental [4]. The kinematic and dynamic assessment of both NNS and NS tasks could be of aid to investigate problems and/or pathologies related to the orofacial functionality. To reach this objective it could be useful to design and construct a specific medical device. However, as it has been shown by a literature research, up to now no one has explored this.

OBJECTIVE AND METHODS

The general idea was:

(a) To design a medical device to assess the NNS.
(b) To bench test the medical device.
(c) To insert the medical device in an experimental study.

In order to reach this objective, we activated a research of specific sensors suitable to assess the dynamic and kinematic properties and set-up a specific biomedical measurement chain to test different sensors and different conditioning chains.

RESULTS AND DISCUSSION

At the moment we have implemented step (a) and are terminating step (b). In particular we have selected a peculiar sensor capable to assess the dynamic properties as a function of time in the range of interest [1-4]. The Figure 1 shows the architecture of the system and a photo with the sensorized pacifier. It has also been introduced a led based biofeedback function, to show by means of a led array the activity and strength mapped with a proportional led number.

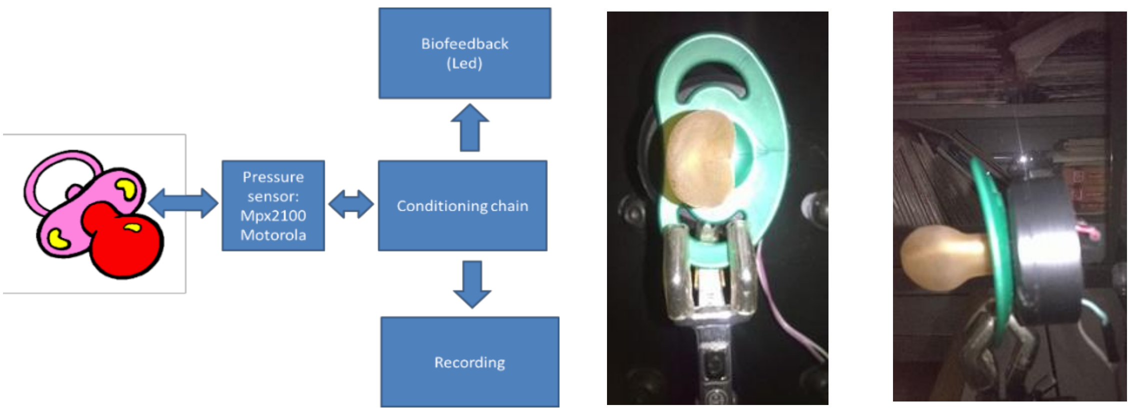

Figure 1 Sensorized pacifier

The next steps will be focused to the bench test completion and successive phases necessary to insert the device in an experimental study according to the national regulation.

REFERENCES

[1] E.B.A.F. Thomaz et al. J. Hum. Lact. 34 (2018) 768–788,
[2] N.C. Rollins et al. Lancet. 387 (2016) 491–504.
[3] C.G. Victora, et al. Lancet. 387 (2016) 475–490.
[4] A. Grassi, et al .Med. Eng. Phys. 38 (2016) 398–402

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THE POWERED EXOSKELETON AND THE USABILITY: THE DESIGN OF AN ELECTRONIC BASED SURVEY FOR THE HEALTH PROFESSIONALS

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INTRODUCTION

The medullar damage is a very wide ranging health problem. The impact of the problem for the health care system is very high and complex for the risk of death and for the costs. The rehabilitation and the design of specific aids are a key point. It is widely demonstrated that solutions for rehabilitation and for the aids which allow the "upright position" are also very useful to improve the functionality of the internal organs and avoid the bedsores [1]. The introduction of the mechatronics is allowing new opportunities to the exoskeletons in rehabilitation with the so called powered exoskeleton (PE). Several commercial PE systems and PE [2] systems developed in the academic and research bodies have been very recently introduced in different scenarios of life.

METHODS

The study focused on these systems and the health professionals and addressed the design of a tool to investigate the appreciation and feasibility of the introduction of these systems in the care processes.
The tool was based on a dedicated questionnaire that generally was divided into three sections: *Section 1)* Basic knowledge on the PE; *Section 2)* General opinions on the PE *Section 3)* Opinions of professionals on the PE clinical use. Section 1 and Section 2 are not specific for health care professionals (HCP)s and can be filled either by the citizen or the HCP.

RESULTS AND DISCUSSION

The questionnaires were organized using an electronic methodology based on Forms (Microsoft,USA).
This methodology is particularly useful for the electronic surveys: it allows an easy sending of the questionnaire using for example WhatsApp or other messengers. Data are automatically stored in a database a report is automatically updated with graphics and statistics. The electronic survey has been designed. This is the link of the section 3 of the electronic form electronically developed https://forms.office.com/Pages/ResponsePage.aspx?id=DQSIkWdsW0yxEjajBLZtrQAAAAAAAAAAAAZ__ghPqE5UNEJCMERaOUxVN0hLTUZWN0YzWFlCRzdXRS4u. Figure 1 shows an extract of the survey.

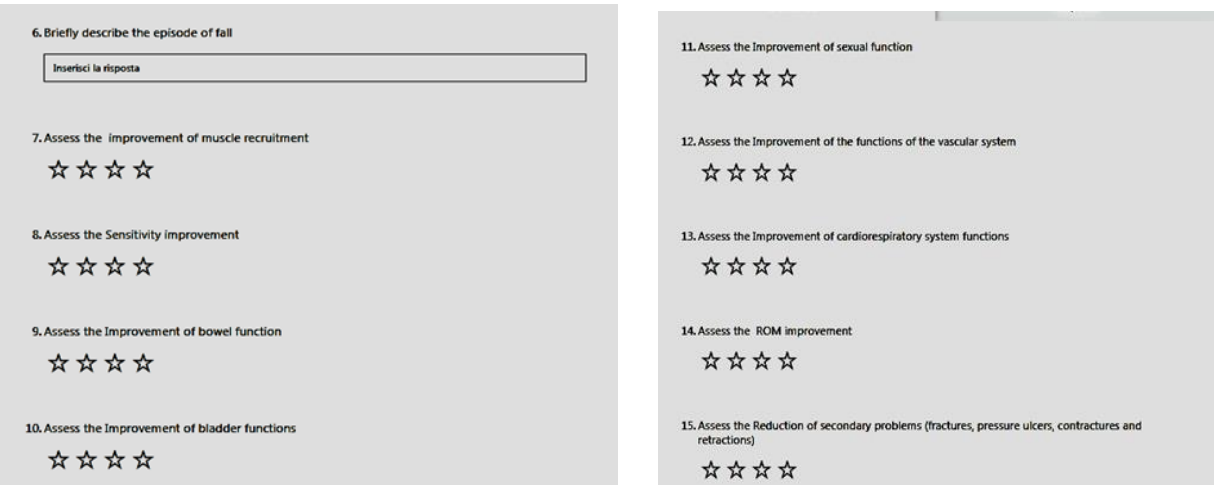

Figure 1 Two pieces of the electronic survey

At the moment we have submitted the electronic survey to 40 professional and are performing the data-mining. Preliminary results are indicating that 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.

REFERENCES

[1] Scivoletto G. et al. *Istisan Report* 08/39, ISS, Rome
[2] Giansanti D. *Istisan Report* 18/10, ISS, Rome

TOWARDS A PERSONALIZED PROSTHETIC PRESCRIPTION FOR TRANSFEMORAL AMPUTEES: THE STRATEGY OF THE MOTU PROJECT

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INTRODUCTION

The estimated annual incidence of lower limb amputation is around 20 new cases per 100,000 inhabitants, with considerable differences from country to country. More than half of this population fall at least once a year.

A remarkable heterogeneity characterizes the population of lower limb amputees (e.g. in terms of different causes of amputation) and several prosthetic components are available on the market, but scant evidence is available about which prosthetic option can give each different patient the highest level of static and dynamic balance (the so-called "heterogeneity of treatment effect"). Here we present the strategy to fill this evidence gap that we have been developing within the MOTU project.

METHODS

Our strategy is made of two main components: a retrospective and a prospective study.

The retrospective study is ongoing. It is based on the archive of INAIL Prosthetic Centre. It targets all unilateral transfemoral amputees, aged 18 years or more, having had a hospital stay between 2011 and 2017. Information is available on patients' characteristics and prostheses. The primary outcome is falls occurred within the Centre during the hospital stay. Secondary outcomes are represented by clinical scales about mobility.

The prospective study is under development. It will be set up firstly in the form of a pilot, feasibility trial at INAIL Prosthetic Centre. It will target transfemoral amputees, observed from their first delivery of a prosthesis after the amputation. Patients balance will be assessed with clinical scales as well as instruments for movement analysis (wearable inertial sensors, force platform, sensorized treadmill). Patients will be followed up for falls and possible change of prosthesis. The clinical staff involved in the pilot study will be interviewed after 6 and 12 months, to have their feedbacks and reports about technical and logistical problems. We will measure the execution time of the protocol and analyze the collected data for their validity and redundancy. The data will be integrated with those coming from the retrospective study. According to the results of the pilot study, the protocol will be refined and applied on multiple clinical centers.

RESULTS

The retrospective study is ongoing. We have collected complete data about 218 hospital stays during 2015 and the first quarter of 2016. Data about hospital stays outside this time window are being acquired following a faster procedure that leverages on the digital database of the Centre. Data quality checks are continuously under way.

The prospective study is under development. We have sketched a first measurement protocol and we are customizing commercially available mobile health solutions for the specificities of our target population (e.g., we are adapting a mobile health system for the Timed Up and Go test, in order to be used on the L-test). Full engagement of INAIL clinical staff is being sought through the organization of workshops and personal meetings.

DISCUSSION

According to a preliminary power analysis, hundreds of subjects are needed for the development of an evidence-based system that can provide suggestions on the best patient-prosthesis coupling. The clinical studies carried out so far have small sample sizes, thus proving to be inadequate for our purposes. We aim to draw up a protocol that is informative and lean enough to be adopted in the normal practice of various clinical centers and, therefore, reach the appropriate number of subjects. As a result, it will be possible to develop new policy models for the prescription of prosthetic components.

In this context, balance and mobility tests instrumented with wearable inertial sensors could bring considerable benefits: they are not affected by inter-rater variability, are expected to be more sensitive to the treatment effect, and they can provide useful insights about the balance of the amputees that cannot be obtained by the standard clinical scales.

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RESPIRATORY REHABILITATION: BETWEEN MECHATRONICS AND EXERGAMES

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INTRODUCTION

Respiratory rehabilitation aims to modify the impact that the respiratory disease has on the patient's quality of life, reducing the severity of the symptoms and improving their ability to adhere to the activities of daily life. Following an initial assessment, they are prescribed (a) different forms and modes of physical exercise and (b) exercise of pulmonary musculature to improve individual performance and the consequences of the symptoms of the emotional sphere related to the pathological condition. At the moment the devices for pulmonary exercitation/stimulation, even if gamified, give out qualitative information and are not provided with electronics and/or are not connected to the network. Figure 1 (A) shows an example of a commercial gamified lung exerciser based on three chambers with balls. The balls rise according to the flow intensity (*1 ball=t 400 cc/s ; 2 balls=800 cc/s ; 3 balls=1200 cc/s*)

METHODS

We have designed a prototypal exerciser/stimulator system for expiration improvement through the execution of gamified exercises. The system comprehends (a) an electronic device for the expiration flow measurement; (b) An USB 6008 A/D converter (National Instruments, USA) for the integration to a PC. (c) A biofeedback software application on the PC with a gamified representation of the flow, allowing also the data storing; designed by means of Labview 10 (National Instruments, USA).

RESULTS AND DISCUSSION

Figure 1 (B) shows the Hardware of the system and (C) the biofeedback software. The core element of the hardware is a hot-wire-measurement sensor: the anemometer component Mini Anemometer 490 (Kurtz Instruments inc, USA). A tube with a section with the diameter equal to 9.65 mm is connected to the mouth using a removable adaptor for reasons of hygiene. After a first bench test it has been decided to apply a flow-splitting fluidodinamic solution to improve the measurement scale. The initial tube has been splitted into 4 tubes with identical section. This mechanic architecture has been proposed to optimize and better center the dynamics for the hot wire measurement sensor. Φi is the initial air flow; $\Phi 1 = \Phi i /4$ is the flow input to the hot-wire sensor. The hot-wire sensor has been electronically polarized and powered according to the datasheet.

The biofeedback software shows three tanks, filled according to the flow intensity:
(*1 tank=400 cc/s; 2 tanks=800 cc/s; 3 tanks=1200 cc/s*)

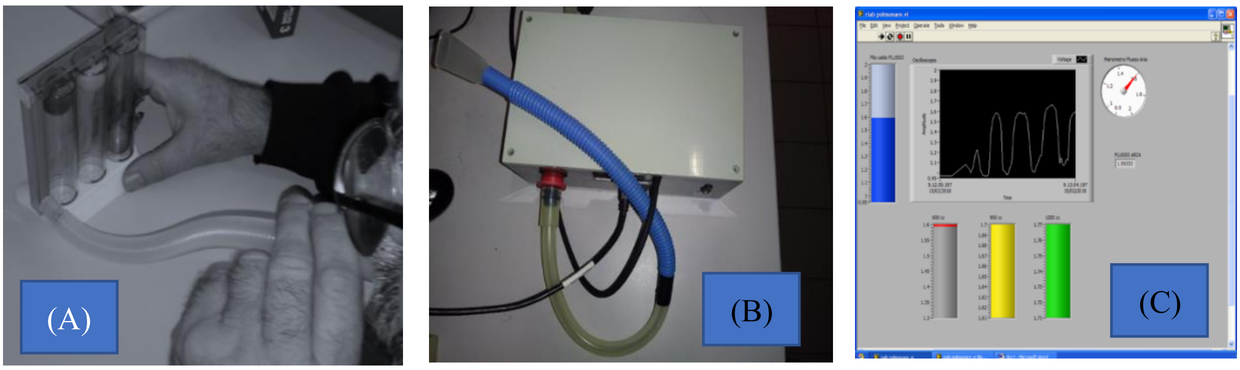

Figure 1 (A) Example of commercial gamified lung exerciser (B) Hardware (C) The biofeedback software

The system has been successfully bench tested. We have planned to introduce it into a full clinical use In particular the plan is to use it at the patient's home alone or in combination and integrated with and equipment which performs an automatic 6 minutes walking test [2-3]. This could allow a daily remote medical data-exchange useful to follow the patient's conditions improvements.

REFERENCES

[1] Giansanti D and Maccioni G. Telemed J E Health. 2019 Mar;25(3):257-259
[2] Giansanti D and Maccioni G. Telemed J E Health. 2017 Aug;23(8):694-696
[3] Giansanti D. Istisan Report 17/30, ISS, Rome, 2017

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A KIT FOR THE ASSESSMENT OF THE HAND FORCES WITH EXERGAMES: TOWARDS THE INTEGRATION

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INTRODUCTION

Severe neuropathies, arthrosis, tendon inflammations, poor working practices, repeated use of working devices and elderly pathologies can lead to severe damage to the functionality of the hand and therefore to the need of design of appropriate tools for hand neuro-motion rehabilitation. Many commercial devices are designed to assess the overall hand force, without investigating the force of the single fingers involved in the motor tasks. Ideally, functionality in daily motor tasks (such as pushing buttons, pulling levers and grasping objects) should be evaluated by quantifying the individual finger force expressed in the tasks. Different approaches have been reported in the literature [1], investigating both the delivered force of single fingers and the finger force coordination, and the grasping force, other studies have described home-care systems for hand rehabilitation. We are propsing a kit for the assessment of the hand–finger functionality in pressing tasks integrated with exergames [1].

METHODS

Two types of sensor-based measurement [1] devices were constructed for measuring the fingers' force in two different hand postures . The first type was named the *keyboard* and consisted on a flat box containing five sensor-equipped keys for measuring the force of all fingers (Figure 1,A). The second type was named *the mouse* and consisted of a mouse-like shaped backing containing a single sensor-equipped key for measuring the force of the thumb or of the little finger. Two software applications have been proposed in this study for the two different devices (*mouse* and *keyboard*). The application software (Figure 1,B) was developed using Labview 2010 (National Instruments, USA). It allows the following functions: Five virtual tanks are interactively filled on the basis of the exerted force by means of each finger.

RESULTS AND DISCUSSION

The kit comprehending the 4 devices has been:

- Updated to the new operative systems and pc platforms.
- Updated with the new software developed by means of Labview 2010 for the gamified restitutions through exergames.

The completed kit has been successfully tested in performance, no failures have been detected. The Force resolution is now 0,05 N , the maximal acceptable force is 100 N.

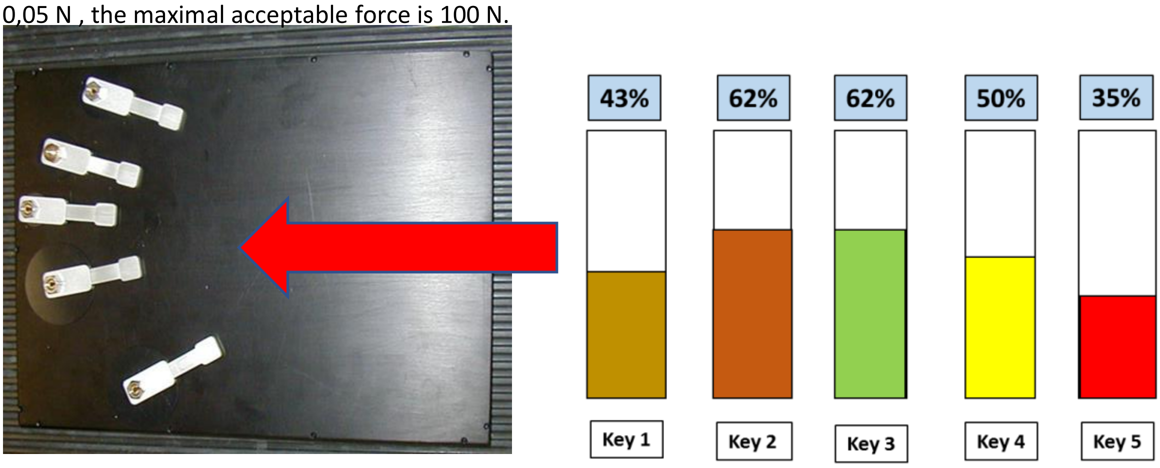

Figure 1 The flat keyboard and the SW virtual based representation

CONCLUSION

A new instrumental kit for the measurement of the hand forces with exergames has been proposed. It allows both a measurement function and a biofeedback restitution through an exergame designed to motivate the subject involved in a rehabilitation process. The next step will be focused to (a) the selection of clinical cases to assess the efficacy of the kit in the rehabilitation protocols with the particular reference to the (b) the functionalities of the exergame.

REFERENCES

[1] Giansanti D et al. Istisan Report 08/05,ISS,Rome,Italy

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PLANTAR PRESSURE MEASUREMENTS DURING DIFFERENT SHOT IN ELITE TENNIS PLAYERS: PRELIMINARY RESULTS FROM A PILOT STUDY

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INTRODUCTION

In order to obtain the best possible result during competitions, tennis players are required to execute different strokes with the greatest accuracy in response of a combination of various aspects as different playing surfaces (i.e., clay court, greenset, carpet, etc.), ball speed, velocity changes, perceptual-motor processing and postural control. Moreover, athletes must to adapt the abovementioned variables in relation to the progressive level of difficulty existing from juniors to professional, in male as well as in female players [1,2].

Thus, the aim of the study was to evaluate plantar pressure in a male and in a female professional tennis player during different shot.

METHODS

A number of 2 right-handed elite tennis players, comprising 1 male and 1 female, was included for the study. The protocol assessment, performed in a clay court, consisted of: a) 3 sets of 10 forehand shot; b) 3 sets of 10 two-handed backhand shot with a 3-minute rest between the first 3 and the last 3 sets. During the protocol, plantar pressure parameter (gr/cm^2) of each participant was measured via a sensorized system for the foot pressure evaluation inside the shoe (FlexInFit; Sensor Medica®; Guidonia Montecelio, Roma, Italia) and a Bluetooth® device computer-aided using freeStep® software (Sensor Medica®; Guidonia Montecelio, Roma, Italia). Mean values and standard deviations were calculated using Statistica Software 12 (StatSoft®, TIBCO® Software Inc., Palo Alto, CA, USA).

RESULTS

Our result showed similar mean plantar pressures between left and right foot both in the forehand shot and in the two-handed backhand shot in the male as well as in the female tennis player. Regarding gender differences, although no differences in mean plantar pressures were found in the two-handed backhand shot, as concern the forehand shot, the female tennis player showed a greater plantar pressure compared to the male tennis player.

Table 1. Mean values and standard deviations of plantar pressure parameter in the two different shots

	Male player		Female player	
	forehand	two-handed backhand	forehand	two-handed backhand
Left plantar pressure (gr/cm^2)	240,86±4,19	278,12±3,09	339,74±5,88	280,54±3,16
Right plantar pressure (gr/cm^2)	243,21±3,96	284,53±4,21	340,44±5,47	291,67±6,52

DISCUSSION

Based on our results, we suppose that elite tennis players, regardless of the types of shot, show an equal plantar pressure distribution between foot, probably an adaptation in order to prevent injury. A larger sample, different category level, characteristics of different playing surfaces and sport footwears need to be investigated in order to confirm our findings [3].

REFERENCES

[1] Brechbuhl C, Girard O, Millet GP, Schmitt L. *Med Sci Sports Exerc* 2018; 50(12):2465-2473.

[2] Fernandez-Fernandez J, Kinner V, Ferrauti A. *J Strength Cond Res* 2010; 24(12):3255-3264.

[3] Girard O, Eicher F, Fourchet F, Micallef JP, Millet GP. *Br J Sports Med* 2007; 41(11):733-738.

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THE DIABETIC FOOT PREVENTION: HOW MODEL-BASED ASSESSMENT OF PLANTAR TISSUES INTERNAL STRESSES CAN INFORM CLINICAL PRACTICE

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INTRODUCTION

Chronic diabetes complications represent the most relevant problem in terms of clinical management and healthcare system costs linked to diabetes [1]. Ten years after disease onset, between 20 and 50% type-2 diabetic patients develop diabetic neuropathy (DN), which is a major risk factor for diabetic foot problems. This represents the most common cause of non-traumatic amputation despite the fact that nowadays various foot orthoses have been optimized to offload areas with high plantar pressure [2]. With a re-ulceration risk of 65% in 5 years, there is an important potential to optimize foot orthosis prescription by accounting for the diabetic specificities affecting dynamic foot function [1]. The goal of this study was to verify the role of intrinsic foot muscle forces on foot internal stresses and strain, in order to inform clinical practice in diabetic foot prevention. For this purpose, gait analysis, musculoskeletal dynamic simulations (Opensim) and finite element models (FEMs) (Abaqus) were combined [3], thus muscles forces, internal stresses and plantar pressure distribution were estimated.

METHODS

Ten subjects (5 healthy (HS): age 44.20±16.66 years, BMI 21.53±1.13 kg/m^2, 5 diabetic neuropathic subjects (DNS): age 58.40±7.76 years, BMI 25.93±2.67 kg/m^2) were analyzed. A stereophotogrammetric system (BTS) synchronized with 2 pressure plates (Imagortesi), 2 force plates (Bertec), and a 16 channels surface electromyographic system (BTS) were used for gait analysis, adopting a 3D multi-segment foot markerset with a full body one for kinematics [4]. In term of musculoskeletal modelling, 2 6DOF foot models were generated: one with (Inner) and one without (No Inner) intrinsic foot muscles [5]. The extrinsic muscle activations were validated against experimental surface electromyography [3]. Two FEMs, one for the HS and one for the DNS, were defined with respectively a healthy and a diabetic foot geometry (from MRI) [6]. Subject-specific kinematics, muscle forces and ground reaction forces were applied as boundary conditions. Four phases of the gait cycle were simulated and simulated plantar pressures were validated against the experimental ones [5]. Kruskal-Wallis test ($p<0.05$) was used for comparing results among the two cohorts of subjects and among the two approaches. RMSD was calculated between measured and simulated plantar pressures.

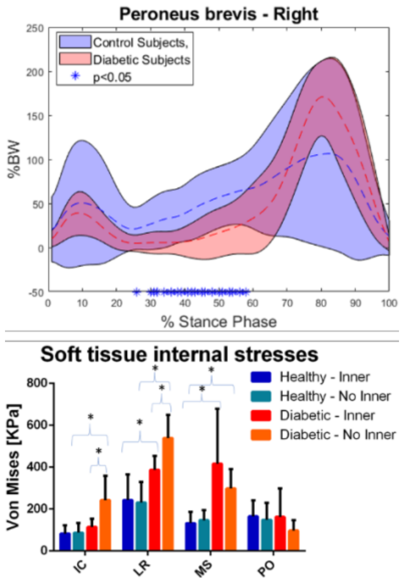

Figure 4: Top: Peroneus brevis force (mean± SD)
Bottom: Soft tissue internal stresses

RESULTS

DNS displayed significantly higher internal stresses at soft tissues (Fig.1 Up) and a higher intrinsic muscles forces (Fig.1 Down) with respect to the HS. While the maximum RMSD, between experimental and simulated plantar pressure, was registered at the hindfoot, the Inner showed a better performance. The latter determined lower Von Mises stresses at initial contact and loading response while higher stresses at midstance and push-off phases.

DISCUSSION

The intrinsic muscles showed to play an important role in determining internal stresses at the plantar aspect of the foot. The interdependency of muscle force and tissue response justifies a concurrent multiscale-modeling approach. Moreover, subject-specific characteristics in foot morphology, tissue mechanics and gait should be accounted for to achieve optimal offloading.

REFERENCES

[1] Armstrong DG, et al. *N Engl J Med,* 2017; 376:2367–75.
[2] Telfer S, et al. *J Biomech* 2017; 60: 157–161.
[3] Scarton A, et al. *Gait Posture* 2018; 60:279–285.
[4] Sawacha Z, et al. *Gait Posture* 2012; 36:20–26.
[5] Malaquias TM, et al. CMBBE. 2017; 20(2):153-159.

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FINITE ELEMENT MODELING ANALYSIS AND OPTIMAL DESIGN OF CUSTOMIZED FOOT INSOLES

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INTRODUCTION

Abnormal loading patterns are frequently determined by foot deformities and/or biomechanical alterations in static or dynamic conditions. Although insoles are frequently used to reduce the plantar pressure under painful areas of the foot, there is still no consensus about the best way to manage high-risk patient's complaints with insoles [1]. However, The insole manufacturing process is subjective and foot experts personal experience in designing and producing foot insoles still plays a relevant role. A computational approach such as the finite element modelling (FEM) could provide on one side a more efficient and repeatable design, and on the other further measures, besides plantar pressure such as soft tissue deformation and internal stresses determined by the proposed insole shape and material [1]. The aim of this study was twofold: to propose a methodology to assess the behavior of the designed insole prior to the subject's use based on experimentally acquired subject-specific geometry and loads as input for the FEM simulation; to propose a methodology easily applicable in foot orthosis manufacture.

METHODS

The foot geometry of a healthy subject (female, age 26 years, shoe size 37, BMI 19 Kg/m^2) and the shape of a customized insole were acquired through a 3D scanner. Foot bones geometry was reconstructed starting from a previously acquired foot MRI [2] of a subject with the same type of foot (Simpleware ScanIP). The foot and insole 3D shapes were meshed in Geomagic with tetrahedral elements [2] and imported into Abaqus (Simulia) (Figure 1). Foot material properties were adopted from [2] and insole material characteristics were declared by the manufacturer. The subject plantar pressures was acquired during static posture and gait on a treadmill walking at 5 km speed, with and without the insoles. Four different phases of the stance phase of gait (heel strike, loading response, midstance, push off) were simulated [2] by applying the loads registered during gait onto the foot FEM. without and with the insole. Validity of the FEMs was assessed through the comparison between the experimental and the simulated plantar pressures (peaks and pressure maps). Internal Von Mises stresses in plantar soft tissues were also extracted.

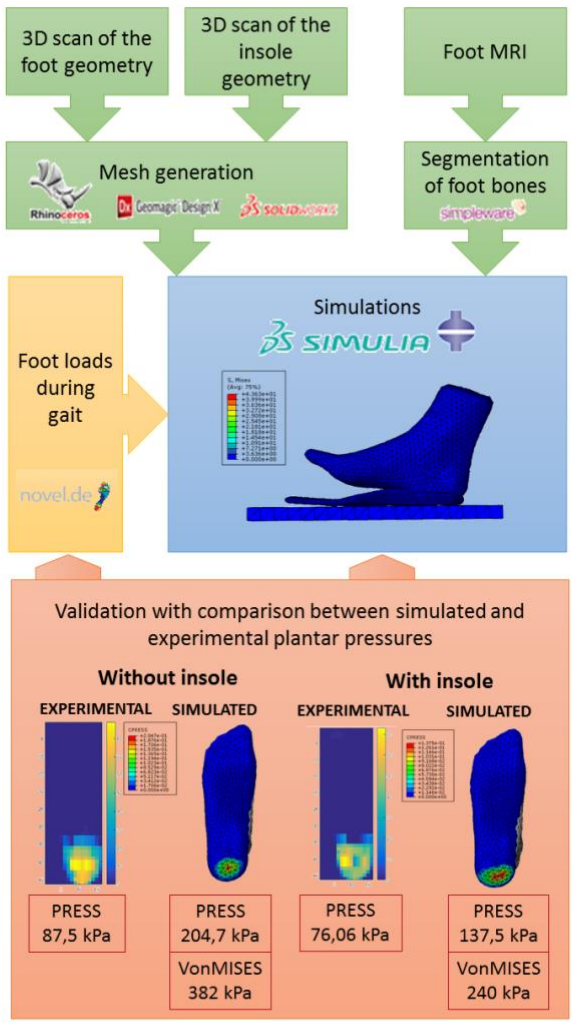

Figure 1: Pipeline for the FEM creation with example of model and results for the heel strike phase without and with insole.

RESULTS

A good agreement was reached between the experimental and the simulated plantar pressure. Simulated insole succeed in spreading the plantar surface loads and in reducing the Von Mises stresses. Examples of some results were reported in Figure 1.

DISCUSSION

The insole behavior in response to a subject specific loading was successfully simulated with the proposed pipeline: this can be used to promote customization of plantar foot orthosis' design.

REFERENCES

[1] Cheung JT-M, et al. *Med Eng Phys*, 2008; 30:269–277.
[2] Guiotto A, et al. *J Biomech*, 2014;47:3064-71.
[3] Cavanagh PR et al. *J Biomech*, 1987; 20:547-51.

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WALKING ON A SPLIT-BELT TREADMILL INDUCES A HIGHER POWER OUTPUT AND A SHORTER STEP LENGTH FROM THE FASTER LEG IN HEALTHY SUBJECTS, WITH OPPOSITE (AFTER)-EFFECT LASTING LESS THAN 5 MINUTES AFTER EXERCISE

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INTRODUCTION

Walking on a split-belt treadmill has been claimed as a possible treatment of pathologic step asymmetries: in particular, the step lengthening on the affected side [1]. Placing the paretic limb on the slower belt would increase this asymmetry, reverting to long-lasting symmetry after exposure (after-effect). These studies neglected the underlying dynamics. Recently, it has been demonstrated that this paradigm entails an opposite spatial and dynamic asymmetry in healthy subjects. The stance on the faster belt is shortened, thus mimicking the paretic step temporally. On the contrary, the step is shorter and more muscle power is produced [2]. This challenges the rationale of the previous researches. The present study aims at extending these findings by investigating the after-effect both on spatiotemporal step parameters and power output from the plantar flexors on either belt.

METHODS

Ten healthy adults (21-34 years, 1.61-1.91 m tall, 5 women) participated in the study. After a brief familiarization, participants walked on a force-sensorized split-belt treadmill with one belt running at 0.4 m s^{-1} and the other belt running at 1.2 m s^{-1} (split condition) for 15 minutes and then, with no interruption, with the belts running at the same velocity (0.4 m s^{-1}, tied condition) for other 5 minutes. The dominant lower limb was assigned to the faster belt. Kinematic data were recorded through an optoelectronic system as per the Davis anthropometric model. Joint sagittal power was computed by multiplying the moment generated by the ground reaction forces at the joints, times the rotation speed. All signals were simultaneously recorded [2]. The study was approved by the Local Ethics Committee.

RESULTS

Consistently with previous studies [3], during the split condition, the step length on the slower belt was longer, reaching gradually about 130% of the opposite step length. Ankle peak power attained about 15% of that observed on the opposite side. During the following tied condition, the step length on the formerly slower belt initially shortened by about 65% (after-effect), compared to the opposite step, and returned to values similar to that of the opposite side within 5 minutes. During this transition phase, ankle peak power gradually increased by up to 50% compared to baseline. On the formerly faster belt, step length did not change, while ankle peak power suddenly dropped to the contralateral level (Figure 1).

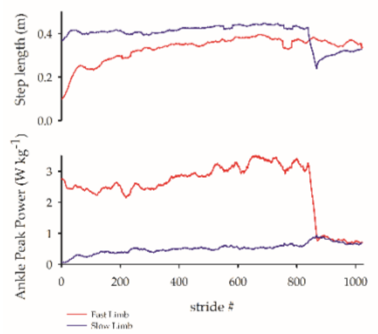

Figure 1 Stride by stride plots (moving average, time-window 30 strides) of step length (upper panel) and ankle power (lower panel) from one representative subject (woman, 21 years, 1.65 m tall, body mass 60 kg) walking on a split-belt treadmill with the dominant lower limb on the faster belt (red) and the non-dominant lower limb on the slower belt (blue). Strides from 1 to 867 refer to the split condition, and stride from 868 to 1025 refer to the following tied condition.

DISCUSSION

The increase in plantar flexor power on the faster belt, despite the shorter stance period and length, may reflect the priority need to counteract the backward drag from the faster belt, with respect to the slower one. This adaptation does not seem to lead to substantial learning, given that an after-effect, both on step length and ankle peak power, is only seen during the 5 minutes following split walking.

In pathologic claudication, placing the affected lower limb on the faster belt might represent an effective form of "forced-use" [4], as far as enhanced power is requested. Long term effects remain questionable.

REFERENCES

[1] Reisman DS, et al. *Neurorehabil Neural Repair*, 2013;27(5):460-468

[2] Tesio L, et al. *Int J Rehabil Res* 2018;41(4):304-315

[3] Reisman DS, et al. *J Neurophysiol* 2005;94:2403-2415

[4] Tesio L, et al. *Int J Rehabuil Med* 2017;40:254-267

BIPEDAL WALKING IS STILL ORPHAN OF A THEORY: REVIEW

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INTRODUCTION

Recent reviews were addressed to the definition of a theory on walking. They analyzed the general theories[1], the neurophysiologic knowledge[2], the concept of Central Pattern Generators (CPG)[3-6], and the role of epigenetic[7].The original knowledge are based on invasive studies conducted on mammals, and considering that the current technology does not allow non invasive investigation in humans the main proceedings in literature are based on deductive methods. Meantime, the interpretation of gait analysis and the clinical decision making procedures in pathologic conditions depend on implicit or explicit bipedal walking theory[8]. Here, the effort is to define a framework that could guide the future use of the gait analysis for contributing to a theory on bipedal walking.

METHODS

A systematic revision of recent reviews will be finalized for understanding what can be considered a clearly acquired knowledge and what is still in progress along the path for the definition of a bipedal walking theory. Consequently, will be proposed a theoretical framework and some hypotheses on promising future actions.

RESULTS

The theories on bipedal walking derive mainly on the following hypotheses: evolution, minimizing energy, maturation, CPG, control-effect link, and bipedal robots [1]. Among them, CPG is the most studied and the one that more influenced gait rehabilitation[8]. Although, there is a general consensus on the role of the tone in generating alternate activity between flexors and extensors, what is not clear is the location of CPG in the nervous system in humans, see [3] v.s. [4]. In fact, also the role: of the supra-spinal influence; of the sensorial feedback; and of the regulation of the stretch reflex threshold are largely discussed without a consensus [2-6]. Another issue in progress is the role of the epigenetic in conjunction with experiences and their spatial and temporal expression[7]. Although, there is a general consensus on the evidence of a system of oscillators that constitutes the core of the CPG their configuration appear still unclear, i.e., it is not clear their internal mutual influence and if they need to generate a symmetric activity between flexors and extensors[4] or an asymmetric one[5]. Furthermore, is under investigation what happens in case of a gait perturbation that could be anticipated, predicted or reacted, opening three different levels of superimposed modulation[5].

DISCUSSION

The development of a shared theoretical framework is essential for the definition and the assessment of clinical intervention, but also in other fields like robotics. When we apply the motor control theory, based on the ecological approach [9] to this field same suggestions, not yet completely examined, come out. In the framework of the ecological approach the behavior emerges from the interaction of an individual with a task in a specific context. The biomechanics, the nature of the environment and the shared information define and constraint this interaction. In this frame one of the possible future incarnations lays in the use of gait analysis not only in different task but also in different context for example on uneven terrains.The analysis of not stereotyped behavior could increase the knowledge on the gait structure using the peculiar constraints induced by the context, i.e., during trials of continuously controlled manipulation of the dynamic system.

REFERENCES

[1] Vaughan CL, et al.*JBiomech* 2003;36:513-23.
[2] TakakusakiK.*Mov Dis* 2013;28(11):1483-1491.
[3] Klarner T, Zehr EP.*J Neurophysiol* 2018;120:53-77.
[4] Hofstoetter US, et al.*Curr Pharm Des* 2017;23(00):1-16.
[5] Duysens J, Forner-Cordero A.*BioinspirBiomim* 2018 Sep 4;13(6):061001.
[6] Ivanenko Y, et al.*Curr Pharm Des* 2017 May 12;23(12):1753-1763.
[7]Goulding M.*Nat Rev Neurosci* 2009;10(7):507–518.
[8] Maguire CC, et al.*Journal of Bodywork & Movement Therapies* 2017;21:422-434.
[9] Richardson MJ. et al.*Handbook of cognitive science*, Elsevier, 2008.

REAL TIME KINEMATIC AND ELECTROMYOGRAPHIC ANALYSIS: A FEASIBLE METHODOLOGY FOR ASSESSING COMFORT PERCEPTION.

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INTRODUCTION

Driving comfort is a key emerging factor for the marketability of cars due to the growing interest in the evaluation of ergonomics in cars. Typical ergonomic issues, related to the locomotor system, happen when the muscular effort is too high to perform the task or kinematics is too restricted [1]. The ergonomic evaluation identifies the critical aspects of the steering task and intervenes to reduce injuries, thus increasing the driver's well-being.

The subjective evaluation of driving comfort is still the most used way to design a car seat; this limitation could be overcome by using emerging technologies [1].

The activity of trapezius muscles of both shoulders is assumed as predicting factor of car seat comfort while driving.

The present research aims to analyze the feasibility of kinematic analysis and muscle activity during car driving in terms of quantitatively detecting trapezius muscle activity in real-time condition.

METHODS

One subject was examined using SHoW Motion (NCS Lab – Carpi, Italy). This software platform combines, in real-time, motion tracking and superficial electromyographic analysis in the attempt of monitoring the motion pattern and the related muscles activity. This tracking system can manage and synchronize the signals measured by superficial EMG (Cometa – Wave Plus Wireless EMG) and Magnetic Inertial Measuring Unit (WISE, NCS Lab – Carpi, Italy). According to ISEO protocol [1], 7 wireless MIMUs were placed on thorax, left and right scapula, left and humerus, left and right forearm. 6 muscles were acquired (3 on the right side and 3 on the left side): superior trapezius, major pectoralis and medial deltoid.

After a sensors calibration procedure, including Maximum Voluntary Contraction measurements [3], the pilot adjusted the seat setup according to his own comfort feeling and performed a figure-of-eight circuit with two different cars: Levante Maserati® and Quattroporte Maserati®.

Range Of Motion (ROM), scapula humeral rhythm (SHR) and muscles activities were calculated for each car, giving the possibility to analyze the specific posture of the pilot in the different cars.

RESULTS

Both right and left shoulder kinematics were calculated, for all the tasks acquired. The flexion-extension ROM estimated in the two different acquisitions over the two cars was compared, as reported in table 1. Electromyographic analysis revealed a major activation of the monitored muscles in the Quattroporte Maserati®, especially for the superior trapezius, while SHR did not show significant differences.

Table 1 The table reports the ROM of right and left humerus (Right ROM and Left ROM) and the right and left activation of the superior trapezius (Right Trap Act and Left Trap Act), calculated at the maximum elevation of the humerus and expressed as percentage of their respective MVC.

	Right ROM	Right Trap Act	Left ROM	Left Trap Act
Levante	55.4 °	25.0 % MVC	50.6 °	20.4 % MVC
Quattroporte	58.1 °	32.2 % MVC	61.0 °	30.8 % MVC

DISCUSSION

The study confirmed that a real-time measurement of kinematics and muscle activation is a feasible methodology that can be used for ergonomic evaluation during car driving. Even though the evaluation was limited at one driver, the data calculated clearly discriminated two different biomechanical situations. More specifically, larger ROM and higher muscles activation was shown driving a Quattroporte Maserati®. Future studies must include a greater number of subjects to confirm these findings and to study the interplay of the biomechanical parameters with comfort perception.

REFERENCES

[1] Marek. C, et al. Encyclopedia of Automotive Engineering 2014
[2] Cutti A.G, et al. Medical & Biological Engineering & Computing 2008;Vol 46:169-178.
[3] The ABC of EMG, Book_Lib. (2006).

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PARAVERTEBRAL MUSCLES METABOLISM CHANGES WITH AGE IN AGREEMENT WITH EMG PARTICULARLY AT L4-5, LESS AT HIGHER LEVELS: A NEAR INFRARED SPECTROSCOPY (NIRS) EVALUATION

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INTRODUCTION

There is evidence of a correlation between highly fatigable back muscles and chronic low back pain.[1] The metabolic changes that occur over time in paravertebral muscles during sustained contraction are not yet well-characterized. The aim of this study was to explore the value of a non-invasive method for the evaluation of the paravertebral lumbar muscles during a fatiguing test.

METHODS

We recruited a convenience sample of 37 healthy subjects (18-80 yrs) (20 males and 17 females). All patients reported no episodes of back pain in the last 5 years. The Biering Sorensen Muscle Test (BSME) was used to cause fatigue: it was repeated three times. Muscular metabolism of paravertebral muscles was studied checking blood deoxygenation using Near Infrared Spectroscopy (NIRS) [2] at the L2-3, L3-4 and L4-5 levels. According to the literature, we used the only reliable phase of the hemoglobin deoxygenated curve (HHb) that is the rapid one (*Figure 1*), corresponding to the growth of oxygen consumption before reaching a fully aerobic steady state. We compared all parameters among groups and searched correlations with age, weight, height and BMI. Muscle contraction was studied with surface EMG using the Slope Coefficient of Mean Frequency (MNF).

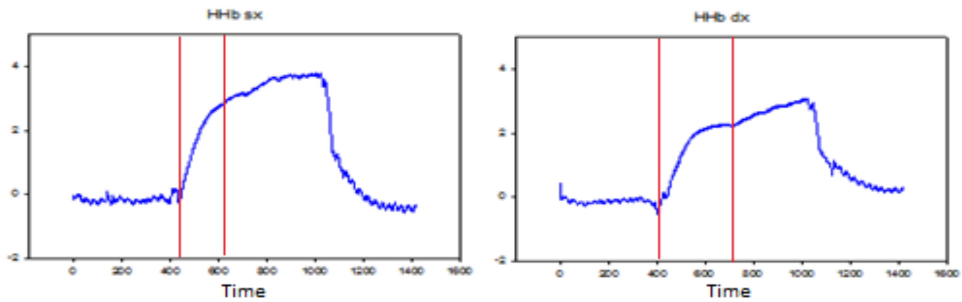

Figure 2: deoxygenated hemoglobin curve; between the red lines is represented the rapid phase of hemoglobin deoxygenation

RESULTS

We did not find any difference in the results for the examined levels, even if L2-3 showed to be the most reliable (82% of evaluable curves versus L4=76% and L5=71%). We did not find any difference for sex or side neither for NIRS nor for EMG. EMG slope decreased with age (R = 0,5; Rsqr = 0,2), while the NIRS angle of slope decreased with age only at the L4-5 level (R = 0,4; Rsqr = 0,1). We found a direct correlation between EMG and NIRS slope (R = 0,7; Rsqr = 0,5). EMG slope was also directly correlated with height, but only in males (R = 0,6; Rsqr = 0,3). We did not find correlations with weight and BMI. With age the time to reach an aerobic steady state increases (R = 0,5; Rsqr = 0,2) but only at L4-5 level.

DISCUSSION

A correlation between metabolic and electromyographic activity has already been demonstrated in low back pain patients, but using a dynamic test and with older, less reliable instruments [3]. Even if the phenomena are clearly physiologically linked, there are other factors to be understood that could play a role (like vascularization, oxygen consumption capacity, etc.)[4]. While L3 is the most used level for NIRS studies, we found correlations only with the L4-5 level, where the analysis of rapid phase of hemoglobin deoxygenation was correlated with age, but not to anthropometric parameters.

REFERENCES

[1] Russo, M. et al. Neuromodulation J. Int. Neuromodulation Soc. 21, 1–9(2018)
[2] Ferrari, M. et al. Philos. Transact. A Math. Phys. Eng. Sci. 369, 4577–4590(2011)
[3] Kovacs, KM. et al. J Spinal Disord. Apr;14(2):150-8 (2001)
[4] Kalichman, L. et al. BioMed Res. Int. 2017, (2017)Introduction

IDENTIFICATION THROUGH MOVEMENT ANALYSIS OF CHRONIC LOW BACK PAIN PATHOLOGICAL SPINAL MOVEMENTS PATTERNS AND THEIR SENSIBILITY TO CHANGE DURING EXERCISE TREATMENT

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INTRODUCTION

Chronic low back pain (CLBP) is a bio-psycho-social syndrome. Movement analysis is a well-established methodology to study Gait patterns and Upper limb movements. Trunk movement analysis could lead to interesting insights into the "biological" factors of CLBP. We recently developed and tested a methodology for trunk movement analysis in healthy subjects[1] .

METHODS

In Current pilot study in we recruited a convenience sample of 10 CLBP patients who were referred for a group exercise therapy (strengthening, core stability, active stretching and postural re-education) 3,4. We used a non-invasive optoelectronic full spine evaluation according to a previously developed protocol 2 . We analyzed anterior flexion, lateral bending and rotation movements, and collected Numerical Rating (NRS) and Oswestry (ODI) scales before and after treatment. We performed a qualitative analysis to identify possible abnormal movement patterns, that have been quantified through 4 points Likert scales: their inter-observers repeatability has been checked comparing two operators (1 experienced 2 ratings 1 month between evaluations; 1 inexperienced). Blind evaluation of movement patterns each movement rated independently.

Then been calculated intra- and inter-rater reliability, comparison to healthy participants, correlations with pain and disability, changes with treatment.

RESULTS

Acceptable reliability of the identified spinal movements patterns, particularly intra-rater. Overall items better than individual items. Some differences found between healthy and CLBP patients. Future developments: identification of quantitative indexes for movement patterns, bigger populations for better validation.

DISCUSSION

In this study we have identified some reliable qualitative patterns of pathological movement in CLBP that showed to be sensible to treatment, even if not correlated to subjective scales like ODI and NRS. Future studies should check these preliminary results in wider populations and different treatments, while a quantification of these qualitative parameters is under development.

REFERENCES

1. Negrini, S. et al. Eur. J. Phys. Rehabil. Med. 52, 583–592 (2016)
2. Barbara, P. et al. Gait & Posture Volume 57, Supplement 1, Pages 347-348 (2017)
3. Sahin, N. et al. J. Rehabil. Med. 43, 224–229 (2011)
4. Pfingsten, M. et al. Schmerz Berl. Ger. 10, 326–344 (1996)

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TITLE MINIMALLY INVASIVE DIRECT ANTERIOR APPROACH FOR TOTAL HIP ARTHROPLASTY IMPROVES HIP BIOMECHANICAL FUNCTION AND PRESERVES HIP MUSCLE ACTIVATION DURING FORWARD, BACKWARD, AND LATERAL WALKING

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INTRODUCTION

Total hip replacement with minimally invasive direct anterior approach (DAA) is an alternative technique to conventional surgery aimed at preserving the integrity of the muscles around the hip joint [1]. This study aimed to verify whether the DAA could improve hip biomechanics and gait variables during different locomotor tasks, while preserving hip muscle function.

METHODS

Fourteen patients (age 53.8 ±9) with primary osteoarthritis who underwent minimally invasive DAA were included in the study. The spatio-temporal, dynamic, and hip muscle electromyographic parameters (Center of Activation, CoA and Full Width Half Maximum, FWHM) during forward, lateral, and backward walking were analyzed using an optoelectronic 3-D motion analysis system integrated with an electromyography (EMG) surface device (SMART DX500 BTS, Milan) before surgery (T0) and at 3 (T1) and 6 (T2) months post-surgery. The following hip muscles were analyzed: Rectus Femoris (RF), Tensor Fasciae Latae (TFL), Gluteus Medius (GLME) and Gluteus Maximus (GLMA).

RESULTS

Kinematic and kinetic and gait parameters improved after surgery, as regard the EMG parameters, we found that the increased of the activation of the muscles around the hip joint was reduced at 6 months post-surgery (figure 1). In details, a greater FWHM of both the RF and GLME muscles, and greater CoA of the RF muscle, were observed in patients compared to healthy subjects at baseline and T1, while a reduced CoA value of RF muscle was found between both T1 and T2 compared to T0 in patients.

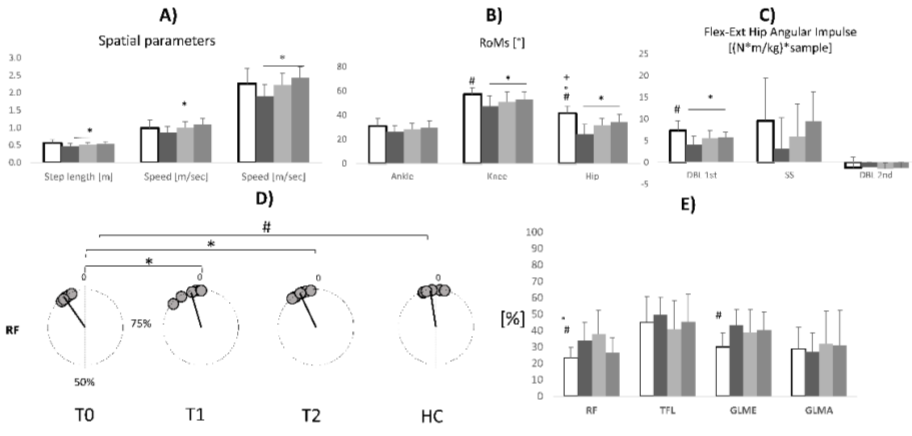

Figure 1. Mean values and standard deviation of the spatial parameters **A)**, Range of Motion (RoMs) **B)** and angular Impulse of the hip flexion-extension **C)**, mean circular plot of the CoA (The circular plot from 0 to 2 π represents the 0-100% of the gait cycle) **D)**, mean values and standard deviations of the FWHM **E)**. ***** $p<0.05$ between T0, T1 and T2; **#** $p<0.05$ between T0 vs HC; **°** $p<0.05$ between T1 vs HC; **+** $p<0.05$ between T2 vs HC.

DISCUSSION

Our results indicate that a minimally invasive DAA could improve hip and gait function during several locomotor tasks while simultaneously either improving or sparing the function of the muscles around the hip joint. A full biomechanical evaluation of the hip function during locomotion may aid physicians and surgeons in optimizing the management of patients before and after hip replacement surgery.

REFERENCES

[1] Berger RA. *Clin Orthop Relat Res* 2003;(417):232–41.

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DEEP LEARNING FOR EEG DECODING OF MOVEMENTS AND INTERPRETATION OF THE LEARNED FEATURES

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INTRODUCTION

Motor decoding from electroencephalographic (EEG) signals traditionally exploits a strong a priori knowledge about the relevant features to discriminate different movements [1]. Deep convolutional neural networks (CNNs) have been recently applied to EEG data for movement decoding. These techniques do not exploit a priori knowledge but automatically extract relevant features that better represent and separate the investigated movements. Since the features are automatically learned from data, CNNs represent a framework potentially exploiting new EEG features for an improved characterization of the specific movement. This could be extremely useful to enhance comprehension of motor neural correlates. However, a drawback of such networks is the lack of clear interpretability of the learned features. The aim of this study was: i) the development of a novel interpretable CNN to decode executed movements from EEG, and ii) the interpretation of the learned features [3].

METHODS

The used dataset is a freely available [2] 128 EEG channels set (500 Hz) of four-seconds trials acquired during 3 simple executed movements: repetitive right- and left-hand finger tapping, and toes clenching. Ten participant EEG data were selected from this dataset to train and test the subject-specific CNNs for the movement classification. Signals from 44 electrodes covering the motor cortex were selected and windowed between -0.5 and 4 s (0 s movement onset). For each subject, 160 trials were used as test set and the remaining as training set. The proposed CNN is a modified version of a previous one [2] and includes 5 convolutional layers. At variance with the previous network [2], the proposed one realizes the temporal filtering via a sinc-convolutional layer [4]. This layer constraints the temporal filtering to a band-pass filtering and during the training the band-pass cutoff frequencies are directly learned. Furthermore, it reduces 5-fold the number of trainable parameters. Once the training was completed, the modified layer provided a set of temporal filters learned for each movement and subject. Among each set, we identified the most important filtering bands and the most relevant electrodes exploited by these bands, via a gradient-based analysis [3]. This procedure quantifies the influence that the temporally filtered versions of the EEG channels have on the classification, identifying the filters and electrodes that contribute more.

RESULTS

The average test accuracy across the participants was 94.6±3.9%, confirming that the sinc-convolutional layer provided similar performance (avg +0.7%) as the previous CNN [2]. For each movement, the temporal filters belonging to the high-gamma EEG band (60-125 Hz) were the most important and the corresponding gradient distribution across the electrodes is reported in Figure 1. The high-gamma filtering importance was larger for the left- and right-hand finger tapping than the toes clenching. Moreover, the maps were contralateral to the hand movement and symmetric for the feet, and localized at specific electrodes.

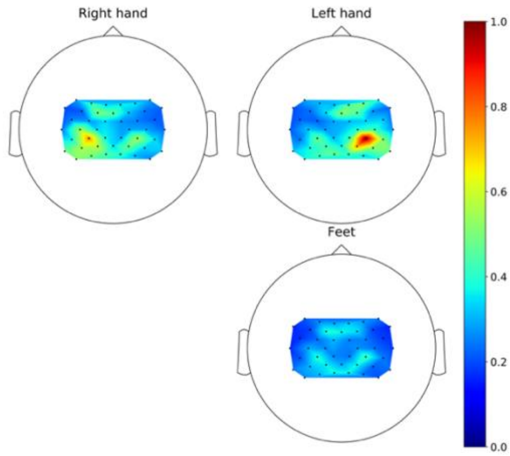

Figure 5. High-gamma gradient maps, averaged across subjects and represented for each movement. The higher the value at an electrode the higher the importance of the temporal filtering for a specific movement classification.

DISCUSSION

The proposed CNN learned interpretable features and, with an appropriate analysis, allows the identification of the best EEG band and electrodes for a better classification. The results suggest that a specific subset of electrodes have differences in the high-gamma band depending on the movement. This approach was applied to simple movements as a feasibility study and can be prospectively applied to better understand EEG neural correlates linked to kinematic parameters.

REFERENCES

[1] Wolpaw J, et al. Brain-Computer Interfaces: Principles and Practice, OUP, USA, 2012
[2] Schirrmeister RT, et al. Hum. Brain Mapp. 2017; 38(11):5391-5420
[3] Simonyan K, et al. CoRR 2013; abs/1312.6034
[4] Ravanelli M, et al. IEEE SLT Workshop 2018;1021-1028

http://doi.org/10.6092/unibo/amsacta/6260

ARTIFICIAL NEURAL NETWORKS FOR STAGING THE GAIT DEFICIT IN PARKINSON DISEASE

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INTRODUCTION

The gait deficit represents one of the most debilitating aspect in Parkinson's disease (PD), whom inexorably declines over the course of the disease, strongly increases the risk of falls, and greatly reduces patients' autonomy and quality of life [1]. Therefore, beyond the use of clinical scales, which suffer from the dependence of the operator, and fail to capture the objective details of the gait disturbance, the gait analysis is becoming an essential tool to objectify the gait changes induced by pharmacological and rehabilitation interventions: it would be an ideal instrument to classify gait patterns according to both the underlying disease and to the disease severity [2]. The aim of our study was to develop a diagnostic algorithm based on machine-learning technique (i.e. Artificial Neural Networks (ANNs)) able to automatically classify the gait deficit according to the disease severity staging.

METHODS

Seventy-six patients with PD were enrolled for the study (age, 69.68±8.92 years). The severity of PD was evaluated using the Hoehn and Yahr (H&Y) staging system [3] (H&Y=1: 20; H&Y=2: 17; H&Y=3:27; H&Y=4:12). Patients were asked to walk barefoot at comfortable self-selected speeds along a walkway with twenty-two reflective spherical markers attached on the anatomical landmarks, in accordance with a validated biomechanical model [4]. Time-distance, joint and trunk kinematics (range of motion, RoM) were recorded using an optoelectronic motion analysis system. An ANNs approach based on Levenberg-Marquardt back-propagation algorithm [5], was used to estimate staging of the gait deficit in Parkinson disease in terms of H&Y scale starting with time-distance and kinematic features used in different combinations (see Fig. 1). Different topologies of networks with different numbers of hidden layers and different numbers of neurons (Fig. 1) were trained. For each trained network, a confusion matrix was calculated based on the real H&Y value and the one estimated on the randomly extracted testing set. The mean 4 × 4 confusion matrix was then obtained by averaging the confusion matrixes of the trained ANNs. A performance parameter (P) was calculated as the mean (%) of the elements on the diagonal of the mean confusion matrix, where 100% indicates the absence of misclassifications.

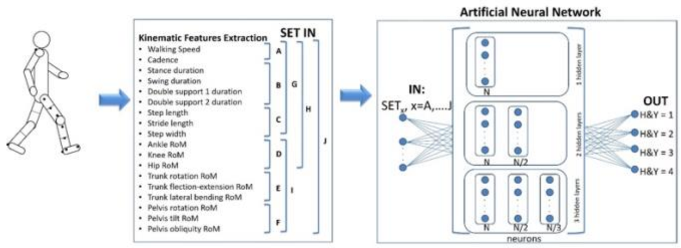

Fig. 1. A schematic description of experimental set-up and methodological approach based on ANNs method used to map time-distance and kinematic features on the H&Y levels.

RESULTS

Three-way ANOVA showed significant effects of multiple factors on the performances considering training set ($p < 0.001$), numbers of hidden layers ($p < 0.001$) and numbers of neurons ($p < 0.001$).

The best performance was obtained with SET_G, 3 hidden layers and 20 neurons on first layer (P=88.82% ±5.58%), while the worst performance was obtained with SET_B, 2 hidden layers and 20 neurons on first layer (P=55.02% ±27.31%).

DISCUSSION

ANNs, that recently have been used as diagnostic tool in several clinical conditions, could be used with gait analysis to identify the severity of gait deficit in PD. Indeed, a diagnostic algorithm based on ANNs technique is able to automatically classify the gait deficit according to the disease progression.

REFERENCES

[1] Morris ME et al. Brain: A Journal of Neurology, 1994; vol.117 (5), pp. 1169–81.
[2] Serrao M et al., *Hum Mov Sci,* 2018 Feb;57, pp. 267-279.
[3] Hoehn MM and M. D. Yahr, *Neurology*, 1967, vol. 17 (5), pp. 427-427.
[4] Davis III RB et al. Human Movement Science, 1991, vol. 10, pp. 575–587.
[5] Rumelhart DE et al., In: Parallel Distributed Processing, 1986, vol. 1. MIT Press, Cambridge, MA, pp. 318-362.

Sessione 4 – VALUTAZIONE DELLA FUNZIONE MOTORIA PER L'ERGONOMIA E L'ORTOPEDIA

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CUSTOM-MADE TOTAL TALONAVICULAR REPLACEMENT IN A PROFESSIONAL ROCK CLIMBER: FUNCTIONAL EVALUATION WITH GAIT ANALYSIS AND 3D VIDEO-FLUOROSCOPY

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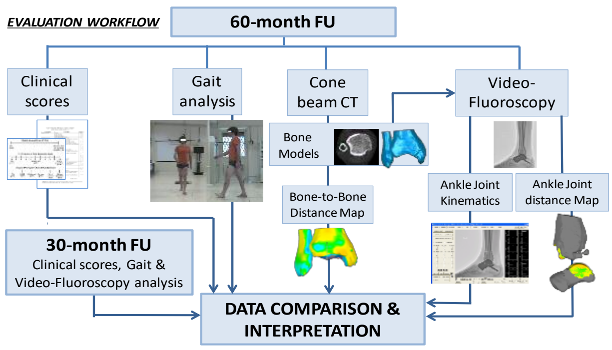
INTRODUCTION

Rock-climbing is an high impact activity, frequently resulting in traumatic events at lower limbs. Among these, talus fractures occur in 2% of cases (1). Generally, these are treated via surgical fixation, resulting often in post-operative pain, deformity and reduced function. To cope with these issues, custom-made implantable bone replica may represent an alternative to ankle arthrodesis. The aim of this study is to present the case of a young professional rock climbing athlete who underwent the implant of the first custom-made talonavicular prosthesis following a talar avascular necrosis after talonavicular fractures (2). Functional evaluations via multi-instrumental analysis at two different post-operative follow-ups (FU) are here reported to corroborate preliminary observations (3).

METHODS

A 27-year-old professional rock climber (W: 75 kg; H: 180 cm) was treated for talonavicular fractures of the right foot, after falling while climbing (2), by implantation of a custom-made talonavicular structure to preserve hindfoot/ankle structure. To this, a pre-operative bilateral computer tomography (CT) of the foot/ankle structures was obtained. Relevant DICOM files were used to reconstruct the left, i.e. unimpaired, ankle bones, which were used to design the customized model of the right talonavicular prosthesis after mirroring process. This model was then manufactured via 3D printing, using ISO-based CoCr alloy via SLM process, and implanted (2). At 30-month FU, i.e. after rehabilitation program completion, the patient received clinical/functional evaluations, via Gait, Dynamometric, EMG and 3D Video-Fluoroscopy analyses during activities of daily living (3). At 60-month FU, i.e. after full patient recovery and restoration of sporting activities, these evaluations were repeated; an additional CT in upstanding posture, i.e. under real weight bearing conditions, was also acquired using a innovative low-radiation cone-beam CT device for morphological examination (see figure). This study received local IRB approval.



RESULTS

Excellent clinic scoring were observed in terms of VAS, AOFAS, SF-36 (Physical/Mental) and Tegner values. These were, respectively, 1, 81, 36/54 and 9 at 30-month FU and fully maintained at 60- month FU, i.e. 1, 75, 37/50, 8. During walking by Gait analysis, symmetrical physiological values were observed at both FU in terms of stance/swing time, stride length, gait cadence and speed. These parameters were almost symmetrical in stair climbing/descending, chair rising/sitting, foot lunge, squatting and climb-on-tips; in these tasks, the dorsi/plantar flexion in the treated side is generally more limited than in the healthy side, but it seems well compensated by larger knee/hip flexion. At 30-month FU, the Video-Fluoroscopy analysis showed a partial ankle kinematic recovery, which was fully restored at 60-month FU (ROM for ankle dorsi-plantar flexion, ad-abduction and internal-external rotation being 21°, 3° and 5°). The morphological examination revealed a good prosthesis-to-tibia surface adaptation, along with local cartilage wear at 60-month FU.

DISCUSSION

From these multi-instrumental biomechanical evaluations, a custom-made talonavicular replacement seems to be a viable clinical option in treating necrosis with severe bone deformation. In particular, this option can be an effective solution for complex ankle injuries, especially in patients with highly demanding motor functionality.

REFERENCES

[1] Elgafy H, et al. *Foot Ankle Int* 2000;21:1023-9.
[2] Giannini S, et al. *J Foot Ankle Surg* 2016;55:1271-75.
[3] Belvedere C, et al. *J Foot Ankle Surg* 2017;56:836-44.

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EFFECT OF ELECTRICAL STIMULATION SITE ON ARCHITECTURAL CHANGES AND FATIGUE OF TIBIALIS ANTERIOR

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INTRODUCTION

Electrical stimulation is used in rehabilitation to prevent muscle weakness and atrophy or to compensate for functional deficits after neural damage (e.g. to improve gait quality in post-stroke patients [1]). However, its use is often limited by the rapid development of muscle fatigue, mainly because of the non-physiological pattern of motor unit (MU) recruitment. One approach to address this limitation is to interleave nerve trunk stimulation (nStim) and muscle belly stimulation (mStim) with the goal to distribute the temporal recruitment among different MU pools (interleaved stimulation, iStim [2]). The extent to which iStim is effective in reducing muscle fatigue depends on the degree of overlapping between the MU pools recruited at the two stimulation sites. In this study we investigated whether nStim and mStim result in the activation of different tibialis anterior (TA) regions. We hypothesized that mStim would mostly activate the superficial portion of TA, contrary to nStim (more distributed activation pattern), and consequently that the onset of electrically-induced muscle fatigue would occur later with iStim than with either previous methods.

METHODS

Nine healthy subjects participated in the study. Each subject sat on a chair with the right leg in an isometric pedal-like dynamometer (Fig. 1A). Ultrasound images were recorded during 3 types of dorsiflexion contractions at 25% MVC: voluntary (Vol), evoked by mStim and nStim (both at 40 pps). Fascicle length (FL) and pennation angle (PA) were estimated in the superficial and deep TA regions in order to quantify the degree of local tissue deformation associated with the three contraction types. Afterwards, a sustained contraction (25% MVC until task failure) was induced by the 3 stimulation modalities (mStim, nStim, iStim) to compare the fatigue-related torque decline.

RESULTS

Changes in PA relative to resting conditions for each contraction types are shown in Fig. 1B (similar changes were observed for FL). Superficial (not deep) PA changes were greater for mStim compared to Vol and nStim which instead had similar PA changes in both TA regions. By interleaving nStim and mStim (iStim), time to task failure was ~80% longer with respect to nStim and mStim alone (Fig. 1C).

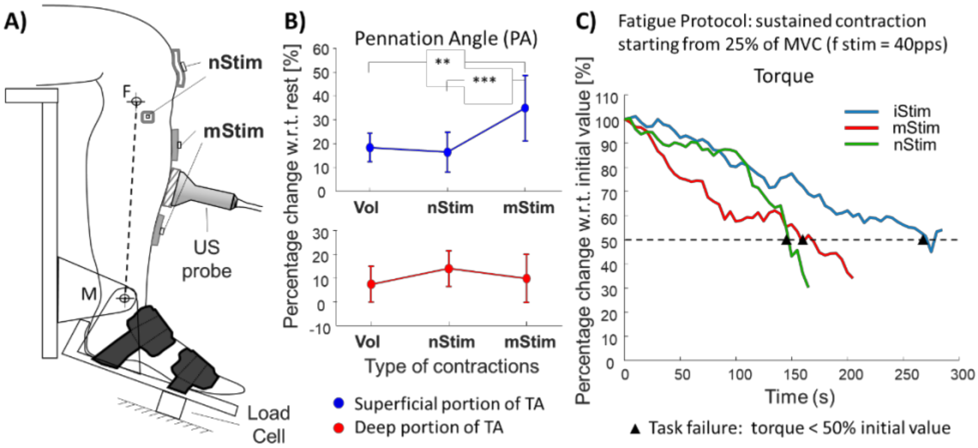

Figure 1. A) Experimental setup; B) Percent change of PA for the superficial and deep TA. C) Comparison between the fatigue-induced torque decline associated with three stimulation modalities.

DISCUSSION

We showed that mStim and nStim induced different patterns of tissue deformation in superficial and deep portions of TA, suggesting that different MU pools are recruited for the same torque output. By interleaving mStim and nStim, it was therefore possible to reduce the fatigue-induced torque decline. Minimizing the amount and time course of muscle fatigue induced by electrically-evoked contractions is crucial in several rehabilitation fields, such as functional electrical stimulation and neuroprosthesis.

REFERENCES

[1] Lyons GM, et al. *IEEE Trans Neural Syst Rehabil Eng.* 2002;10(4):260-279.
[2] Lou JW, et al. *Muscle and Nerve* 2016;55(2):179-189.

http://doi.org/10.6092/unibo/amsacta/6260

EVALUATION OF HAND SKILLS USING TOUCHSCREEN TECHNOLOGY IN THE ELDERLY POPULATION

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INTRODUCTION

In a modern environment, optimal and effective hand function is essential for performing daily living activities. Healthy aging has a direct effect on functional capabilities, including those related to arm and hand functions [1]. A touchscreen is an excellent example of state-of-the-art technology that requires unique, fine motor skills such as tapping, swiping and virtual pinching. Assessing these specific hand skills is essential for screening and development of appropriate treatment protocols for the elderly population. The Touchscreen Assessment Tool (TATOO) is an Android application (app) developed to objectively assess hand performance abilities required when using a touchscreen [2]. This pilot study examines the feasibility of using the TATOO app to evaluate touchscreen ability in elderly individuals.

METHODS

Sixteen community-dwelling older subjects (81.9 ± 4.2 year) and twelve middle-aged individuals (53.7 ± 6.2 year) participated in this study. Correlations between traditional hands function assessment tools (a. hand grip strength, pinch tip to tip, 3-point pinch using a calibrated JAMAR hand dynamometer; b. hand dexterity by Functional Dexterity Test) and the results of TATOO tests has been done. In particular, analysis of the temporal and movement accuracy variables obtained in performing three TATOO tests (1. Touch all corners, 2. Perform a double tap, 3. Drag object in all directions) were analyzed. After completion of the TATOO test, the users' subjective assessment of its usability was determined with the System Usability Scale (SUS) [3].

RESULTS

No significant difference was found between the two groups for the two types of pinch strength tests in either hand, except for the 3-point pinch strength test of the non-dominant side. The elderly group demonstrated significantly lower bilateral hand grip strength and poorer manual dexterity. No correlation was found between the TATOO results and the hand grip strength measures or the dexterity test results of the elderly individuals. The elderly group demonstrated lower performance ability in the TATOO as was reflected by the temporal measures (e.g., reaction and duration times) and reduced accuracy. The usability of the TATOO app was reported as good by both the elderly and middle-aged groups, as determined by the SUS (76.2 ± 20.7 and 80.0 ± 15.4, respectively).

Table 1. Comparison of the TATOO performance between the two groups.

TATOO Tests	Variables	Middle-aged (n=12) Right / Left	Elderly (n=16) Right / Left	P-value Right / Left
1. Touch all corners	Reaction time [s]	1.2±0.6 / 0.9±0.2	1.9±1.1 / 1.5±0.8	0.04 / 0.01
	Test duration [s]	10.7±0.7 / 10.8±0.6	11.7±1.1 / 11.7±1.2	0.01 / 0.03
2. Double tap	Reaction time [s]	1.3±0.6 / 1.1±0.5	2.0±0.6 / 1.5±0.5	0.005 / 0.03
	Test duration [s]	8.6±1.9 / 8.1±0.9	17.9±10.0 / 18.7±11.6	0.004 / 0.004
	Number of taps	11.3±3.4 / 10.6±1.4	19.4±10.4 / 23.3±14.9	0.02 / 0.01
3. Drag in all directions	Reaction time [s]	2.1±1.0 / 1.5±0.5	4.5±3.1 / 3.6±2.6	0.02 / 0.01
	Test duration [s]	29.8±14.8 / 24.5±9.7	65.4±25.1 / 60.0±25.3	0.0002 / 0.0001
	Number of drags completed	4.9±0.3 / 4.9±0.3	3.7±1.6 / 3.8±1.3	0.02 / 0.01
	Number of drag attempts	8.8±3.9 / 6.3±1.5	14.5±5.6 / 8.00±3.00	0.01 / 0.07
	Number of touches outside the target	1.7±1.5/1.7±2.7	8.8±6.7 / 14.2±9.5	0.001 / 0.0002

DISCUSSION

The present study indicates that the TATOO app may be used successfully by both middle-aged and elderly adults. This system may quantify hand performance when using a touchscreen. A non-significant correlation was observed between the TATOO outcomes and the measures obtained by traditional hand assessment tools. This result supports the claim that conventional tools cannot accurately predict an individual's ability to use common technological applications that rely on manipulating a touchscreen. The present study also suggests that TATOO may become an important add-on of the toolbox that clinical professionals can use to evaluate and treat fine motor skills in the elderly.

REFERENCES

[1] D. Rand et al. *Am J Occup Ther*. 2010; 64(6):877-885.
[2] A. Danial-Saad et al. *Disabil Rehabil Assist Technol*. 2018; 13(8): 745-753.
[3] J. Brooke. *Usability Eval Industry*. 1996; 189(194): 4-7.

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EFFECTS OF SCAPULA KINEMATIC BIOFEEDBACK IN PATIENTS SURGICALLY TREATED FOR ROTATOR-CUFF TEAR

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INTRODUCTION

ISEO (INAIL Shoulder and Elbow Outpatient protocol) is one of the most frequently used and documented systems for the real-time evaluation of shoulder biomechanics [1], including the scapulo-humeral coordination (SHC). Its exploitation as assessment tool is well-described [2], but its effect as biofeedback device during physical therapy has never been documented. Therefore, a Randomized Control Trial is currently ongoing to verify if ISEO improves the functionality and activity of patient surgically treated for rotator cuff tear, both in the short and medium term.

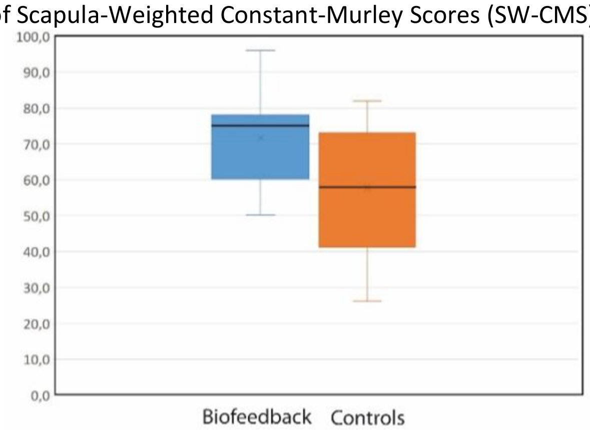
METHODS

Twenty-eight, 35-65 year-old patients were recruited at the time of writing and randomly assigned to two groups: 16 patients to the *Control* group, which follows a conventional rehabilitation program based on hydrotherapy and manual therapy; 12 patients to the *Biofeedback* group, which exploits ISEO for visual kinematic biofeedback for at least 70% of the non-hydrotherapy time. The same Surgical Unit arthroscopically treated all patients, and the same physical therapy team completed their rehabilitation. Patients were evaluated before surgery (T0), at 45 days after surgery (T1) and at the return-to-work time (T2). Each evaluation included the assessment of SHC during humerus elevation in the sagittal and scapular planes by means of ISEO, and the administration of a set of clinical scores including the Constant-Murley Score (CMS). For each patient, scapula kinematics was assessed by comparing the mean pattern to the relevant reference band of asymptomatic patients [2], and the correspondent Scapula-Weighted CMS (SW-CMS) was calculated [3]. Possible statistical significant differences between groups were analyzed with non-parametric statistics (Mann-Whitney), separately for CMS and SW-CMS.

RESULTS

At T0 and T1 there were no significant differences between the two groups, either for the CMS and the SW-CMS. At T2, for SW-CMS there were significant differences ($p = 0.029$) between the Control (median value 58/100) and Biofeedback group (median value 75/100), with a difference of 17 points, which is also clinically significant. For CMS there were no significant differences at T2 ($p=0.06$), but differences were 7 points higher for the Biofeedback vs the Control group.

Figure 1. Boxplot of Scapula-Weighted Constant-Murley Scores (SW-CMS) at T2 for the two groups.



DISCUSSION

The preliminary results reported here show that ISEO can be effective as biofeedback tool to improve scapula kinematics at the time of return-to-work. This conclusion needs further confirmations, which will be possible once the target number of patients per group (20) will be reached.

REFERENCES

[1] De Baets et al. *Gait Posture* 2017; 57:278-294.
[2] Cutti et al. *J Biomech* 2014; 21;47(5):1035-44.
[3] Merolla G et al. *IntOrthop 2019*; 43(3):659-667.

http://doi.org/10.6092/unibo/amsacta/6260

KINEMATIC AND ELECTROMYOGRAPHIC ANALYSIS OF THE SHOULDER IN PATIENTS UNDERGOING LATISSIMUS DORSI TENDON TRANSFER DUE TO MASSIVE ROTATOR CUFF TEARS

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INTRODUCTION

Latissimus dorsi (LD) tendon transfer is a surgical treatment for massive and irreparable posterosuperior rotator cuff tears, mainly in young and active patients. So far, there are a few studies, with different methods of evaluation and opposite results and there is not a common interpretation of data [1-3]. The aim of this study is to quantify clinical and functional results after LD transfer, in order to evaluate the role of the LD transferred, and, possibly, to discriminate between tenodesis effect and active recruitment.

METHODS

In our study we included 20 patients, undergoing LD transfer, and evaluated at 16 ± 12,2 months after surgery; 5 of them were also evaluated before the surgery. Each patient was evaluated bilaterally. Each evaluation included the administration of the Constant-Murley Score (CMS) and the quantitative analysis of shoulder biomechanics, including a kinematic analysis of the scapulo-humeral rythm (SHR) (stereophotogrammetry with Vicon system) and a concurrent dynamic surface electromyography (Cometa Wave). All patients performed movements of humerus flexion (FLEX), abduction (ABD), external rotation in 0° of adduction (EXT). Thirteen patients were also able to perform humerus internal and external rotation in 90° of abduction (INT ABD, EXT ABD). The ULEMA software was used to calculate the SHR, following ISB guidelines [4]. EMG was recorded for the subsequent muscles: pectoral, anterior and posterior deltoid, upper, middle and lower trapezius, upper and lower LD. Electrodes were applied according to the Basmajian and Blank minor cross-talk protocol [5]. Possible statistical significant differences between preoperative VS postoperative, and operated VS non-operated side data were analyzed with the Wilcoxon signed-rank test ($p \leq 0.05$).

RESULTS

In the comparison between preoperative and postoperative, the CMS showed a statistically significant improvement, both for the total and pain score; an increase in EXT (from -2°± 36.6 to 14°± 34.3) and EXT ABD (from 30°± 29.8 to 40°± 28,6) with disappearance of posterosuperior cuff insufficiency signs, although values did not differ significantly. In the comparison between operated and non-operated side there are no significant differences in pain score; humerus range of motion (ROM) did not differ significantly in FLEX and ABD, while in EXT and EXT ABD there are significant differences (12°± 25,7 and 22°± 26,5 for the operated, 35°± 28,3 and 41°± 36,8 for the non-operated). The EMG activity of LD muscle is reported in Table 1.

Table 1. Patients with EMG activity of LD muscle, during rotations (%, n° of patients with activation).

	Preoperative evaluation	Postoperative evaluation	Non-operated
INT ABD	100 (5/5)	38.5 (5/13)	100 (20/20)
EXT ABD	20 (1/5)	100 (13/13)	20 (4/20)
EXT	60 (3/5)	95 (19/20)	65 (13/20)

DISCUSSION

In this study, we quantified the results of LD tendon transfer, finding significant improvements both in clinical and kinematic evaluations. The EMG analysis of transferred LDs showed an active recruitment in most of patients and a recurrent morphology. These preliminary results do not find comparison in the literature, leading to the need for further studies.

REFERENCES

[1] Henseler JF, et al. J Shoulder Elbow Surg 2017. 1058-2746.
[2] Ippolito G, Serrao M. Arch Orthop Trauma Surg 2016. 136:1363-1370.
[3] De Casas R, et al. J Orthop Surg Res 2014. 8:9-83.
[4] Jaspers E, et al. Gait Posture 2014. 39:S76–S77.
[5] Blumenstein R, Basmajian J. Electrode placement in EMG biofeedback. Williams & Wilkins, Baltimore, 1980.

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Sensorized Treadmill Gait Analysis One Year After Total Hip or Total Knee Replacement Surgery

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INTRODUCTION

Patients underwent total hip (THR) or total knee replacement (TKR) surgery often show gait abnormalities. The recognition and correction of these anomalies is essential for a complete functional recovery. In clinical practice, quantitative measurement of gait parameters is required[1] and can be obtained in different ways. The gold standard is represented by the three-dimensional (3-D) motion capture systems[2], but this method is rarely used in clinical practice due to high cost and long execution time needed to perform a single test[3]. Currently, sensorized treadmills are available, which make gait analysis easier. The aim of the present study is to compare the parameters of gait in patients after one year joint replacement surgery, recorded by means of sensorized treadmill, with normative reference values of healthy adult subjects available in literature[4].

METHODS

28 subjects one year after THR (n=13) or TKR (n=15) were enrolled. Each patient was asked to perform 3 consecutive gait analysis on a sensorized treadmill (WalkerView Tecnobody). Each patient has previously performed a training in order to detect a comfortable speed with which perform the 3 gait analysis trials. 9 subjects did not perform the test due to the difficulties reported during treadmill walking.

RESULTS

Patients with THR and TKR showed reduction in cadence (THR = 99.5 steps / min; TKR = 81.4 steps / min) if compared to the normative reference values (109 steps / min). The step length of the affected limb in both THR and TKR is lower (THR = 33.5 cm; TKR = 35.9 cm) than the reference values (66 cm), but if compared with their healthy limb (THR = 33.9 cm; TKR 37.5 cm) values are similar not showing asymmetry. The stance time (% of gait cycle) shows an increased duration in patients with TKR (73.3%) if compared to patients with THR (66%) and to reference values (57.8%). The swing time (% of gait cycle) shows lower values for TKR (26.6%) compared to THA (33%) and to the reference values (32.2%). The kinematic data show a slight reduction of the sagittal range of motion of the affected hip (THR = 30.8 °; TKR = 31.4°) and of the healthy limb (THR = 31.8 °; TKR = 30.4°) compared to the reference value (33.6°). Greater reduction was observed in the average knee flexion-extension range of motion both on the affected (THR = 41 °; TKR = 37.2 °) and on the healthy limb (THR = 43.4°; TKR = 36.2°) compared to reference values (47.7°).

DISCUSSION

Although in the literature differences between overground walking and treadmill walking have been reported[5], these differences are typically very small suggesting that there are no clinically relevant differences between the two different walking modalities. Therefore, our results confirms that patients with THR and TKR have an altered gait pattern one year after surgery.

The treadmill turned out to be an easy and quick tool to perform gait analysis but given the high frequency of dropouts observed in our study, a feasibility study of its use in daily clinical practice should be carried out.

REFERENCES

[1] Saleh M, Murdoch G. *The Journal of bone and joint surgery. British volume* 1985;67(2):237–241
[2] Wong WY, et al. *Prosthetics and Orthotics International* 2007;31(1):62–75
[3] Mayagoitia RE, et al. *Journal of Biomechanics* 2002;35(4):537–542
[4] Bovi G, et al. *Gait and Posture*. 2011;33(1):6–13
[5] Stolze H, et al. *Electroencephalography and clinical Neurophysiology* 1997;105:490–497
[6] Watt JR, et al. *Clinical Biomechanics* 2010;25(5):444-449.

Sessione 5 – ANALISI DEL MOVIMENTO PER LA CLINICA

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ASSESSMENT OF THE INTER-LABORATORY REPEATABILITY OF GAIT ANALYSIS MEASUREMENTS IN PATIENTS WITH MULTIPLE SCLEROSIS

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INTRODUCTION

Inertial measurement units (IMUs) allow to objectively quantify gait impairment [1]. To be clinically meaningful and reliable, gait parameters obtained from these IMUs data should not be influenced by differences in the clinical environment and by changes in the experimental protocols. This study aims to verify the inter-laboratory reliability of wearable-sensor based gait analysis in patients with multiple sclerosis (MS) by comparing the measures obtained from tests performed in two different research centres located in the United Kingdom (*centre1*) and Italy (*centre2*).

METHODS

Twenty-six patients with MS were selected from two larger datasets following best-matching criteria according to age, gender, Expanding Disability Status Scale (EDSS) score and use of assistive devices (*centre1*: n=13; age: 53 ± 8 years; 5 males; EDSS: 2.5-6; *centre2*: n=13; age: 50 ± 9 years; 5 males; EDSS: 2-6). All participants performed a six-minute walk test but with different walkway length and patients' instructions (10m corridor at preferred speed in *centre1* vs 30m corridor at the maximum speed in *centre2*). Fourteen gait measures representative of rhythm, variability, and asymmetry [2] and fifteen gait measures representative of balance and coordination (i.e., magnitude, smoothness, step and stride regularity, and symmetry [2]) were calculated from data measured with three IMUs (APDM, OPAL, sampling rate: 128Hz, down sampling to 75Hz in *centre1;* MTw, Xsens, NL, sample rate: 75Hz in *centre2).* Two IMUs were wrapped to the ankles (frontally in *centre1* and laterally in *centre2*) and one at L5*.* Inter-laboratory repeatability was assessed comparing *centre1* and *centre2* measures using a non-parametric Wilcox test (p=0.05) and a linear regression model.

RESULTS

11 out of 29 parameters (red dots in Figure 1) were statistically different between the two *centres* with centre-to-centre relative percentage differences ranging between 15% and 60%. The lowest centre-to-centre relative percentage differences were found for stride regularity, stride and step time.

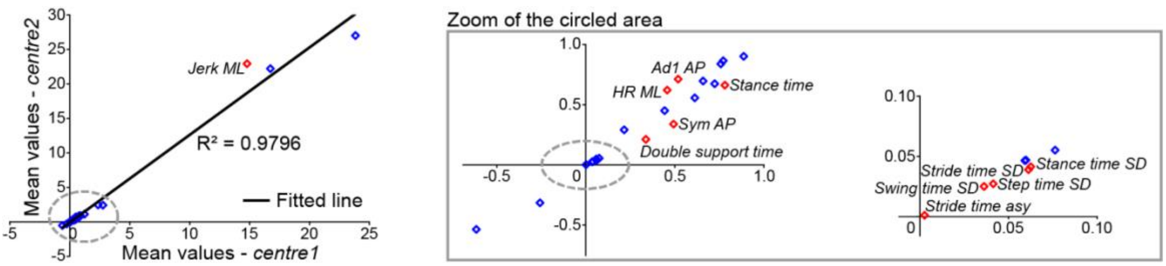

Figure 6. Centre-to-centre scatter plot for gait parameters representative of rhythm, variability, asymmetry and balance and coordination domains. Red dots indicate p<0.05. Ad1: step regularity; HR: harmonic ratio; Sym: symmetry; SD: variability; AP: anterior-posterior; ML: medio-lateral.

DISCUSSION

A set of reliable gait measures, which are robust with respect to a different environment, different measurement systems and variations in experimental protocols, was determined. This suggests that wearable sensors may allow to identify intrinsic characteristics of multiple sclerosis.

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REFERENCES

[1] Spain RI, et al. Gait & Posture 2012;35(4):573-578.
[2] Angelini L, et al. Gait & Posture 2018;66:S1.

ITUG AND TUG WITH DUAL TASK FOR FALLS RISK IN STROKE PATIENTS

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INTRODUCTION

The Time Up and Go score (TUG) ≥ 13.5 has been used for years to identify individuals at higher risk of falling [1]. Recently a systematic review denied this hypothesis stating that the TUG test has a limited capacity to predict falls in the elderly and should not be used in isolation to identify individuals at high risk of falls [2]. Moreover dual task could compromise patient's balance causing falls and often patients refers to have fallen during activities in dual task. Evidence are growing about the importance of cognition for safe walking [3].
The purpose of this study is to determine whether the instrumental Time Up and Go (iTUG) 180°Turn Duration and the dual task TUG (dtTUG) could be more accurate, to predict fall event, than iTUG total duration.

METHODS

Ninety-four (94) post-stroke patients completed, at discharge, the iTUG test. During the tests, the patients wore on the lumbar tract, a smartphone connected to the application that recorded parameters wanted during the tests. Patients, also completed Mini-Best, a balance test that contains TUG in dual task, the test that requires, in addition to the motor task, also a cognitive task. Patients were contacted monthly along 3 months to monitor numbers and modalities of falls. The t-test and U di Mann-Whitney was used to compare differences between groups.

RESULTS

27 of the 94 patients enrolled fell down. We divided the sample in 2 groups : fallers and non fallers.
Instrumental TUG (iTUG) total Duration mean time of non fallers was lower than instrumental TUG of fallers, but not significant (p=0,35), on the other hand instrumental TUG 180°turn duration and total score of Mini-Best were significant between groups. Moreover dtTUG was significant between groups (p=0,008).

	Fallers, mean(SD)	Non fallers, mean(SD)	Significance
Total Duration [s]	21,91 (9,33)	19,74 (10,40)	p=0,35
180°Turn Duration[s]	3,99 (2,03)	3,14 (1,27)	p=0,016
Mini-Best (total score-28)	14 (5,95)	18,56 (6,56)	p=0,02

Table 1. Mean and standard deviation (SD, between brackets) of two groups (fallers/non fallers).Significance (p).

DISCUSSION

From data emerged that TUG variations (e.g. TUG test with dual task and iTUG 180° Turn Duration) are more accurate instruments than iTUG total duration in the study of fall's risk.

Bibliography:

1] Tinetti ME et al. J Am Geriatr Soc. 1995 Nov;43(11):1214-21.
2]Barry E et al. BMC Geriatr. 2014 Feb 1;14:14. doi: 10.1186/1471-2318-14-14.
3]Manuel Montero-Odasso et al. J Am Geriatr Soc. 2012 Nov; 60(11): 2127–2136.

IDENTIFICATION OF KEY SPATIOTEMPORAL GAIT VARIABLES IN ELDERLY SUBJECTS

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INTRODUCTION

Spatiotemporal variables of gait are commonly evaluated to identify possible gait abnormalities in elderly, neurological and orthopaedic patients. In fact, gait performance is an important indicator for assessing quality of life, cognitive decline and risk of falls in older adults [1]. Gait can be conveniently assessed by electronic walkway, an instrument of evaluation that provide a large number of spatiotemporal variables. In order to easily analyse gait in elderly, it is important to found which variables need to be considered. To do that, some authors created models in which gait variables were divided in specific factors (e.g. “pace”, “rhythm”, “variability”) [1-7]. The aims of this study were to identify which of the models presented in literature could better describe gait in elderly subjects and, subsequently, to present normative data of variables included in the model identified as the more appropriate.

METHODS

Gait variables of 82 elderly subjects (mean age 71.6 ± 8.0 yrs) were obtained with a baropodometric walkway (GAITRite®). Subjects were instructed to walk on the mat at their comfortable speed for four trials. Since the first trial was statistically different from the other three, it was considered as a practical trial and we analyzed only the 2nd, 3rd and 4th trials. The confirmatory factor analysis (CFA) was conducted for testing the seven conceptual models of gait presented in literature. The goodness of fit of the models was expressed with the following indexes: Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA) with 90% CI (CI_{90}) and the Standardized Root Mean square Residual (SRMR). A CFI and TLI>0.95, RMSEA<0.06 and SRMR<0.08 indicate a good fit [8]. Reference values of gait parameters, with 95% CI (CI_{95}), were then presented for the variables found in the model identified as the more appropriate.

RESULTS

When conducting the CFA, only one [7] of the seven models considered reached the convergence with an excellent fit: χ^2=14.58, df=13, p=0.33, RMSEA=0.04 (CI_{90}=0.00-0.13), CFI=0.99, TLI=0.99, SRMR=0.05. This model comprised 8 gait variables, divided into three factor: pace/rhythm, variability and asymmetry. The normative values ($C.I._{95}$) of gait variables of elderly are shown in Table 1.

Table 1. Mean gait variables [CI_{95}] of elderly subjects.

Variables	Mean [CI_{95}]
Pace/rhythm	
Gait speed (cm/s)	125.6 [121.3-129.9]
Step time (s)	0.51 [0.50-0.52]
Double support time (s)	0.26 [0.25-0.27]
Variability	
Step length (%CV)	3.38 [3.07-3.69]
Swing time (%CV)	3.56 [3.14-3.99]
Step velocity (%CV)	3.02 [2.72-3.32]
Asymmetry	
Step time asymmetry (%)	3.16 [2.76-3.55]
Swing time asymmetry (%)	3.70 [3.22-4.18]

DISCUSSION

The results confirmed that only one model was appropriate for assessing gait of elderly. As reported in a previous study conducted with a sample of patients with Parkinson’s Disease (PD) [7], the other models considered could not be appropriate for evaluating gait since they presents some shortcomings. In particular, authors included some variables that were highly inter-related and/or variables with low levels of reliability. Consequently, we suggest to consider these 8 variables when evaluating linear gait of both elderly and patients with PD.

The normative data of spatiotemporal variables of gait included in the model can be useful for interpreting gait dysfunction in aging persons.

REFERENCES

[1] Verghese J, et al. *J Neurol Neurosurg Psychiatry* 2007;78(9):929-935.
[2] Verghese J, et al*. J Am Geriatr Soc.* 2008;56(7):1244-1251.
[2] Verghese J, et al. *J Gerontol A Biol Sci Med Sci* 2009;64(8):896-901.
[3] Hollman JH, et al. *Gait Posture* 2010;32:23-28.
[4] Lord S, et al*. J Gerontol A Biol Sci Med Sci* 2013;68(7): 820-827.
[6] Thingstad P, et al. *BMC Geriatr* 2015;15:150.
[7] Arcolin I, et al. *Gait & Posture* 2018;66:S1-S2.
[8] Browne MW, Cudeck R. Testing Structural Equation Models. Sage, Newbury Park, 1993.

LACKING FOOT DORSIFLEXION DURING SWING AFTER STROKE. PARESIS, SPASTICITY OR MUSCLE SHORTENING?

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INTRODUCTION

Equinus foot deformity (EFD) is the most frequent lower limb deformity in stroke survivors. It can be provoked by a combination of factors, including lack of activity from ankle dorsiflexors and overactivity and/or shortening of plantarflexor (PF) muscles [1]. According to its causes, EFD can be treated by means of focal inhibition of PF muscles by botulinum toxin, neuro-orthopedic surgery, physiotherapy and by the use of orthoses. Clinical evaluation at the bedside, inclusive of ROM, force and spasticity assessment by the Modified Ashworth scale (MAS), is typically used for treatment selection [2]. In this study, we assessed the occurrence EFD causes in a large sample of stroke patients, based on the analysis of gait analysis (GA) data inclusive of EMG, to estimate the potential contribution of GA to treatment appropriateness.

METHODS

We retrospectively analyzed GA data (BTS Smart-DX system, Conventional *Davis* Protocol, 5 trials per subject) from chronic stroke patients referred to our laboratory over a two-years period because of EFD and clinically evaluated ankle spasticity. Subjects with available gait kinematics and surface EMG data from Soleus (SOL), medial and lateral gastrocnemius (GAM, GAL), and tibialis anterior (TA) were included. Subjects were excluded in the case of any recent (<6months) treatment or concurrent pathologies. Ankle dorsiflexion velocity (DFVel) was computed from kinematics data. DFvel was preferred to the peak of dorsiflexion, as outcome measure, as it is insensitive to offsets due to markers misplacement. Mean DFVel during initial swing (ISw) was computed and averaged among trials. DFVel is positive in the case of ankle dorsiflexion after foot off, null or negative otherwise. In normal subjects, during slow walking, DFVel∼70 deg/sec. To ensure data consistency EMG data were checked for motion artifacts in the time-frequency domain and discharged when necessary. Muscle activity intervals were then computed as in [3]. When present, EMG activity during ISw was further classified as burst-like or continuous.

RESULTS

Data from 122 chronic stroke patients with MAS≥1 at PFs were included, age 53(13) years, affected side 57/65. Walking speed was 0.51(0.28) m/s (range 0.1-1.1 m/s) thus providing external validity to results. TA was active, continuous or subcontinuous, in 120/122 (98.5%) cases during ISW. Despite of this TA activity, DFVel was impaired in 112/122 (92%) cases, ranging between X and x. SOL, GAM, GAL were silent during ISW in 60/112 (54%) cases. In all these cases, spasticity was not the cause of EFD. A burst-like activation of at least one amongst GAM, GAL or SOL was found in the remaining 52/112 (46%) patients. This occurred during plantarflexion in 16/52 (31%) cases (PF abnormal pattern), with no or very limited DFvel in 33/52 (63%) cases and with slow or moderate DFvel in 3/52 (6%) cases. Hence, PF activity was triggered by muscle tension rather than by muscle fast stretch.

DISCUSSION

The modification of PFs passive rheologic characteristics, including shortening, stiffness increased and altered viscosity [1] was the primary cause of the lack or absence of ankle dorsiflexion after foot-off. Noteworthy, missing dorsiflexion during ISw was characterized by active TA and completely silent PFs in more than 50% of the sample patients, irrespective of the clinical assessment of spasticity. This may explain the limited average recovery after PF inhibition [2]. The second most frequent scenario was a combination of passive and active PF contributions, with muscle activation triggered by muscle tension rather the muscle fast stretch. The absence of TA activity was rare. When active, GAM GAL and SOL presented different patterns among subjects, thus requiring for a direct assessment of each PF during walking. These results strongly promote the use of an instrumental analysis of walking, including EMG, to complete the clinical evaluation, in order to identify the patient-specific causes of EFD. This approach can greatly increase the appropriateness of the treatment selection, support the design of tailored clinical pathways and decrease the related costs by avoiding unnecessary treatments.

REFERENCES

[1] Gracies JM. *Muscle Nerve* 2005;31(5):535-51.
[2] Picelli A, et al. *Am J Phys Med Rehabil* 2012;91(11):957-64.
[3] Merlo A et al. *IEEE Trans Biomed Eng* 2005;50(3):316-23.

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FUNCTIONAL EVALUATION OF A NOVEL CUSTOM ANKLE-FOOT-ORTHOSIS IN A PATIENT WITH SEVERE DROP-FOOT

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INTRODUCTION

Ankle Foot Orthoses (AFO) can be prescribed to address functional impairment of the main ankle dorsiflexor muscles in drop-foot patients, as a consequence of neuromuscular pathologies. 3D scanning devices, in combination with additive manufacturing technology, allow to design and produce custom AFOs with improved fit and comfort [1, 2]. In this pilot study, a novel AFO device was designed and manufactured via Selective Laser Sintering (SLS) using a commercial lightweight composite material. The hypothesis of the study was that a custom AFO produced via SLS and made with the novel composite material allows to address fully the functional deficit and results in improved comfort with respect to off-the-shelf solutions.

METHODS

One patient (67 years, 83 kg, 1.8 m) with left drop-foot diagnosed with paraparesis in severe spondylodiscoarthosis after spine stabilization surgery T9-S1, volunteered in the study. The patient's foot and lower limb was scanned in bipedal upright posture using a custom 3D foot scanner based on the Microsoft Kinect depth sensor. The STL of the foot shape was used to design a custom AFO in Blender (Blender Foundation, Amsterdam) printed via SLS using a fiber-glass reinforced polyamide based composite material (Windform GT®, CRP Technology, Modena). Functional evaluation (figure 1) was performed using the IOR-gait lower limb protocol [3] in three conditions: 1) without the AFO; 2) wearing the custom AFO, and 3) wearing a standard off-the-shelf AFO in polyethylene (Molla di Codivilla, Ottobock). The perceived comfort while wearing the two AFOs was assessed via a 0-10 VAS scale.

RESULTS

The subject walked at faster speed and with increased stride length wearing the custom AFO (0.91 ± 0.04 m/s; 1.22 ± 0.03m) with respect to both the Codivilla (0.85 ± 0.03 m/s; 1.17 ± 0.03 m) and the no-AFO (0.67 ± 0.01 m/s; 1.09 ± 0.02 m) conditions. The ankle maximum dorsiflexion in the swing phase was larger while wearing the custom AFO (-16.9 ± 0.3 deg) with respect to the no-AFO condition (-33.4 ± 0.4 deg). The custom AFO resulted overall more comfortable than the Codivilla (9.7 vs. 7.3); in particular in the shank support (9.6 vs. 7.5), the plantar aspect (9.8 vs. 3.5) and in the perceived elastic return (9.7 vs. 6.9).

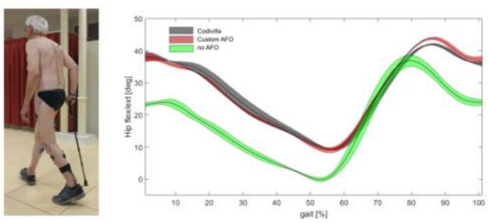

Figure 7 Left, gait analysis of the patient while wearing the custom AFO on the left foot. Right, mean temporal profiles of hip flexion/extension angle [deg] during normalized gait-cycle in the three conditions: Codivilla, custom AFO and no-AFO (shod condition).

DISCUSSION

Designing personalized orthotics is becoming increasingly feasible and useful to improve the functional outcome of patients with lower limb pathologies. This pilot study has further confirmed that custom AFOs are feasible via additive manufacturing and can be used to improve patients' gait and quality of life. The novel SLS-printed custom AFO has proved to be more comfortable than a standard off-the-shelf AFO and has resulted in faster gait speed and longer stride length. The positive outcome of the present pilot study is encouraging a thorough validation in a larger population of drop-foot patients and further customization of the mechanical properties with respect to the subject-specific functional impairment.

REFERENCES

[1] Telfer S, et al. *BMC Muscolskeletal Disord.* 2012; 13: 84.
[2] Wojciechowski E, et al. *J Foot Ankle Research* 2019; 12(1): 11
[3] Leardini A, et al. *Gait & Posture* 2007; 26(4): 560-71

LOCAL DYNAMIC STABILITY OF GAIT IN PEOPLE WITH EARLY MULTIPLE SCLEROSIS AND MINIMAL IMPAIRMENT. A CROSS-SECTIONAL STUDY.

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INTRODUCTION

Poor dynamic balance, such as poor stability during walking, is an hallmark of multiple sclerosis [1] and people with multiple sclerosis (PWMS) can suffer subtle gait impairments at the very beginning of their disease. Measures of local dynamic stability of gait (such as the Lyapunov exponent, LyE [2]) are genuine measures of stability during walking and are being increasingly used as proper dynamic balance indicators [3]. The aim of the currentwork is to investigate if PWMS with no clinical evidence of gait impairment according to EDSS, suffer poor stability of gait as indicated by increased LyE values, reflecting in turn poor dynamic balance.This study is part of a multi-center project funded by the Italian Multiple Sclerosis Foundation (FISM) (project code 2016/R/1).

METHODS

Eighty people with “early” MS and mild neurological impairment (EDSS ≤ 2.5, disease duration ≤ 5 years) and 20 age- and sex-matched healthy controls completed the six minute walk test (6MWT) at their maximum gait speed wearing inertial sensors (MTw, Xsens, NL) on ankles and posterior lower trunk (L4–L5 level). Short-term LyE (sLyE) was calculated from trunk acceleration along the vertical ($sLyE_{VT}$), anteroposterior ($sLyE_{AP}$) and mediolateral ($sLyE_{ML}$) axes. PWMS also completed a full gait and balance clinical assessment, which included the timed up and go (TUG) test. The multiple sclerosis walking scale (MSWS) and the fatigue severity scale (FSS) questionnaires were administered to evaluate the disease’s effects on gait and the level of fatigue, respectively.

RESULTS

Gait speed during the 6MWT was significantly lower in PWMS than in controls [mean(sem): 1.96(0.04) vs 2.25(0.07) m/s; mixed-effects ANOVA: $F_{1,94} = 12.28$, $p < 0.001$]. All three sLyEs were larger in PWMS than controls [$sLyE_{VT}$:0.76(0.01) vs 0.68(0.03); $F_{1,98} = 7.74$, $p = 0.006$; $sLyE_{AP}$: 0.70(0.01) vs 0.61(0.03); $F_{1,97} = 7.07$, $p = 0.009$; $sLyE_{ML}$: 0.76(0.01) vs 0.68(0.03); $F_{1,97} = 7.86$, $p = 0.006$], even after adjusting for the difference in gait speed. $sLyE_{AP}$ showed mild to moderate correlations with several gait measures and questionnaires scores. A negative correlation was found between $sLyE_{AP}$ and the 6MWT distance (Spearman’s correlation: $\rho = -0.25$, $p = 0.046$) and $sLyE_{AP}$ positively correlated with the TUG duration ($\rho = 0.38$, $p = 0.006$). $sLyE_{AP}$ also correlated with the MSWS score ($\rho = 0.32$, $p = 0.017$) and the FSS score ($\rho = 0.44$, $p < 0.001$). No correlations were found for $sLyE_{VT}$ and $sLyE_{ML}$. A significant correlation between LyE_{AP} and FSS was still present after adjusting for the 6MWT distance, TUG duration and MSWS score (partial Spearman’s correlation: $\rho = 0.33$, $p = 0.008$), while the correlation between LyE_{AP} and MSWS was not significant anymore after adjusting for 6MWT distance, TUG duration and FSS score ($\rho = 0.02$, $p = 0.863$).

DISCUSSION

Gait speed of PWMS with no-to-mild neurological impairment is lower than that of healthy controls during 6MWT at maximum gait velocity. Net of the difference in gait speed, sLyE is higher in PWMS, thus indicating poorer local stability of gait. The association between high sLyE and increased TUG duration suggests the validity of sLyE as a dynamic balance measure. The inverse relationship between sLyE and the distance covered during the 6MWT is consistent with the view that good dynamic balance is important for achieving high gait speed in PWMS. Our results are also in agreement with the vicious circle linking poor balance and fatigue in multiple sclerosis, with fatigue making balance worse, but also poor balance causing fatigue by itself [4].

REFERENCES

[1] Cattaneo D, et al. *Disabil.Rehabil.*2006;28(12):789-795.
[2] Dingwell JB, et al. *J.Biomech.Eng.*2001;123(1):27-32.
[3] Siragy T, Nantel *J. Front Aging Neurosci*. 2018; 10:387.
[4] Hebert JR, Corboy JR.*Gait Posture* 2013; 38(1):37-42.

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SHOULDER KINEMATICS IN HEMIPLEGIC PATIENTS AFTER STROKE. PILOT STUDY

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INTRODUCTION

The movements of the scapulo-thoracic joint in patients with hemiparesis after stroke are poorly studied due to the complexity of the kinematic investigation. A study [1] highlights the relationship between the limitation of movements and the greater cranial rotation of the scapula in the paretic side. The inertial systems (Magnetic Inertial Measurement Unit, MIMU) allow a rapid and accurate analysis of shoulder movements succeeding in highlighting the scapula rotations in relation to the movements of flexion and abduction of the humerus [2] in clinical practice. The aim of the study is to measure the scapulo-humeral rhythm (SHR) in hemiplegic patients after stroke and compare it with a healthy population.

METHODS

Population:16 stroke patients (averaging 53.31±13.25years) who were able to perform an active shoulder elevation movement were included in the study. 25 healthy subjects(averaging 37±11.05 years) were used as comparison tests.

Study design:

CLINICAL EVALUATION: Fuglmeyer assessment (FMI) and Brunnstrom Index from 1 to 6 (BRI)

INSTRUMENTAL ASSESSMENT: Patients performed active bilateral flexion-extension and ab-adduction movements while sitting. The Range of Movement (ROM) of humerus in the elevation plane and the SHR that quantifies the scapula rotations (Proto-Retraction PR, Up-Down Rotation UD, Tilt Anterior-Posterior TI) during elevation were measured. SHoW Motion system (NCS Lab, Carpi) has been used, which provides wireless MIMUs (WISE, NCS Lab, Carpi) positioned on the thorax, and bilaterally on the scapula and humerus according to the ISEO protocol [2].

The correlation between clinical and instrumental data was assessed by the Spearman coefficient.

RESULTS

Results of patients with FMI<8 & BRI<4 & ROM HUM<70° are not shown in the following table due to insufficient SHR data at high angles of humerus. Instead, for the selected group, the Table 1 shows the results, including the qualitative comparison of SHR with respect the healthy population. Concordant results emerged between the clinical and instrumental assessments, with a Spearman correlation coefficient greater than 0.78 for FMI-ROM and BR-ROM analyzes.

Table 1. BRI and FMI values, maximum ROM of humerus and qualitative SHR comparison are reported for selected patient, both in flexion and in abduction tasks.

Pz	FMI	BR	FLEXION TASK				ABDUCTION TASK			
			MAX ROM HUM	SHR			MAX ROM HUM	SHR		
				PR	UP	TI		PR	UP	TI
1	15	5	119.23°	↑	≈	≈	98.30°	↑	≈	≈
3	12	5	130.61°	≈	≈	↑	179.90°	≈	≈	≈
8	11	5	121.69°	↑	↑	↑	160.97°	↑	↑	↑
9	10	4	153.47°	≈	↑	↓	125.15°	≈	↑	≈
10	8	5	96.08°	↓	↑	≈	107.99°	↓	↑	≈
15	10	5	125.03°	≈	≈	↓	179.36°	≈	≈	≈
16	9	4	103.56°	≈	↑	↓	126.03°	↑	↑	↓

DISCUSSION

The SHR analysis showed a high scapular compensation in hemiplegic subjects, particularly in cranial rotation. This study demonstrates the possibilities of applications offered by inertial technology in the evaluation of hemiplegic patients. The clinical scales, currently widely used, provide information correlated with kinematic data, but are not sensitive for the study of SHR.

REFERENCES

[1] Niessen M, et al. *J Rehabil Med* 2008;40(6):482-486.

[2] Cutti AG, et al. *Med Biol Eng Comput* 2008;46(2):169-178.

CLINICAL AND 3D INSTRUMENTAL ASSESSMENT OF THE SHORT-TERM EFFECT OF SATIVEX ON PATIENTS WITH MULTIPLE SCLEROSIS.

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INTRODUCTION

The spasticity, in patients with Sclerosis Multiple(pwsm), is referred as the most disabling and interfering symptom on walking and main cause of falls [1]. It worsens the quality of life, increases the days of sick leave and social and health service costs [2].

On this basis, it is extremely important to optimize the management of the spasticity, using systemic or focal pharmacological therapy in combination with rehabilitation treatment.

Among the systemic muscle relaxants drugs, Nabiximols (Delta-9-Tetrahydrocannabinol/Cannabidiol Oromucosal Spray-"Sativex") showed a good safe profile, high tolerability and efficacy [3].

The aim of our study is to evaluate the immediate effects of Sativex on a homogeneous sample of patients, excluding confounding factors and using reliable clinical and instrumental scales for spasticity and disability.

METHODS

30 patients affected by Multiple Sclerosis aged between 30 and 70, were recruited in according to the following inclusion criteria: Relapsing-Remitting form, EDSS range from 3.5 to 6 with prevalent involvement of the pyramidal system; the possibility of walking at least 5 mt without aid; no treatment with systemic muscle relaxants (or with a stable treatment in the least 6 months). Patients were randomized and enrolled in 2 groups: Sativex and a control group (15 and 15 respectively).

All of patients were assessed at T0 (pre-treatment Sativex) and T1 (after 45 minutes) using impairments and disability scales (MAS-Tardieu-pendulum test- NRS for spasticity, MRC, ROM, 2mwt, 10mwt, BERG, 4 stairs and TUG) and instrumental evaluation with stereophotogrammetric system, force platforms, surface poliEMG (gait analysis-"GA") using the Helen Hayes marker placement protocol.

A monovariate statistical analysis was performed by means of boxplot/stripcharts to describe qualitative differences in results and by Wilcoxon-Mann-Whitney test to evaluate their significance quantitatively.

RESULTS

Our study revealed significant differences between the control and Sativex groups in clinical scales such as BERG, 10mwt, TUG, NRS which are improved in the sativex group, while the 2mwt was not significant. Spatio-temporal parameters of GA showed an increase in the length, speed, single support phase and swing phase and a reduction in gait cycle duration in patients treated with Sativex compared to controls.

The analysis of the kinematic parameters showed a statistically significant difference pre and post treatment in the peak of hip extension and of the knee flexion in phase of stance in the treated group.

Furthermore, in the control group, there is an increase in the variability of the obliquity of the trunk and pelvic tilt.

DISCUSSION

Our study showed the significant effects of Sativex to improve spatio-temporal and kinematic parameters, reducing the fatigue due to spasticity and improve balance and coordination during walking and motor skills.

Future studies are needed to assess the effects of Sativex over time and in association with rehabilitation treatment.

REFERENCES

[1] Gunn H et al. Mult Scler 2013: 19 (14): 1913–1922.

[2] Flachenecker P, et al. Expert Rev Neurother 2013 Feb;13(3 Suppl 1):15-9.

[3] Keating G.M. Drugs. 2017 April

Sessione 6 – ANALISI DEL MOVIMENTO PER LA CLINICA 2

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QUANTITATIVE ASSESSMENT OF NEURO REHABILITATION EFFICACY IN PATIENTS AFFECTED BY FOCAL DYSTONIA

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INTRODUCTION

Rehabilitation in dystonia is directed to neuromotor treatment of disease symptoms[1]. Neuro rehabilitation joins drug therapy in order to counter some of the symptoms of the disease and to prevent the resulting secondary damage. In this sense, rehabilitation becomes a constant and systematic "re-training" in the movement, to counter disharmony, postural changes and reduction the motor gesture control using exercises designed for this purpose. According to the new classification[2] “focal dystonia” is the dystonia that affected a single body region. The aim of our study is to assess and quantify the efficacy of integrated neuro rehabilitation in patients affected by three different focal dystonia: lower limb, upper limb and cervical dystonia. The developed protocols are based on motion analysis and are specific for each body region assessed.

METHODS

The first study investigated the role of lower limb dystonia analysing spatiotemporal, kinematic, and kinetic gait parameters in 10 patients during walking at self speed[3]; the second study investigated the movement in 10 patients affected by focal upper limb dystonia during the execution of a goal-directed task: the finger-nose test was assessed by means of an optoelectronic system to characterize by kinematic parameters this movement[4]; the third study assessed the dystonic movement in 10 patients with cervical dystonia, characterizing quantitatively the postural and motor adjustment and computing significant kinematic parameters that define the motor strategies adopted by the patients during the execution of the movements of the head (flexion-extension, rotation, later flexion)[4]. The measurements were performed before and after neuro rehabilitation program: individual 90-minute daily sessions, 5 days a week for 4 weeks. The kinematic parameters between the two conditions for each group of subjects were compared.

RESULTS

The results obtained from our study demonstrated the presence of differences in motor control of subjects with dystonia compared to healthy subjects. In each study, some characterizing parameters were found suitable to evidence the presence of different movement strategies and the major effect of a disturbing factor on the motor performance and quality of movements in dystonia respect to controls. These parameters showed how the movements were imprecise, not linear and not smooth, characterized by spasms and constant changes of direction and speed. At the end of treatment, there was an improvement of control of body region affected by dystonia and increased of movement smoothness in all the subjects.

DISCUSSION

Our results confirm the hypothesis that patients with focal dystonia have a conservation of movement skills and a good response to numerous riadattative strategies as many brain circuits maintain functional integrity or re training capacity[1]. This study shows how the motion analysis could provide an objective methodology to characterize and to assess focal dystonia in a clinical setting. Indeed, each protocol has objectively characterized motor abnormalities in focal dystonia by identifying specific parameters resulting from the valuation of motor patterns. The quantitative analysis of the dystonia becomes important in the clinic environment because not only it allows quantifying movement alterations following the pathology, but also assessing the motor condition of a patient before and after a neuro rehabilitation treatment.

REFERENCES

[1] Albanese A, et al. *European Journal of Neurology* 2011;18(6):5-18
[2] Albanese A, et al. *Movement Disorders* 2013;28(7):863-73
[3] Castagna A, et al. *Movement Disorders* 2016;31(11):1720-1728
[4] Menegoni F, et al. *European Journal of Neurology* 2009;16:232–239

IMPROVED DUAL-TASK PERFORMANCE DURING TURNING AFTER A SINGLE SESSION OF ACTION OBSERVATION TRAINING IN PARKINSON'S DISEASE PATIENTS

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INTRODUCTION

Parkinson's disease (PD) patients usually show a reduced gait speed and postural instability performing attention-demanding tasks such as turning and dual-task conditions [1]. A single session of action observation (AO) has the potential to improve hand motor performance in PD patients [2]. The aim of this study is to assess the effect of a single session of AO on spatio-temporal dual-task gait parameters, particularly during the turning phase, in PD patients with postural instability and gait disorders (PIGD).

METHODS

Fourteen PD-PIGD patients were randomized into two groups: "AO group" and "Landscape group". Both groups performed a baseline (T0) evaluation including Timed Up and Go (TUG) test and TUG with cognitive dual-task (TUG-COG), which consisted in TUG while counting backwards by threes starting from 100 or 82. After the baseline acquisition, the AO group was asked to watch a video representing a high quality TUG performance while the Landscape group observed a control video. After the video observation (T1), both groups performed again TUG and TUG-COG. Spatio-temporal gait parameters were acquired using a six cameras SMART-DX7000 optoelectronic system.

RESULTS

After the video observation, the AO group showed a significant improvement in execution time both in TUG and TUG-COG and in turning stride length during TUG, while Landscape group did not show any significant change. AO group also showed a trend toward an increased mean turning velocity during TUG-COG.

Table 1. *Comparisons within and between groups in time. Values are mean ± standard deviation before (T0) and after (T1) watching videos.* $p^{\S}$ *referred to Wilcoxon test;* $p^{\#}$ *referred to Mann Whitney test on delta values.*

	Landscape			Action observation (AO)			$p^{\#}$ AO vs Landscape
	T0	T1	$p^{\S}$	T0	T1	$p^{\S}$	
Execution time TUG (s)	10.0 ± 1.8	9.5 ± 2.0	0.280	9.2 ± 2.3	8.0 ± 1.8	0.046	0.228
Turning stride length TUG (m)	0.9 ± 0.1	0.9 ± 0.1	0.446	0.9 ± 0.2	1.1 ± 0.2	0.046	0.138
Execution time TUG-COG (s)	11.8 ± 3.6	11.6 ± 3.8	0.499	12.9 ± 7.7	9.4 ± 2.9	0.046	0.108
Mean turning velocity TUG-COG (deg/s)	73.1 ± 16.2	67.4 ± 15.7	0.069	70.1 ± 24.1	75.3 ± 27.7	0.249	0.059

DISCUSSION

PD-PIGD patients usually show difficulty performing dual-task likely because of the automaticity loss and the consequent cognitive overload [3]. Also turning represents a challenge as it requests an increased cognitive engagement in order to modify the locomotor pattern and to increase interlimb coordination [4]. A single session of AO showed the possibility to improve gait performance of PD-PIGD patients during TUG both with and without dual-task, particularly during turning. We hypothesized that AO might facilitate motor-learning, thus reducing the necessity to control movement also during dual-task. A randomized controlled trial investigating the effect of an AO training on dual-task gait abilities is needed to validate our hypothesis.

REFERENCES

[1] de Souza Fortaleza AC, et al. *Gait & Posture* 2017;56:76-81.
[2] Pelosin E, et al. *Neurorehabilitation and Neural Repair* 2013;27:552-560.
[3] Vandenbossche J, et al. *Frontiers in Human Neuroscience* 2012;6:356.
[4] Mellone S et al. *Journal of NeuroEngineering and Rehabilitation* 2016;13:39.

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PERFORMANCE COMPARISON OF CARBON SPRING AFO AND SOLID AFO IN THE GAIT OF THREE CHILDREN AFFECTED BY MYELOMENINGOCELE

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INTRODUCTION

Children with myelomeningocele (MMC) with sacral and low lumbar lesions often benefit from the support of Ankle Foot Orthoses (AFO). AFOs compensate for the weakness of the plantarflexors, allowing to stand upright and walk [1]. The Solid AFO (SAFO) stabilizes the foot in a functional position by reducing ankle movements. The Carbon fiber spring AFO (CAFO) is specifically designed to store energy when loaded and release it in push-off [2]. In our knowledge, no studies have been carried out to compare gait performance of CAFO and SAFO in these patients.

METHODS

The retrospective study was conducted on 3 children - C1 (female, 11y, 54kg, lesion level (LL) S1-S2), C2 (male 7y, 14kg, LL L5-S1), C3 (female 13y, 55kg, LL S1-S2). The children wore SAFO orthoses bilaterally and were later provided with CAFO. Data were collected by means of 3D gait analysis with total3DGait protocol with both AFO types. Normalized walking speed (SPEED), normalized stride length (STRIDE), Biomechanical Efficiency Quotient (BEQ) [3], normalized maximum push off power of the ankle (POWER), normalized energy produced (ENERGY) at both ankles, knees, hips and whole legs, GRF based parameters (Propulsive Mean Amplitude – PMA; Vertical Mean Amplitude – VMA [4]) were calculated. Reference data were collected from 24 typically developing children (HEALTHY - mean age 12y, bw 47kg). QUEST was administered to evaluate children and parents' satisfaction about CAFO.

RESULTS

Results are reported in Table 1.

Table 1: The average of right and left side is presented for POWER, PMA and LMA. In ENERGY right and left side were added.

	Condition tested	SPEED [%h/s]	STRIDE [%h]	BEQ	POWER [%bw*m^2/s^3]	ENERGY (R+L) [%bw*m^2/s^2] Leg	Ankle	Knee	Hip	PMA	VMA	QUEST Median	Efficacy
C1	CAFO	78 ±4	85 ±2	1,9	1,4	46	18	39	20	8,2	80	5	5
	SAFO	75 ±2	84 ±2	2,1	0,6	51	7	44	21	8,6	82		
C2	CAFO	93 ±9	84 ±4	2,3	1,6	54	22	21	39	9,7	89	5	5
	SAFO	92 ±4	85 ±3	1,6	0,4	28	6	22	19	8,8	95		
C3	CAFO	65 ±1	70 ±1	1,9	1,1	43	14	42	16	6,5	84	5	5
	SAFO	66 ±1	69 ±1	1,7	0,4	23	5	39	13	6,1	86		
HEALTHY	BAREFOOT	82±11	83 ±6	1	1,8	33	30	6	7	5,1	85		

DISCUSSION

As expected, POWER markedly increased with CAFO for all patients. Thus, no evident modification of SPEED and STRIDE was found. With CAFO, C1 slightly improved SPEED and BEQ, with a reduction of ENERGY (except for the ankle). Variations of PMA and VMA were below minimal clinically important difference. In C2 and C3, BEQ worsened, ENERGY increased (especially at hips), SPEED and STRIDE did not significantly vary. Only VMA of C2 was lower with CAFO. These parameters suggested a more efficient gait for C1 with CAFO and for C1-C2 with SAFO. Anyway, children and parents considered CAFO completely satisfying in all the 3 cases.

REFERENCES

[1] Ivanyi B et al. *Prosthetics and Orthotics Int.* 2015; 39(6):437-443.
[2] Wolf SI et al. *Gait & Posture* 2008; 28:175-177.
[3] Kerrigan DC et al. *Am J Phys Med Rehabil* 75(1): 3-8, 1996.
[4] Campanini I, Merlo A, *Gait & Posture* 2009; 30:127-131.

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NOVEL SUBGROUPS OF DIABETIC PATIENTS WITH AND WITHOUT NEUROPATHY AND THEIR ASSOCIATION WITH CLINICAL OUTCOMES: A 15 YEARS FOLLOW UP STUDY BASED ON GAIT ANALYSIS DRIVEN CLUSTER ANALYSIS

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INTRODUCTION

Diabetic foot ulcers occur in approximately 15% of patients with diabetes mellitus. Of those patients who develop ulcers, 6% will be hospitalized for infection or other ulcer-related complications, and 1% of these will require amputation. The annual incidence worldwide is between 9.1 to 26.1 million. The etiology for ulceration is multifactorial: the common underlying causes are poor glycemic control, calluses, foot deformities, improper foot care, ill-fitting footwear, underlying peripheral neuropathy (PN) and peripheral vascular disease, dry skin, etc. [1]. The mixture of gait deviations seen in these patients has recently been indicated as an associated factor. This study compares two patients' stratification approaches based on cluster analysis of gait parameters, grouping patients into disease sub-groups.

METHODS

Eighty subjects took part in the study, after signing informed consent and clinical examination: 21 controls ((CS) mean(± SD) age 61,3±4,4 years and BMI 24,5±2,4 kg/m^2); 30 diabetic subjects (DS - age 61,5±9 years and BMI 26,9±2,9 kg/m^2); 29 DS with PN ((DPNS - age 61.7±8,9 years and BMI 25,5±2,9 kg/m^2). A stereophotogrammetric system (BTS) synchronized with 2 force plates (Bertec) was used. Several self-selected speed gait trials were acquired and the following variables were extracted bilaterally [2]: 3D trunk, pelvis, hip, knee and ankle joint angles and moments, 3D ground reaction forces. Two clusters analysis were performed: 1) Euclidean separation (ES), where K-means cluster algorithm is applied with Euclidean distance and K-means++ as initialization step; 2) Spectral separation (SS) with extraction of the spectral components on a 100-point windows of each subject and then ES procedure on the spectral components. A code was implemented in C++ and the MLPACK and FFT3 libraries for clustering and spectral analysis were used respectively. Each subject was represented by 280 points: left and right values for each variable (for noise reduction without affecting the final cluster structure) were averaged; 28 trajectories of 100 points each were concatenated for creating the final one. Afterward T-Test ($p<0.05$) and Person Correlation were performed in order to compare the clinical characteristics of the subjects across the different clusters [2].

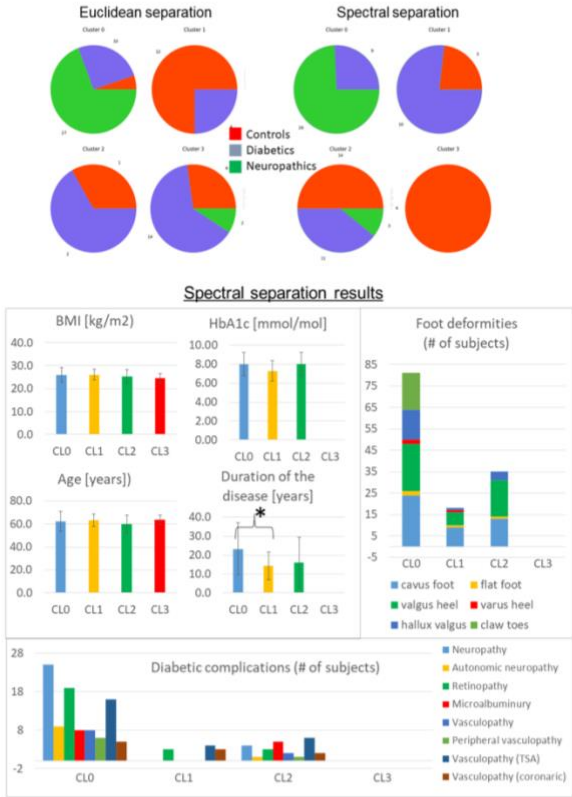

Figure 8: Subjects grouping in the 2 clustering methods (top) and results for the Spectral separation method (bottom).

RESULTS

Results are reported in figure 1. The SS worked better for the CS and the DPNS separation respectively in cluster 3 and 0. Here subjects with higher prevalence of diabetic complications and foot deformities where included. DS grouped in cluster 2 displayed gait patterns characteristics similar to DPNS.

DISCUSSION

An objective system for classification of gait patterns of this population could be used to develop targeted therapies, optimizing the intervention to individual patients, thus achieving greater success in treating patients.

REFERENCES

[1] Oliver TI, Mutluoglu M. *StatPearls* 2019.
[2] Z. Sawacha, et al. *J Diabetes Sci Technol*. 2010;4(5):1127-38.

http://doi.org/10.6092/unibo/amsacta/6260

CHANGES IN GAIT PARAMETERS AFTER A VIRTUAL REALITY PROTOCOL (V-TIME) IN PATIENTS WITH PARKINSON'S DISEASE.

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INTRODUCTION

Age-associated motor and cognitive deficits increase the risk of fall. A randomized control trial was designed and developed to assess the effectiveness of integrated training of treadmill and non-immersive virtual reality (V-time) for fall risk prevention in patients with Parkinson Disease (PD) [1]. The purpose of present study was to analyze changes induced by a V-Time training on PD subjects by estimating spatio-temporal parameters using magneto inertial units (MIMUs).

METHODS

Ninety-three patients with PD were enrolled in this sub-study. Participants demographic and clinical characteristics were (mean ± SD): age 73.42±6.75, Hoehn and Yahr stage 2,44±0,58, UPDRS motor part (III) 31,11± 13,86, disease duration 9.36± 6.31. Data were collected while a dual task condition (i.e. verbal fluency task) were performed. During each test three MIMU sensors were mounted just above left and right ankles and one on the first sacral vertebrae.

Spatio-temporal parameters were estimated based on a previously validated method, (TEADRIP -Trusted Events and Acceleration Direct and Reverse Integration along the direction of Progression) [2]. Main descriptive gait parameters for this population were selected as suggested by scientific evidence [3]. Data were analysed with a repeated-measure analysis of variance (RM- ANOVA) with TIME (Pre, Post) as within subject factors and TREATMENT (TT = treadmill, TT+VR =treadmill and virtual reality) as between subjects factors.

RESULTS

Statistical analysis showed significant TIME × TREATMENT interactions for: cadence ($P = .000$), gait speed ($P = .049$), stance time ($P = .010$), stride time ($P = .009$) and number of turn ($P = .012$). Post-hoc analyses (table 1) revealed that all parameters were improved after TT+VR treatment except for cadence that showed positive change after both TT and TT+VR training.

Table 1. Post-hoc results for participants assigned to TT and TT+VR training

	TT (p value)	**TT+VR** (p value)
Cadence (steps/min)	0.033	0.003
Gait Speed (m/sec)	0.651	0.001
Stance Time (sec)	0.398	0.004
Stride Time (sec)	0.392	0.004
Number of Turn in 1 minute	0.137	0.030
TT, Treadmill Training; TT+VR, Treadmill Training and Virtual Reality.		

DISCUSSION

In this sub-study DT gait performance was measured using data collected by MIMUs. Our results are in line with previous findings [3] supporting the efficacy of TT+VR treatment in improving DT gait performance in patients with PD. In addition, our results corroborate the ability of TEADRIP method to estimate gait parameter under dual task performance in PD patients. Future analysis will be focused on gait data collected under obstacle negotiation task with the aim to obtain and validate clearance data related to obstacle crossing phase.

REFERENCES

[1] Mirelman A. et al, *Lancet*, 2016 Vol 388 (issue 10050): 1170-1182.
[2] Bertoli, et al. *Biomed Eng Online* 2018 Vol 17 (1) :58.
[3] Mirelman et al. *Lancet*, 2019 doi:10.1016/S1474-4422(19)30044-4

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GAIT CONTROL IN RETT SYNDROME: AN EXPLORATIVE STUDY

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INTRODUCTION

Rett Syndrome (RS) is a rare developmental X-linked disorder affecting almost exclusively females characterized by regression of acquired development milestones after the second life year. Slightly less than half of the subjects with RS can maintain independent walking after regression [1]. Motricity in RS is affected by apraxia and ataxia which complicate the control of voluntary movements [2]. Detailed data on motor derangements and locomotion in RS remain poor. Gait in RS was reported as ataxic, but high variability of the observable pattern remains the norm [2]. During gait we frequently observed these subjects increasing the Lower Limb (LL) and trunk rigidity. We hypothesized that they increase body stiffness in order to reduce joints Degrees of Freedom (DoF) simplifying the body control.

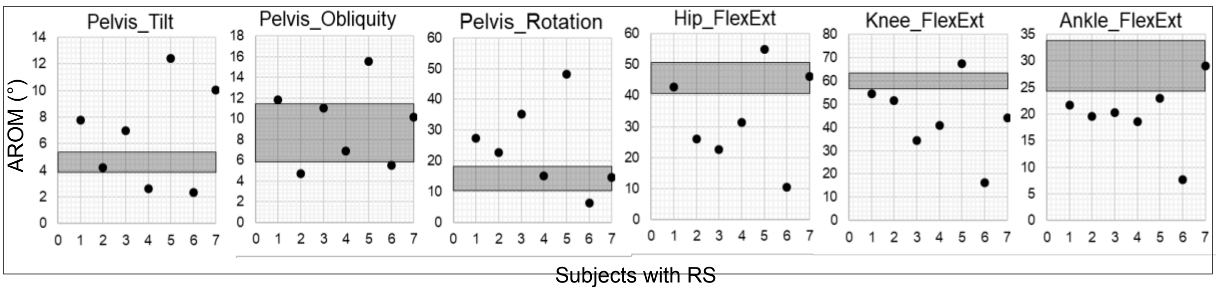
METHODS

Seven females (average age 14,7±1,7yo) with genetic confirmed RS and 15 age matched healthy subjects were evaluated through 3D gait analysis and Passive Range Of Motions (PROM). For each participant average of six strides were obtained. The full body Plug-in-Gait model was used. Active Range Of Motions (AROM) during walking were extracted for pelvis on all three planes and for LL major joints on sagittal plane. Comparison between individuals with RS and healthy subjects were carried out. PROM were measured manually for ankles, knees and hips on sagittal plane.

RESULTS

Two subjects with RS (n: 1 and 3) showed bilateral ankle dorsiflexion PROM limited to 0°. Participants' AROM data were showed in figure 1. Statistical differences were found between RS and healthy group in the knee and ankle AROM ($p=0{,}032$ and $p=0{,}001$ respectively). Four subjects with RS increase pelvic tilt and rotation AROM. Four participants with RS reduced hip AROM. Six subjects with RS reduced knee and ankle AROM. All but one subjects with RS increase pelvis AROM on sagittal or transversal planes. Reduction in at least two LL major joints AROM were found in five individuals with RS. One subject (n: 7) reduced AROM only at the knee. One subject (n: 5) increased the AROM of pelvis (all planes), hip and knee, but reduced movement excursion at the ankle. One subject (n: 6) reduced all evaluated AROM.

Figure 1. Graphic representation of the AROM of each subject with RS (dots) and healthy group's first standard deviation AROM (grey band).



DISCUSSION

As showed, subjects with RS seemed to reduce LL major joints AROM even in absence of musculoskeletal limitations. This AROM reduction is obvious at knee and ankle level (the joints mainly affected by secondary deformities in RS [3]). Considering the ataxia and apraxia of these subjects, these preliminary findings support the idea that individuals with RS increase the LL joints rigidity to reduce DoF in order to easily control body segments and perform gait. At the same time, they increase pelvis AROM on sagittal and transversal planes likely to allow anterior trunk and leg propulsion. This altered way of movements control could contribute to the development of musculoskeletal deformities and should be part of future investigations to better understand the motricity of this population.

REFERENCES

[1] Downs J, et al. *Disability and Rehabilitation* 2015;37(21):1992–1996.
[2] Fabio RA, et al. in: Adv. Genet. Res. Vol. 14, Nova Science Publisher, New York, 2017.
[3] Borst HE, et al. *Journal of developmental and physical disabilities* 2018;30(2):281–295.

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7-DAYS ACTIGRAPHY IN PATIENTS WITH PARKINSON DISEASE: A 2-YEARS FOLLOW-UP

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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. The aim of this study is to analyze the use of actigraphs (wearable sensors for long-term motor activity tracking [1]) for the evaluation of motor symptoms progression in PD patients.

METHODS

Twelve participants with Parkinson disease under pharmacological treatment and with preserved motor functions were recruited at Centro Medico Riabilita – Mano Amica Onlus (Schio, VI). Inclusion criteria were the absence of 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 participated to group activities including motor and logopedic rehabilitation as well as cognitive stimulation exercises. Participants were assessed at baseline and at 1-year and 2-year follow-ups. 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 were analysed according [2] producing time profiles of motor activity (MA). The average daily distribution of activity levels let to extract two indexes: 1) AD, duration of active behaviour; 2) AP: peak of motor activity, i.e. the activity threshold surpassed for one hour a day.

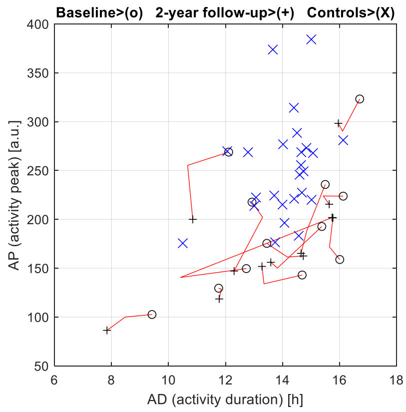

Fig. 3 - 2-year follow-ups (red lines) of patients' duration and peak of daily activities; controls (X)

RESULTS

The outcome of the three assessments for each patients are reported in figure 1 as a AD vs. AP scatterplot. Control data (X) were obtained from 25 age-matched healthy subjects.

DISCUSSION

The two indexes are intended to summarize and quantify two complementary aspects of daily activity: the time spent active, possibly related to endurance/fatigue, and a peak activity level, related to patient capacity. The results evidenced that such values are valuable tools in assessing the evolution of the functional status of a patient affected by a degenerative disease. The scatterplot shows that there are patients quite stable and other that show an evolution during the 2 years follow-up. In general a data point inside the cloud of control points implies a normal-like functional status, a drift of values towards the plot left bottom part marks a worsening. Interestingly a patient evidenced a worsening followed by a relevant improvement which was determined by a newly introduced drug treatment. While in general the actigraphic assessment complies with the clinical anamnestic patient figure, the detailed functional follow-up by quantitative actigraphy may evidence trends which let the medical staff to carry out earlier decision making.

REFERENCES

[1] Rabuffetti M., Meriggi P., Pagliari C., Bartolomeo P. *Physiol. Meas.* (2016); 37 1798-1812
[2] Rabuffetti M et al. Sensors. 2019;19(3)

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EMG ACTIVATION DURING WALKING IN PARKINSON'S DISEASE PATIENTS

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INTRODUCTION

In Parkinson's disease patients (PDP), over-ground walking performance has been related to motor symptoms, balance and mobility [1]. Gait dysfunctions in PDP are often associated with abnormal muscular activations [2], as demonstrated by the quantification of the rhythmicity and variability of the EMG pattern during gait in PDP in general and as associated to freezing in particular [3,4]. Variability of the muscle activation can be analyzed through the identification of the different activation patterns (in terms of number and timing within each stride per muscle) occurring over different strides during the same walking trial, allowing to discriminate pathological behaviors [6]. The aim of the study was to investigate the variability of muscle activation during over-ground walking in PDP.

METHODS

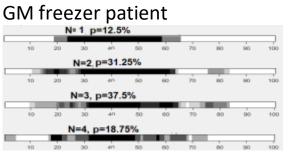
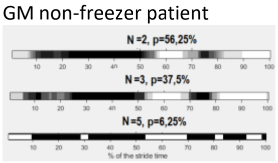
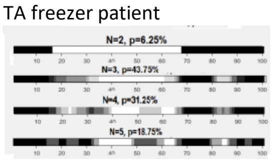
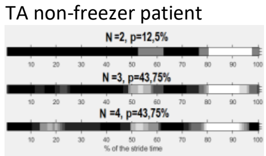
Twenty PDP with Hoehn-Yahr stage III (10 freezers and 10 non freezers; 12F,8M; 67.2±9.1y.o.; 1.65±0.12m; 67.3±13.1Kg) performed a 6-min walking test. EMG signals of tibialis anterior (TA) and gastrocnemius medialis (GM) were acquired using wireless electromyograph (Cometa, Italy, sf=2000Hz), following the SENIAM guidelines [5]. Walking tasks were filmed using a GoPro (Hero4, USA, sf=240Hz), and EMG led flashing used for synchronization. Gait events identified from videos were assumed as reference. EMG data were band-pass filtered at 20–100 Hz, full-wave rectified, filtered with a moving average window and then processed by a double threshold statistical detector to obtain muscle activation intervals [6 -7].

RESULTS

Preliminary results showed that GM presented from 1 to 5 activations for both freezers and non-freezers, while TA highlighted from 2 to 5/6 activations for freezers/non-freezers within the same subject (Table 1). Most of the patterns presented 1, 2, 3 (87.6%/84.3% of the total for freezers/non-freezers) activations for GM and 2, 3, 4 (90.7%/95.1% of the total for freezers/non-freezers) activations for TA.

Table 1. Percentages of occurrence of different N averaged across the patients and gray-scale images for two representative patients (one freezer and one non-freezer).

Muscle	N=1	N=2	N=3	N=4	N=5	N=6
GM (freezers/non-freezers)	9,4%/15,6%	18,8%/42,2%	59,4%/26.5%	9.4%/10.9%	3.1%/4.7%	0%/0%
TA (freezers/non-freezers)	0%/0%	6.3%/12.5%	53.2%/45.3	31.3%/37.3%	9.4%/3.1%	0%/1.6%

GM freezer patient	GM non-freezer patient	TA freezer patient	TA non-freezer patient
			

DISCUSSION

In accordance with what observed in healthy subjects [6], lower limb muscles highlighted different activation patterns within the gait cycles of the single PDP. Higher N=5/6 for TA activations was found in freezer with respect non-freezer PDP. Di Nardo et al. [6] demonstrated that a higher number of activations is associated to different strategies in the recruitment of motor units and reflected higher complexity of the movements. Thus, results of this study seem to explain the modifications in gait stability and movement competence of freezers PDP.

REFERENCES

[1] Oliveira de Carvalho A. K. et al., Clin Pract Epidemiol Ment Health. 2018; 14: 89–98.
[2] Bailey A. et al., Front Neurol. 2018; 9: 211.
[3] Thrasher TA. et al., Journal of Neurological Research And Therapy, 2016 (1): 4, 1-9.
[4] Nieuwboer A. et al., Brain, 2004, (127): 7, 1650–1660
[5] Rainoldi A et al., J Neurosci Methods 2004; 134:37–43.
[6] F. Di Nardo et al., Journal of Electromyography and Kinesiology, 2015; 25: 347–354
[7] Bonato P. et al., 1998 (45): 287-299

Sessione 7 – TECNOLOGIA E RIABILITAZIONE

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PLANAR ROBOTIC TRAINING *VERSUS* ARM-SPECIFIC PHYSIOTHERAPY: EFFECTS ON ARM FUNCTION AND MOTOR STRATEGIES IN POST-STROKE SUBJECTS

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INTRODUCTION

Robotic rehabilitation of post-stroke subjects has demonstrated to improve arm function and activities of daily living as assessed by clinical scales [1]. However, the effects of robot therapy on the motor strategies adopted to execute functional tasks are still under study [2,3]. In this pilot randomized controlled trial (RCT) we assessed the effects of a planar robotic training versus arm-specific physiotherapy on arm function, measured by clinical scales, and on motor strategies assessed with instrumental kinematic analysis.

METHODS

Thirty-eight ST subjects (age: 61 ± 14 years) were randomized to robot group (RG, N = 19) and control group (CG, N = 19). RG underwent a 20-session planar robotic training involving repeated reaching movements of targets presented on a screen, with the help of a minimally assistive force by the robot (Braccio di Ferro, Celin, Italy). CG received 20 sessions of usual care arm-specific physiotherapy. ST subjects were assessed pre and post-training with clinical scales and with kinematic analysis of an untrained virtual 3D task ("move-and-place" test) simulating the transport of an object onto a shelf. The task was executed using the virtual reality system VRRS (Khymeia Group, Italy), while arm and trunk kinematics were recorded using a 9-camera optoelectronic system (SMART-DX, BTS, Italy) and 9 markers. Data from ten healthy subjects (age: 60 ± 18 years) were included to provide reference values. Clinical outcomes included Fugl-Meyer Motor Assessment of Upper Extremity (FM-UE), modified Ashworth Scale (MAS) and Functional Independence Measure (FIM). Instrumental outcomes included maximum elbow extension, shoulder/elbow coordination index and trunk compensation index [4]. Post-training change scores were compared between RG and CG using ANCOVA with baseline scores as covariates.

RESULTS

Post-training change score in FM-UE was comparable between groups (RG: 7 ± 6 pts; CG: 6 ± 9 pts, p = 0.31), as well as that in FIM (RG: 9 ± 6 pts; CG: 9 ± 12 pts; p = 0.44) . In contrast, the reduction of MAS of proximal muscles (pectoralis major and biceps brachii) was larger in RG (RG: -1 ± 1 pts; CT: 0 ± 1 pts; p = 0.02). Instrumental data related to the "move-and-place" test revealed that shoulder/elbow coordination index improved significantly more in RG compared to CG (RG: 0.4 ± 0.6; CG: 0.04 ± 0.1, p = 0.02), as well as maximum elbow extension (RG: 26 ± 35 deg; CG: 6 ± 20 deg, p = 0.04) and trunk compensation index (RG: 4 ± 5 deg; CG: 0.7 ± 6 deg, p = 0.002).The sub-analysis on chronic subjects only (> 3 months post-stroke) confirmed these results and disclosed also, in RG compared to CG, a larger increase in the proximal portion of FM-UE (RG: 4 ± 5 pts; CG: 1 ± 3 pts, p = 0.02) and in FIM (RG: 8 ± 6 pts; CG: 4 ± 5 pts, p = 0.01).

DISCUSSION

Intensive and specific robot-assisted training, involving repeated movements of shoulder and elbow in the horizontal plane, was as effective as arm-specific physiotherapy in reducing arm impairment as measured by FM-UE in persons post-stroke. By contrast, it was more effective in reducing spasticity of arm proximal muscles and in improving the motor control strategies adopted to execute a non-trained functional tasks requiring vertical movements against gravity not performed during the training. Specifically, the proposed robot therapy provided larger improvements of shoulder/elbow coordination and a greater reduction of abnormal trunk movements. Interestingly, the results of the present pilot study suggested that robot-assisted rehabilitation were particularly beneficial for chronic post-stroke subjects. Larger RCTs including more subjects should be performed to confirm the present findings

REFERENCES

[1] Mehrholz J, et al. *Cochrane Database Syst Rev* 2018; 9: CD006876.
[2] Aprile I, et al. *Biomed Res Int* 2014; 2014: 636123.
[3] Alt Murphy M, et al. *Neurorehabil Neural Repair* 2011; 25(1):71-80.
[4] Carpinella I, et al. *Gait Posture* 2016; 49 (Suppl. 1): S23-S24.

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INVESTIGATING THE EFFECT OF A PASSIVE EXOSKELETON ON THE ACTIVITY OF LOW BACK MUSCLES DURING DIFFERENT PHASES OF REPETITIVE DYNAMIC TASK.

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INTRODUCTION

Passive exoskeletons are a promising solution to attenuate the excessive lumbar muscles' effort during working conditions with implications on the prevention of musculoskeletal disorders [1]. Whether, however, a passive exoskeleton affects lumbar muscle's activity similarly in different instants of lifting and lowering phases during the repetitive task is still an open question we addressed here.

METHODS

Ten male volunteers performed a dynamic task, where they lifted and lowered a box at a fixed cadence (4s for lifting/lowering) for 10 minutes, with and without a passive exoskeleton (Laevo 2.5). Monopolar surface electromyograms (EMGs) from the lumbar erector spinae muscles were sampled bilaterally with 16x4 grid of electrodes (inter-electrode distance: 10 mm) and the right, hip and knee angles were measured with an electrogoniometer. EMGs and joint angles were segmented in lifting/lowering phases. The Root Mean Square (RMS) values were computed from single-differential EMGs on epochs of 500ms corresponding to the following hip angles: 20%, 50% and 80% of the maximum hip flexion. For each hip angle, one average RMS map was calculated for the first, middle and last minute of the task. A global index of activity was defined by averaging channels showing an RMS value greater than the 70% of the maximal RMS (Figure 1A). A 3-way ANOVA was applied to assess the effect of Exoskeleton (Exo), Time, and Side on the degree of activity (*post-hoc* Newman-Keuls and significance level of 5%).

RESULTS

Our main results revealed a trend towards lower level of lumbar muscles' activity (~15%) with than without exoskeleton during the dynamic task. For lifting phase, no significant attenuation effect of Exo on muscle activity was observed (Figure 1B) while for lowering phase, ANOVA revealed an interaction effect (F=5.86; P<0.05) between time and Exo at 80% of hip flexion and an Exo effect (P<0.05) at 50% of hip flexion (Figure 1C).

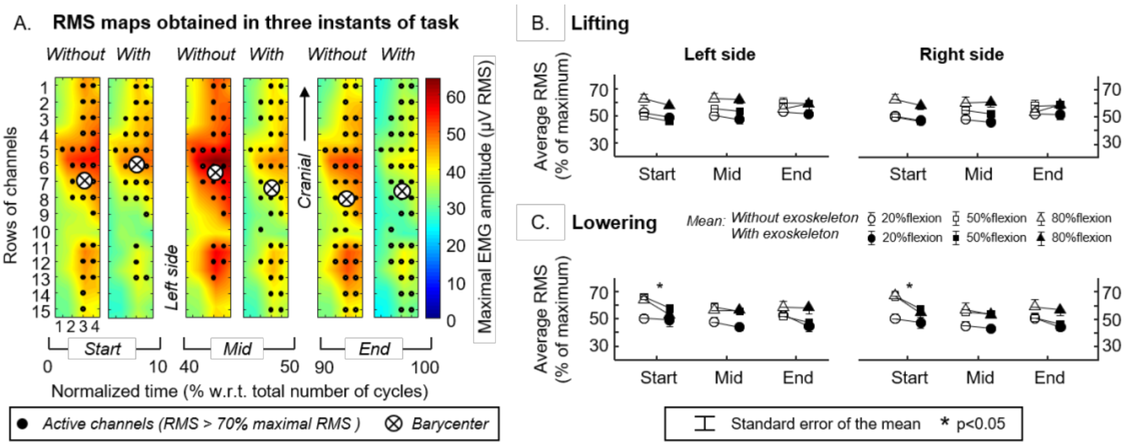

Figure 1. (A) RMS maps at different instants of task (50% of hip flexion) without and with exoskeleton for a representative subject. Mean (±SE) of the RMS values estimated during the lifting (B) and lowering phases (C).

DISCUSSION

The attenuation effect of passive exoskeleton on lumbar activity seems to be time and phase-dependent. A significant exoskeleton effect on muscle activity was revealed at the start of task during lowering phase and at specific periods of workload (Figure 1C). These findings may have implications on the development of passive exoskeleton for industrial applications, focusing on adaptations to reduce low back loading at specific phases (lifting) and workload periods during the dynamic task.

REFERENCES

[1] Bosch T, et al. *Appl. Ergon.* 2016;54:212-217.

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EFFICACY OF UPPER LIMB ROBOT-ASSISTED THERAPY COMPARED WITH CONVENTIONAL THERAPY IN STROKE PATIENTS: PRELIMINARY RESULTS ON A DAILY TASK ASSESSED BY MEANS OF MOTION ANALYSIS.

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INTRODUCTION

In the past years, there has been an increasing focus on Robot - Mediated Therapy (RMT), especially for the upper limb (UL), in the rehabilitation of patients after neurological disease [1]. Several studies have been conducted to evaluate the efficacy of RMT, compared with conventional therapy (CT); however, it is still difficult to assess to what extent its adoption improves the efficacy of traditional therapy in daily life. Therefore, the aim of the study is to assess the effects of robot-assisted therapy of the upper limb in stroke patients, compared with conventional therapy, on patients' performance in a daily task, namely drinking from a glass, using motion analysis.

METHODS

In this study, we enrolled 16 subacute stroke patients (mean age 65±9 years, mean time since stroke 120±60 days), randomized either to RMT (using a set of 4 devices [2]) or CT. In both groups, the treatment was performed daily for 45 minutes, 5 days a week, for 30 sessions. This is a secondary analysis of a wider multicenter, randomized, controlled trial involving 247 stroke patients registered at ClinicalTrials.gov (NCT02879279). The evaluation of the task (reaching and drinking from a glass) was performed using a motion analysis system (SMART D-500, BTS), adopting a protocol previously reported [3]. Motion analysis indices were (a) the ROM of the elbow, shoulder and trunk; (b) the hand mean speed and smoothness (assessed by the Normalized Jerk, NJ); and (c) the specific contribution, expressed in percentage, of the total hand displacement while reaching (arm elongation, trunk forward inclination and trunk axial rotation). UL motor function was clinically assessed with the Fugl-Meyer Assessment for Upper Extremity (UE), while disability was investigated with the Barthel Index. Clinical and motion analysis evaluations were performed before (T0) and after the treatment (T1). To compare the effects of the two treatments, we performed a 2x2 (*timeXgroup*) Mixed Anova test.

RESULTS

In these preliminary results, only the first phase of the investigated movement (i.e., the reaching phase) was analyzed. Considering the motion analysis data, after 30 rehabilitation sessions we found a significant effect of time in the NJ ($p<0.05$, see Figure 1), meaning an improvement of the smoothness after the rehabilitation, without differences between the two groups. With respect to the other investigated parameters, we did not find neither effect of time, nor significant interaction factors (all p higher than 0.05). Finally, both groups improved significantly in motor function and disability, without differences between the two groups, as measured by the clinical scales ($p<0.001$, see Figure 1).

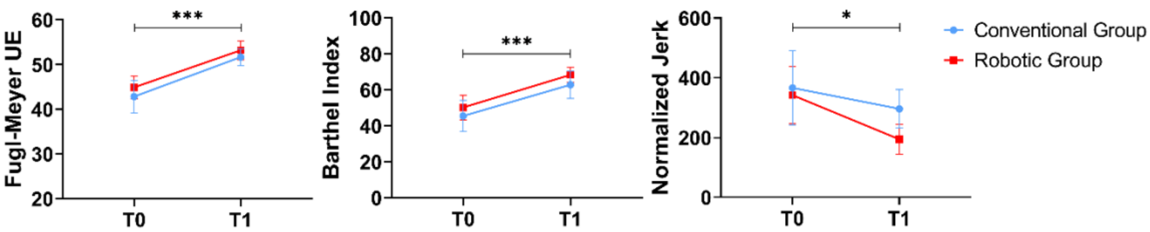

Figure 1. Changes of the Fugl-Meyer, the Barthel Index and the Normalized Jerk during reaching.

DISCUSSION

These preliminary results suggest that the effects of the two treatments were similar, both on clinical scales and on motion analysis parameters. With respect to the latter, they seem to suggest that after a 30-session rehabilitation, patients with stroke firstly reduce their jerky movements, while their joint ROM, and the relative contribution of specific anatomical subparts to the whole body movement strategy do not change. It is likely that more than 30 sessions are needed to observe changes in these motor aspects.

REFERENCES

[1] Mehrholz J, et al. *Cochrane Database Syst Rev* 2018;3(9):CD006876
[2] Jakob I, et al. *PM&R* 2018 10(9S2): S189-S197
[3] Aprile I, et al. *Biomed Res Int*. 2014:636123.

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DOES VIRTUAL REALITY REHABILITATION INFLUENCE POSTURAL CONTROL AFTER TOTAL KNEE REPLACEMENT?

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INTRODUCTION

Knee osteoarthritis patients lead to balance deficits and increased Centre Of Pressure (COP) variation, even after Total Knee Replacement (TKR) [1]. A study on Virtual Reality Rehabilitation (VRR) showed its efficacy in improving motor skills, compared to traditional therapy [2], but no evidence is available on postural sway. This pilot study aims to assess the effects of VRR on postural control in TKR patients.

METHODS

20 subjects were enrolled within 10 days after unilateral TKR and conducted 15 sessions (5 times/week; 45 minutes) of postural control and proprioceptive exercises, depending on the group assignment: 10 subjects (70.8±4.02 y.o.) conventional therapy - Control Group (CG); 10 subjects (68.5±9.37 y.o.) VRR standing on a balance board and receiving a real-time visual bio-feedback in serious video games with VRRS (Khymeia s.r.l., IT) - Virtual Realty Group (VRG). Clinical and computerised posturography (open eyes – OE; closed eyes – CE; Kistler force platform; 30 s; 100 Hz), assessments were performed at baseline (T1) and at the end of rehabilitation (T2). Wilcoxon's test was used ($p<0.05$).

RESULTS

Table 1 shows the results. All clinical tests registered statistically significant pre-post improvements. Between-group differences were found in TUG only. The COP measures shows significant pre-post variations of AP range OE and COP area OE in VRG only. Between-group variations were found in AP range OE, COP length OE, Mean V_{COP} OE. No significant differences were found in CE condition.

Table 1. Clinical assessment and COP measures at T1 and T2 in both groups

		CG					VRG				
		T1		T2		p-value	T1		T2		p-value
		mean	std	mean	std		mean	std	mean	std	
Clinical tests	10mwt (s)	19.1	5.5	10.7	3.8	0.003	16.2	3.7	8.9	2.0	0.001
	TUG (s)	20.9	5.2	14.4	5.6	0.009*	24.8	5.7	11.6	2.4	0.0002*
	MRC QF	3.3	0.7	4.4	0.5	0.003	3.4	0.4	4.4	0.3	0.0004
	MRC TA	3.7	0.5	4.7	0.4	0.001	3.8	0.5	4.6	0.4	0.002
	VAS	6.4	1.4	4.2	1.9	0.01	5.2	1.6	2.6	2.0	0.007
COP measures	ML range OE (mm)	5.4	2.7	4.7	1.7	0.79	6.5	5.1	4.4	2.6	0.34
	AP range OE (mm)	18.9	9.1	19.3	5.9	0.48*	28.7	13.9	16.2	6.4	0.04*
	ML range CE (mm)	5.4	3.2	4.7	3.7	0.52	7.1	4.6	5.6	4.7	0.38
	AP range CE (mm)	19.5	6.8	26.3	16.3	0.31	28.2	11.0	24.8	12.7	0.73
	COP length OE (mm)	263.9	101.6	290.7	156.6	0.79*	331.9	131.0	244.0	65.7	0.14*
	COP length CE (mm)	337.9	162.9	332.0	153.5	0.91	408.4	126.3	372.6	151.1	0.62
	Mean V_{COP} OE (mm/s)	8.8	3.4	9.7	5.2	0.79*	11.1	4.4	8.2	2.2	0.14*
	Mean V_{COP} CE (mm/s)	11.3	5.5	11.1	5.1	0.91	13.7	4.2	12.5	5.1	0.62
	COP area OE (mm^2)	88.7	38.4	85.6	55.1	0.57	174.2	119.4	85.1	30.8	0.04
	COP area CE (mm^2)	102.5	47.4	128.3	116.8	0.97	177.6	76.3	125.5	50.7	0.14

10mwt: 10 metres walking test; TUG: Timed Up and Go test; MRC: Medical Research Council scale Quadriceps Femoris (QF) Tibialis Anterior (TA); VAS: Visual Analog Scale; ML: Medial-Lateral; AP: Anterior-Posterior; V_{COP}: COP velocity; bold: significant pre-post variation; *: significant inter-group difference by comparing the percentage increase of each outcome.

DISCUSSION

Results suggested that VRR improves clinical outcomes, similarly to conventional therapy. The performance of the Timed Up and Go test is different between groups, in favour of VRG. The computerised posturography revealed significant inter-group differences in a subset of COP measures and suggests further analysis of COP signal and the recruitment of additional subjects.

REFERENCES

[1] Clark RA, et al. Osteoarthritis and cartilage, 2017;25.1:42-45.
[2] Pournajaf S, et al. Gait and Posture, 2017;57(3):17-18.

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EFFICACY OF END-EFFECTOR ROBOT-ASSISTED GAIT TRAINING COMBINED WITH ROBOTIC BALANCE TRAINING IN SUB-ACUTE STROKE PATIENTS: PRELIMINARY RESULTS

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INTRODUCTION

Over the last years, the introduction of robotic technologies in gait rehabilitation of stroke patients has aroused great interest. Some studies have been conducted to evaluate the effects of robot-assisted training compared to conventional gait rehabilitation in patients with subacute stroke. The main results were obtained using robotic exoskeletons or a treadmill training with partial body weight support and only a few studies used an end-effector device [1]. Our preliminary studies have shown that End-Effector Robot-Assisted Gait Training has produced promising effects on motor and functional outcomes in chronic and subacute strokes patients comparing with conventional treatment [2,3]. Considering this, we believe that a combined robotic treatment (gait plus balance) could produce more effects than just one robotic gait training. The aim of this study is to evaluate the efficacy of a combined gait and balance robotic rehabilitation compared robotic gait training alone.

METHODS

We enrolled 24 sub-acute stroke patients (within six months from onset). They were randomized into 2 groups: gait group (GG) and robotic gait plus balance group (GHG). 15 patients received robotic gait training using an end-effector system machines (G-EO system device); 12 patients received a combined robotic treatment program with the same end-effector robotic system and a robotic proprioceptive platform (Hunova). The rehabilitation program of both groups was combined with traditional physiotherapy. The clinical evaluation included: Ambulation Index (AI), Motricity Index (MI), Walking Handicap Scale (WHS), Berg Balance Scale (BBS), Tinetti Balance Scale, Numerical Rating Scale (NRS), ID Pain, Functional Ambulation Classification (FAC), 10 Meter Walk Test (10MWT), Timed Up & Go Test (TCT), 6 Minute Walk Test (6MWT), Modified Ashworth Scale (MAS), Barthel Index (BI). Gait analysis was performed by the SMART-D500 optoelectronic system using Davis protocol and all spatio-temporal parameters were calculated. The balance evaluation was performed by Hunova platform, in standing and sitting positions during static and dynamic conditions and all stabilometric parameters were collected. 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 significant changes in most of the clinical scales in both groups. GG showed a statistically improvement in the following scales: Hip MAS (p=0.038), BBS (p= 0.017), WHS (p=0.023), BI (p=0.018), NRS (p=0.041), AI (p=0.042). While GHG showed statistically differences in: Total MAS (p=0.042), BBS (p=0.041), MI (p=0.028), TUG (p=0.043), TCT (p=0.016), FAC (p=0.034), AI (p=0.024). With regard to the between-group analysis, the change from baseline was higher in the GHG than in the GG only in TUG (p=0.043). Regarding the stabilometric evaluation, the within-group analysis revealed statistically significant differences only in the GHG, just in sitting position with open eyes (OE): in static conditions, Area OE (p = 0.013) and A-P oscillations of the Center of Pressure (COP) with OE (p = 0.006); in dynamic conditions, M-L oscillations of the trunk with OE (p = 0.028). In standing condition, we did not found any difference. As regards the between-group analysis, in sitting position during static conditions the change from baseline was greater in GHG compared to GG in COP with OE (p = 0.010) and in the ellipse axes ratio with OE (p = 0.029); in standing position during static conditions, the change was greater at closed eyes (CE) in the A-P average speed (p = 0.029) and in the COP path (p = 0.029). With regard to gait analysis, we found no difference either in the within-group analysis, or in the between-group analysis.

DISCUSSION

Preliminary results show a higher improvement in patients underwent to combined robotic gait training plus balance training than patients underwent robotic gait training alone in clinical evaluation (TUG score) and in static balance (in sitting and standing position). However, given the limited size of the subgroup able to walk, we have not found significant results in gait strategies.

REFERENCES

[1] Mehrholz J et al. *Cochrane Database of Systematic Reviews* 2017; 17; 8:CD002840.
[2] Aprile I, et al. *Neurorehabilitation* 2017;41(4):775-782.
[3] Aprile I, et al. *Neurorehabilitation* 2019 – Accepted.

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DECISION-MAKING FOR ROBOTIC GAIT REHABILITATION IN POST-ACUTE STROKE: A REAL-WORLD DATA ANALYSIS

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INTRODUCTION

In stroke rehabilitation, in particular in the post-acute phase when gait recovery is time dependent, the decision-making process for the most appropriate technology training is strategic to maximize the efficiency of walking recovery [1].
The technologies for gait training integrated with conventional therapy are an important support in the rehabilitation process to improve the ability to walk independently and walking speed [1,2].
Real-World Data (RWD) represents the past experience in terms of treatments received and evaluated patient outcomes. The RWD thus contains information relative to decisions made in clinical practice.
The aim of this work is to identify objective parameters from the RWD analysis that can be useful to guide the decision-making process of choosing the most suitable technology for a specific phase of walking recovery.

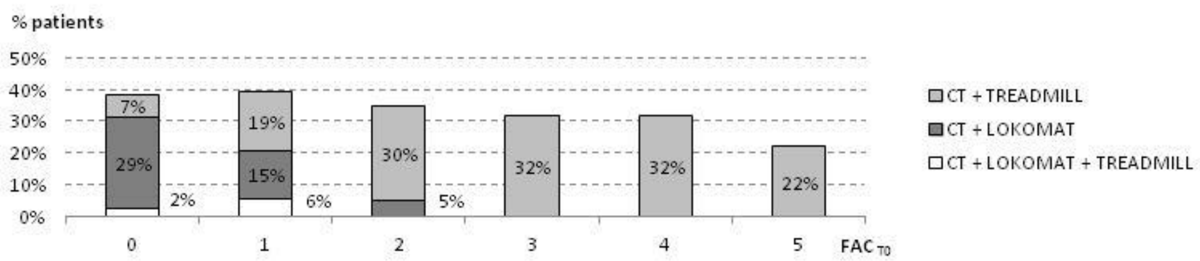
METHODS

A retrospective observational study of 273 post-acute stroke patients (< 6 months) 71±12 years old, consecutively hospitalized at Villa Rosa Rehabilitation Hospital of APSS in Trento from March 2016 to April 2019.
The available rehabilitation devices were the robotic system Lokomat® - Hocoma and the Body Weight Support Treadmill Gait Trainer™ 3 - Biodex.
The recommendation or contraindication to use these robotic technologies was decided by the physiatrist after clinical-functional assessment of the patient.
The evaluated rehabilitation parameters were the FAC (Functional Assessment Classification scale 0-5 score) and the 10MWT (10 Meter Walking Test) assessed at hospital admission (T0) [1,2].

RESULTS

32% of patients (89 of 273) had integrated conventional therapy (CT) with one or both of the available rehabilitation technologies (conventional and robotic therapy - CRT).
The CRT subgroup data analysis showed that for initial values of FAC ≤ 2 the patients were directed to the Lokomat and/or Gait Trainer™.
In particular for FAC = 2 the patients performed Lokomat training only or treadmill training only.
Instead, for initial values of FAC > 2 the patients were directed only to treadmill training.
For FAC = 2 (first cut-off) it resulted that the patients treated with treadmill training had walking average speed at T0 of 0.6 m / s (second cut-off). Instead for FAC > 2 the walking average speed at T0 was greater than 0.6 m / s, reaching 1.1 m / s for FAC = 5.

Figure 1: Rate of rehabilitative technology use for each value of FAC_{T0} at hospital admission.



DISCUSSION

The results show that the choice of the device was primarily based on the initial value of FAC, and secondly on the walking speed. The two cut-off values identified for the FAC and walking speed, allows the development of a decision-making process algorithm.
In clinical practice, the application of the algorithm could support the rehabilitation team in the choice of the more appropriate device for the specific phase of walking recovery [3].

REFERENCES

[1] Mehrholz J, et al. *Cochrane Database Syst Rev.* 2017; (5).
[2] Mehrholz J, et al. *Cochrane Database Syst Rev.* 2017; (8).
[3] Morone G, et al. *Neuropsychiatr Dis Treat.* 2017; (13): 1303-1311.

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A HOME-BASED TELE-REHABILITATION SYSTEM FOR STROKE PATIENTS EXPLOITING MAGNETO-INERTIAL MEASUREMENT UNITS

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INTRODUCTION

Post-stroke patients are required to follow a neurorehabilitation program in the hospital after the stroke event. Unfortunately, due to limitations in funds and facilities of the national health service, patients are discharged soon and can benefit of a limited number of outpatient rehabilitation sessions. Patients, who cannot afford clincal service fee can follow self-managed home rehabilitation protocols [1], typically affectred by lack of compliance [2][3]. These limitations impact on the treatment effectiveness and praise health equality issues. The aim of this work is to present the development of the first prototype of a complete home-based tele-rehabilitation system for stroke patients with moderate disability.

METHODS

The system includes 7 magneto-inertial measurement units (MIMUs), an Android device connected to a TV screen and a tele-health software framework. The adoption of the TV-based approach has already been proved to be effective on elderly patients with reduced computer literacy [4]. Raw data, recorded by each MIMU, are sent to the Android device and real-time processed to obtain different parameters such as joint angles, range of motion, execution time, and number of repetitions [5]. Such parameters are for real-time feedback and quantitative store-and-forward tele-monitoring, while raw data are remotely logged for off-line reanalysis. The tele-health system provides server and database features, enabling the remote data access by a web interface to patient, physiatrist and physiotherapist (Fig. 1a).

RESULTS

The system was functionally successfully tested on healthy subjects, for several upper limb movements. Figure 1b shows the experimental setup and a an example of quantitative visual feedback on the joint range of motion achieved by the subject during a elbow flexion-extension exercise.

Figure 1. a) The scheme of the entire system including both hardware and software components;
b) the experimental setup.

DISCUSSION

The system under development is part of the DoMoMEA project, which includes a cluster of 11 companies active in the technological and clinical market. The rehabilitation protocol in its final version will include a battery of exercixes for reproduce a complete rehabilitation protocol. User-centred design approaches are being implemented. The clinical trial with stroke patients will start by the end of 2019.

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REFERENCES

[1] Anderson C, et al. PHARMACOECONOMICS 2002; 20 (8): 537–552.
[2] Amirabdollahian F, et al. ASSIST TECHN RES SER 2001, 60–65.
[3] Nicholson S, et al. INT J STROKE 2012; (8), 357–364.
[4] Macis S, et al. IEEE Journal of Biomedical and Health Informatics 2019, 1-12.
[5] Cereatti A, et al. Handbook of human motion, Springer, 2017.

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SHORT-TERM IMMOBILIZATION REDUCES THE EXTENT OF THE SELF-PERCEIVED PERIPERSONAL SPACE: AN IMMERSIVE VIRTUAL REALITY STUDY.

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INTRODUCTION

Short-term arm immobilization and nonuse induce not only a reduction of motor cortex excitability and a deterioration of motor performances [1], but also deficits in motor-related perceptual processing, such as space encoding and categorization, which are fundamental for context-dependent action planning and, more in general, motor control. For instance, the extent of the peripersonal space (PPS), i.e. the body-centered region immediately surrounding our body and in which objects can be grasped and manipulated, is reduced by brief (10-24 hrs) arm immobilization periods in healthy people [2, 3]. To date, however, whether the PPS reduction derives mainly from an immediate effect of the arm restriction, or rather it accumulates over the immobilization period remains an open issue. The present study addressed this question, administering a Reachability Judgment Task (RJT) before and during a 1-hour immobilization time-window and taking advantage of immersive virtual reality (VR) technique.

METHODS

Sixteen healthy, right-handed volunteers (9 females, age 25.8±4.1 years) were recruited. They sat on a chair wearing a HTC Vive Pro head-mounted display (HMD), which presented experimental stimuli in an immersive VR environment. Participants performed a Reachability Judgment Task (RJT) [3], by assessing the extension of individual PPS. RJT stimuli consisted in a ball appearing in different positions (from 30 to 170 cm, with steps of 5 cm) on a 2x4 m virtual table. Participants had to quickly report via button push, whether the ball was reachable or not. RJT was performed at three time points: 1) at baseline (T0); 2) immediately after the application of a soft arm bandage to participants' arm and forearm, preventing any arm movement (T1); 3) after 1 hour of immobilization, before the removal of the bandage (T2). During the 1-hour immobilization, participants observed 3D virtual video clips showing landscape devoid of any biological motor content. The individual boundary of the reachable space was determined by fitting data with a logistic regression and calculating the point of subjective equality (PSE). Statistical analyses on PSE values were carried out through a repeated-measures ANOVA ($p<.05$) with Time (3 levels: T0, T1, T2) as within-subject factor and Tukey's post-hoc tests.

RESULTS

A significant TIME effect was found on the PSE values (mean±SD T0=98.11±16.1 cm, T1=88.7±19.5 cm, T2=90.04±20.7 cm; $F(2,30)=10.637$, Greenhouse and Geisser-corrected $p=0.001$). Post-hoc comparisons revealed that the PPS extent was significantly smaller at T1 and T2 relative to T0 ($p=0.006$, $p=0.003$, respectively), while no significance was found between T1 and T2 ($p=0.8$).

DISCUSSION

Our preliminary data show that a shrinkage of the PPS occurs immediately after arm immobilization and that this effect remains stable after 1 hour of immobilization. The perception of the action space plays a key role in the pre-movement phases of action control, providing body- and environment-related constraints, which ultimately may lead to the decision about to act. Hence, in clinical conditions leading to arm non-use (such as in neurological patients with damages to the motor cortex or orthopaedics patients with imposed limb immobilization), the baseline and follow-up evaluation of motor space perception could represent a useful neurophysiological index for the monitoring of motor system recovery during rehabilitative interventions.

These findings present practical implications, suggesting that: 1) the cognitive functions proper of the cortical motor system (here, the encoding of PPS) may provide clinical indicators in rehabilitative settings, even when real movements are impeded, and 2) starting rehabilitative interventions as early as possible could promote a wider and more complete recovery of motor and cognitive functions after cerebral or musculoskeletal damages, leading to arm nonuse.

REFERENCES

[1] Huber R, et al. *Nat Neurosci* 2006; 9:1169-1176.
[2] Bassolino M, et al. *Neuropsychologia* 2015; 70:385-392.
[3] Toussaint L, et al. *Psychol Res* 2018; Nov 12
[4] Randerath J, Frey SH. *Front Hum Neurosci* 2016; 9:674

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VIRTUAL REALITY TRAINING IMPROVES MOTOR OUTCOME IN ADOLESCENTS AFFECTED BY CEREBELLAR ATAXIA SECONDARY TO ACQUIRED BRAIN INJURY: A PILOT STUDY

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INTRODUCTION

Children affected by ataxia secondary to acquired brain injury exhibit significant ambulatory limitations induced by a reduced balance and coordinative control.

Novel strategies based on virtual reality may be of help to facilitate long term motor recovery through ecological, engaging and biofeedback-based training. Some preliminary results obtained with the Gait Real-time Analysis Interactive Lab (GRAIL) in a group of children affected by acquired brain injury have shown promising results but up to now this approach has never been used on ataxic children. The aim of the present work is to assess changes in locomotion and balance functions induced by a rehabilitation treatment with GRAIL in ataxic adolescents.

METHODS

Eleven ataxic adolescents (age 16(5) years - median(interquartile)) underwent 20 sessions of 45 minutes of training with GRAIL and 20 sessions of training with standard physiotherapy over one month. The therapeutic scheme was customized over the patients' need and was oriented to the recovery of balance ability and of a correct locomotion pattern.

Rehabilitation training exploited GRAIL features such as immersive VR, biofeedback and treadmill walking to obtain a personalized and motivating treatment. They were assessed before and after rehabilitation by the mean of scale for the assessment and rating of ataxia (SARA), gross motor function measure (GMFM), Berg Balance Scale (BBS), 6 minutes walking test (6MWT) and multiple step gait analysis.

The Gait Real-time Analysis Interactive Lab (GRAIL) is a device that integrates immersive VR with a sensorized treadmill and a motion capture system, that can be used for assessment and rehabilitation purposes. It's composed by an immersive semicircular screen where the virtual reality is projected and synchronized with an instrumented dual-belt treadmill, which integrates two force platforms. The GRAIL can also be used in evaluation mode. Indeed, it is equipped with 10 optoelectronic cameras and three video cameras that, together with the two force platforms, can be used to acquire spatial, temporal, kinematic and kinetic parameters of gait analysis in real time.

RESULTS

Results showed significant improvements of the 25% in ataxia level assessed by SARA, 5% in dimension D and 4% in dimension E of GMFM, 10% in walking endurance and 2% in balance abilities. Furthermore, some changes were also obtained at hip, knee and ankle levels in terms of kinetics (e.g. improvements of 44% of maximal power at ankle, $p=0.020$) and kinematics (e.g. improvements of 17% in step length $p=0.001$, and of 4% in maximal knee flexion $p=0.032$). Moreover, the gait variability significantly decreased, toward healthy references.

DISCUSSION

Data obtained after the VR treatment in terms of gait analysis showed improvements towards the pattern of typically developing children in terms of step length, gait speed, kinetic of the movement at ankle, and kinematic of knee, hip and pelvic joints. Some evidence of reduction of the variability among steps was also obtained, suggesting the achievement of a more regular gait pattern. Furthermore, a reduction of step width, even if not significant, was observed and the two patients that were affected by knee hyperextension showed improvements after VR treatment.

A training with immersive virtual reality together with standard physiotherapy seems a promising approach for ataxic gait rehabilitation, even in chronic conditions. Further studies should confirm these preliminary results with a randomized controlled study and an adequate sample size.

REFERENCES

[1] Biffi E et al. 2015 37th Annu Int Conf IEEE Eng Med Biol Soc. IEEE; 2015. p. 7406–9.
[2] Küper M et al. The Cerebellum. Springer-Verlag; 2013;12:48–58.
[3] Ilg W, Timmann D. Mov Disord. John Wiley & Sons, Ltd; 2013;28:1566–75.

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VIRTUAL REALITY IN VIRTUAL PATIENTS: EFFICACY OF VR ACTION OBSERVATION TREATMENT IN SPEEDING UP THE FUNCTIONAL RECOVERY OF THE SHOULDER JOINT

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INTRODUCTION

The Action Observation Treatment (AOT) exploits the well-known mirror mechanism [1] for rehabilitation by stimulating the motor system of a patient with motor impairments through the observation of an action, which facilitates his/her functional recovery [2]. The efficacy of AOT was largely demonstrated in patients with neurological diseases [3] and, recently, also in non-neurological patients such as orthopedic and trauma patients [2,4-5].
Virtual reality, largely used in innovative rehabilitative procedures, provides an immersive experience which could favor an enhancement of AOT induced effects. To test this hypothesis, we temporarily immobilized 22 healthy subjects, administering half of them with VR-AOT during the immobilization period. The kinematics of the upper limb was recorded during a standardized set of movements before and immediately after the immobilization, in order to evaluate a possibly faster functional recovery induced by VR-AOT.

METHODS

22 healthy adults (21.6 ± 2.7 years old) were enrolled in this study. Upper limb kinematics were simultaneously recorded with 3D-optoelectronic SMART system (BTS Bioengineering, Milano, Italy) and the Microsoft Kinect v2, embedded in the KHARE platform (INAIL). Four movements were requested to participants: (i) 90° shoulder flexion (low flexion); (ii) 90° shoulder abduction; (iii) 110° shoulder flexion (high flexion); (iv) dragging a target on the transversal plane. Each movement was repeated 10 times, for a total of 40 movements, both before (T0) and after (T1) the immobilization period (16 hours). During the immobilization period, aimed at creating a temporary impairment and thus a model of virtual patient, subjects performed 3 VR sessions with a 3D viewer (HTC Vive PRO). The VR-AOT group observed an avatar performing the same 4 movements from an egocentric perspective, while VR-CTRL group observed 4 landscape stimuli without any motor content. The Range of Motion (ROM) of the shoulder for each movement was calculated at both T0 and T1. In order to assess the rate of shoulder impairment/recovery, data at T1 were z-scored on T0. A quantitative comparison between the opto-electronic system and Kinect was conducted to evaluate the reliability of a low-cost and markerless solution for tracking the shoulder kinematic recovery.

RESULTS

As reported in **Error! Not a valid bookmark self-reference.**, the opto-electronic system indicated a marked decrease of the shoulder ROM at T1, compared to T0 for both experimental groups. Interestingly, while no difference emerged at trial 10, at trial 1 VR-AOT participants exhibited a more preserved shoulder kinematics with a z-score difference of about 1.5. Despite the greater variability, the KHARE platform results show a similar trend, suggesting the feasibility of tele-rehabilitative approaches for monitoring the progress of treatments conducted at home.

Table 2. Average z-scores of the trial 1 and trial 10 for VR-AOT and VR-CTRL, evaluated with data gathered from opto-electronic system and KHARE platform

	Opto-electronic system				**KHARE**			
	VR-AOT		**VR-CTRL**		**VR-AOT**		**VR-CTRL**	
	Trial 1	**Trial 10**	**Trial 1**	**Trial 10**	**Trial 1**	**Trial 10**	**Trial 1**	**Trial 10**
Low-Flex	-0.0 ± 0.7	-0.2 ± 0.5	-2.2 ± 1.8	0.1 ± 0.6	-0.4 ± 0.7	-0.8 ± 1.0	-1.5 ± 1.3	0.8 ± 0.9
Abduction	-2.3 ± 0.8	-1.2 ± 1.0	-3.3 ± 1.6	-0.8 ± 0.7	-2.5 ± 1.5	-3.2 ± 1.7	-2.2 ± 1.7	-1.4 ± 0.5
High-Flex	-0.7 ± 0.5	-0.1 ± 0.5	-3.1 ± 1.6	-0.4 ± 0.9	0.0 ± 0.5	-0.1 ± 0.4	-4.1 ± 4.3	-0.5 ± 0.9
Drag	-3.2 ± 0.6	-1.9 ± 0.7	-4.7 ± 1.7	-1.9 ± 0.8	-2.3 ± 1.4	-1.7 ± 1.3	-10.4±7.0	-4.7 ± 4.4

DISCUSSION

VR-AOT proved to be a promising tool for preserving the cortical excitability of the motor system even when movements are impeded, ultimately speeding up the functional recovery.

REFERENCES

[1] Rizzolatti, G., et al. Physiol. Rev. (2014); 94, 655–706.
[2] Bellelli, G., et al. Arch Phys Med Rehabil. 2010; 91(10):1489-94.
[3] Buccino, G., et al. Philos Trans R Soc Lond B Biol Sci. 2014; 369(1644):20130185.
[4] Park, SD., J et al. Exerc Rehabil. 2014; 10(3):168-71.
[5] Villafañe, JH., et al. Clin Rehabil. 2017; 31(3):361-368.

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FEASIBILITY STUDY OF A ROBOT-BASED TEST FOR MUSCLE FATIGUE ASSESSMENT ON SUBJECTS WITH DUCHENNE AND BECKER MUSCULAR DYSTROPHY

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INTRODUCTION

Subjects with neuromuscular disorders share one common symptom: early muscle fatigue. Despite its importance, conventional tests currently adopted for the assessment of motor functions in neuromuscular population, do not fully capture this crucial aspect of muscle fatigue.

Therefore, quantitative scales for the evaluation of muscle fatigue need to be added in patient management in order to provide useful information about disease progression. Recently, this need has become even stronger due to the flourish of new therapeutic strategies for neuromuscular disorders which require to report and validate their efficacy [1].

With this aim in mind, we developed a fast and simple test to evaluate muscle fatigue, exploiting the potentiality of robotic devices for protocol implementation and surface electromyography (sEMG) analysis for muscle fatigue evaluation. In fact, sEMG parameters have extensively proven to be a reliable measure of muscle fatigue [2] by means of information within the Mean or Median frequency and the RMS of the signal. These indicators are expected to decrease and increase respectively with the occurrence of muscle fatigue reflecting the shift of the PSD toward lower frequencies and the increase in synchronization of motor units.

This test has been previously validated on a healthy population and its repeatability has been already proven [3]. In the current work, we made the further step of testing the method on subjects with two different muscular dystrophies, to investigate the feasibility of its implementation in clinical practice.

METHODS

The experiment was carried out at the joint lab for Robotic Pediatric Rehabilitation between Istituto Italiano di Tecnologia and the G. Gaslini Institute (Genoa). Five children with Duchenne Muscular Dystrophy (DMD) (mean age 9 ± 1.58 years) and five affected by Becker Muscular Dystrophy (BMD) (mean age 19.2 ± 5.9 years) were enrolled in the study.

The test proposed was a simple reaching task consisting on flexion-extension wrist movements performed with a three degrees of freedom robotic device called WRISTBOT. Subjects were requested to flex and extend their dominant wrist, as many times as possible, until the perceived fatigue level was sustainable. sEMG signal from the right *flexor carpi radialis* muscle was recorded throughout the test. Mean frequency of the sEMG signals was calculated in order to obtain information about muscle fatigue and we proposed a new indicator to detect the Onset of Fatigue

RESULTS

As expected, all subjects showed a decreasing trend of the Mean Frequency, revealing the occurrence of muscle fatigue. The percentage of decrease of these curves showed a substantial level of decrement, higher than 15 %. Generally, BMD subjects showed longer resistance to fatigue than the ones with DMD, as proven by the lower number of movements performed by DMD subjects. Viceversa, the Onset of Fatigue, resulted to be comparable between the two neuromuscular populations with an average value of 9.4 ± 3 for the DMD group and 12 ± 1.7 for the BMD ones.

DISCUSSION

All patients correctly performed the test thus proving its feasibility and suitability for this pathological population. The Mean Frequency curves decreased and the Onset of Fatigue showed early fatigability as expected. Thanks to the use of a robotic task, the test guarantees the repeatability and reliability of results, therefore it can be repeated regularly to objectively monitor the progression of the disease and support clinicians with a quantitative assessment of the patient.

REFERENCES

[1] Mazzone, Elena S., et al. *Developmental Medicine & Child Neurology* 54.10 (2012): 879-885

[2] Cifrek, Mario, et al. *Clinical Biomechanics* 24.4 (2009): 327-340.

[3] Mugnosso, Maddalena, et al. *Journal of neuroengineering and rehabilitation* 15.1 (2018): 119

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REHABILITATION OF UPPER LIMB IN CHRONIC STROKE PATIENTS: PILOT STUDY OF FUNCTIONAL AND NEUROMOTOR OUTCOME OF A TASK ORIENTED APPROACH INCLUDING MECFES AND ROBOTIC TREATMENT.

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INTRODUCTION

Functional recovery of the upper plegic limb is fundamental for persons with chronic stroke for autonomy in daily activities. In this preliminary study we applied a combination of myoelectrically controlled functional electrical stimulation (MeCFES) and robotic therapy to facilitate motor recovery [1,2]. The effect on clinical parameters were studied relative to conventional arm treatment and electromyographic parameters of the plegic arm were studied in the experimental group relative to healthy subjects.

METHODS

Ten chronic stroke patients (age 65,5±23,1, onset 20±10,3 months) were consecutively allocated into two groups receiving 20 treatments of 45 minutes each. Patients belonging to the experimental group (M-RG) received a combined treatment of functional electric stimulation with MeCFES during task-oriented reaching movements and a planar robotic treatment, while those belonging to the control group (CG) received conventional therapy aimed at recovery of upper limb functions. Clinical scales for the upper limb: Fugl Meyer Upper Limbs (FM-UE, primary outcome), Action Research Arm Test (ARAT) and QuickDASH (QD) were applied pre and post intervention. M-RG patients and six healthy subjects (age 42,7±17,2) performed a reaching task (ARAT item a5) during which electromyography data from 6 upper limb muscles were collected. Ratio RMS between antagonist and agonist arm muscles was used to evaluate muscle co-activation. Non parametric and parametric tests were used for between group and within group comparisons. $P \leq 0.05$ was considered significant and $P \leq 0.10$ as a trend.

RESULTS

Following intervention, M-RG patients improved significantly more than the CG patients on FM-UE (p=0.03). Intragroup analysis showed an improvement on FM-UE and ARAT in M-RG patients (p=0.04-0.09) while the CG patients improved only on QD (p=0.01). At pre intervention, the ratio RMS of upper limb muscles was different in M-RG from HS in elbow and wrist (p=0.08 e 0.02) and became similar following intervention (p>0.10) (see Table 1).

Table 1. Outcome variables pre and post intervention of stroke groups and normative values of HS

	MR-G (N=5)		CG (N=5)		P	HS (N=6)	P
	Pre	Post	Pre	Post			
FM-UE	32 (17,7)	44,2 (9,6)*	35,2 (15,9)	36,4 (15,3)	**	N/A	
ARAT	32,8 (17,5)	35,2 (17,4)	24,2 (17,5)	25,4 (19,5)		N/A	
QuickDASH	59,1 (8,5)	56,8 (21,4)	50,1 (25,8)	39,1 (24,7)*		N/A	
Ratio RMS Deltoid Ant/Post	0,43 (0,14)	0,48 (0,41)	N/A	N/A		0,28 (0,08)	
Ratio RMS Triceps/Biceps	0,43 (0,19)	0,28 (0,13)*	N/A	N/A		0,25 (0,07)	
Ratio RMS Ext/Flex wrist	1,25 (1,24)	1,59 (0,85)*	N/A	N/A		2,59 (1,09)	***

*significant change intragroup from pre to post; **significant difference in change between stroke groups; ***significant difference at baseline between GM-R and HS but not following intervention.

DISCUSSION

These preliminary results indicate that combining MeCFES and robotic treatment is effective for recovery of motor abilities and coordination in the plegic upper limb in persons with chronic stroke, probably due to the mix of motor learning techniques. The improved muscular coactivation during a reaching movement may indicate a central neuromotor reorganization.

REFERENCES

[1] Jonsdottir J,et al. *PLoS One* 2017;4(12):12.
[2] Barker RN, et al. *Exp Brain Rtes* 2009;196(4):483-96.

http://doi.org/10.6092/unibo/amsacta/6260

TEN MONTHS FOLLOW-UP OF UPPER LIMB FUNCTIONAL RECOVERY THROUGH ROBOTIC REHABILITATION IN FIVE CP HEMIPLEGIC CHILDREN

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INTRODUCTION

In the last years, a growing interest has been given to the integration robotic treatments utility with specific exercise for the recovery of function after central nervous system damage. [1, 2]

Task-oriented training improve arm performance in stroke adult patients, some pilot studies defined the feasibility and interest in using robot assisting therapy in children with CP (Cerebral Palsy) and recognized how this effect could be confirmed in children.[3] The aim of this study is to investigate how an intensive rehabilitative training can improve the upper arm ability.

METHODS

We analyzed five hemiplegic children with cerebral palsy, mean age (9+ 3) years, 4 female and one male; three/right and two/left side affected. The three right side affected have been treated with botulinum toxin injection (TOX) at the beginning of the training. The assessment administrated at T0 (pre-training), T1 (post-training) and T2 (follow-up) were defined by robotic system evaluation tools.

The clinical evaluations test included dexterity skills, with Box Block and Nine Hole Page Test; unilateral functional ability, with Melbourne; bimanual competence, with AHA. The robotic training with InMotion2ARM took place for a duration of 20 sessions (5 sessions for week) of 45 minutes. Adaptive protocol of planar movements was administrated by robot. At the same time, personalized neuromotor training, was performed with the same intensity and frequency. Expert therapist administrated a training based: on unilateral and bimanual activities, on attention and meta-cognition stimulation. The data analysis was conducted on the whole population (TG), botulinum toxin injection (TOX) and no injection (NO TOX). We used a non-parametric statistic: Friedman test.

RESULTS

The TG group showed a significant reduction of reach error (P. Value=0, 05*), the movements were done with less velocity (P. Value=0,029*) and more smoothness (P. Value=0,079) (Fig.1) The two subgroups (TOX /NO TOX) showed no statically significant differences.

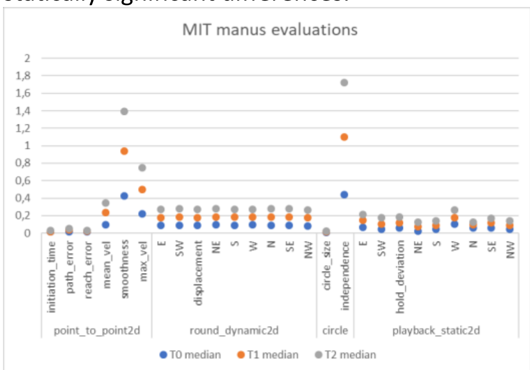

Fig. 1. Median evaluation in time
The figure showed the three-time T0, T1 and T2, median value modifications. Point to point, round dynamic; circle and playback static represent the different evaluation tools utilized by robot.

DISCUSSION

As expected, there was an improvement with an intensive upper arm training; meanwhile, the family referred us improvements in daily life autonomy at the follow-up time. This aspect could also be related to the neuro-cognitive evolution in children during 10 months of growing.

However, the robotic training produced an increasing in the activities of the hemiplegic upper arm. The main limits of the present work were the small group, the differences of the sample studied.

REFERENCES

[1] Marchal-Crespo L. and Reinkensmeyer D.J. *Journal of Neuroeng Rehabil*, 2009; 6-20
[2] Volpe B.T, et al. *Neurorehabil Neural Repair.* 2008, 22(3), 305-10.
[3] Fasoli S, et.al. J Phys Med Rehabil, 2008; 87; 929-936

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EFFECTS OF AN END-EFFECTOR ROBOT, A WEARABLE EXOSKELETON, AND CONVENTIONAL GAIT TRAINING ON CLINICAL OUTCOMES AND SPATIOTEMPORAL GAIT PARAMETERS IN STROKE SUBJECTS

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INTRODUCTION

Post-stroke Robot-Assisted Gait Training (RAGT) showed positive outcomes [1,2], but no evidence comparing different devices is available. We aim to study the effects of treadmill-based (t-RAGT) and overground (o-RAGT) RAGT, compared to conventional gait training (CGT) in stroke subjects.

METHODS

26 stroke subjects conducted 15 one-hour-sessions (3 times/week) of gait training, depending on the group assignment: 8 end-effector t-RAGT (Geo-System, Reha Technology, CH) – GG; 8 exoskeleton o-RAGT (Ekso™, Ekso Bionics, USA) – EG; 10 CGT – CG. Clinical assessment and gait analysis with motion capture (SMART-DX, BTS Bioengineering, IT) were performed at the beginning (T1) and at the end (T2) of the training period. A 3x2 repeated measures ANOVA ($p<0.05$) with post-hoc t-Student test was used to detect significant changes between and within group, respectively.

RESULTS

Significant pre-post variations within each group and no significant between-group difference were found in most of clinical assessments (Table 1). The spasticity (MAS-AL) showed significant pre-post variations and significant between-group differences (between CG and EG only). Even though the between-groups statistical significance was not achieved, the clinical significance was obtained in TUG, 10MWT, and 6MWT since the mean pre-post differences exceed the Minimal Clinical Important Difference [1]. The results of spatio-temporal gait parameters revealed no significant differences between and within the three groups for all gait outcomes (Table 1).

Table 1. Clinical assessment and spatiotemporal gait parameters at T1 and T2 in all groups

	GG (N=8)		EG (N=8)		CG (N=10)	
	T1	T2	T1	T2	T1	T2
mBI (0–100)	42 [11;69]*	81 [74;89]*	63.0 [29;8]*	83 [66;98]*	63 [21;88]*	82 [43;92]*
MI-LL (0–100)	54 [34;76]*	73 [39;76]*	59 [34;76]*	70 [49;100]*	64 [28;84]*	76 [33;100]*
MAS-LL (0-24)	1 [0;7]*^	0.50 [0;4]*^	2 [0;7]*^	1 [0;6]*^	0 [0;4]*^	0 [0;1]*^
TCT (0-100)	80 [36;100]*	100 [61;100]*	74 [61;100]*	100 [61;100]*	74 [61;100]*	100 [49;100]*
FAC (0-5)	2.50 [1;4]*	4 [2;5]*	2.50 [2;4]*	4 [2;5]*	3.50 [1;5]*	4 [3;5]*
WHS (1-6)	3.50 [1;5]*	4 [2;6]*	3 [1;4]*	4 [2;5]*	3 [1;6]*	4 [3;6]*
TUG - time (s)	28.3±17.7*	21.5±15.9*	35.2±17.9*	28.4±20.7*	26.4±14.8*	23.4±13.1*
10MWT - velocity (m/s)	0.6±0.4*	0.7±0.5*	0.4±0.2*	0.6±0.4*	0.6±0.2*	0.66±0.3*
6MWT - distance (m)	157.6±86.7*	222.3±122.4*	176.7±133.8*	227.5±210.8*	193.1±95.3*	210.7±89.5*
Cadence (step/min)	72.4±21.1	75.4±23.3	68.1±19.9	64.5±17.4	79.5±18.9	82.4±17.6
Gait Cycle - GC (s)	1.81±0.58	0.7±0.6	1.9±0.5	1.9±0.5	1.6±0.6	1.57±0.49
Stance time AL (% GC)	64.8±4.0	63.0±4.1	62.8±5.9	65.9±7.0	68.0±8.5	66.8±10.7
Stance time UL (% GC)	71.8±7.0	69.1±7.2	74.1±6.3	73.5±7.6	71.5±5.8	72.6±5.3
Swing time AL (% GC)	35.3±4.0	36.8±4.0	37.4±6.0	35.5±9.3	32.1±8.5	31.5±10.2
Swing time AL (% GC)	28.3±7.0	30.9±7.2	28.1±6.8	26.8±7.4	26.3±4.0	27.5±5.4
Step length (m)	3.93±0.78	4.1±0.9	3.4±1.7	3.5±1.4	3.2±1.1	3.1±1.2
Step width (m)	0.19±0.05	0.2±0.1	0.2±0.1	0.2±0.1	0.2±0.1	0.2±0.1
mBI (0–100)	42 [11;69]*	81 [74;89]*	63.0 [29;8]*	83 [66;98]*	63 [21;88]*	82 [43;92]*

mean±standard deviation; median [min;max]; modified Barthel Index (mBI); Motricity Index Affected Limb (MI-AL); Modified Ashworth Scale Affected Limb (MAS-AL); Trunk Control Test (TCT); Functional Ambulation Classification (FAC); Walking Handicap Scale (WHS); Time Up and Go test (TUG); 10-Meter Walking Test (10MWT); 6-Minute Walking Test (6MWT); Affected Limb (AL); Unaffected Limb (UL); *significant pre-post difference; ^significant between-group difference.

DISCUSSION

Results suggested that both t-RAGT and o-RAGT produce significant improvement in clinical outcomes, similarly to conventional therapy. The performance in executing locomotor tasks is clinically significant in the robotic groups only. The spatio-temporal gait parameters did not reveal any significant difference pave the way to a more detailed analysis of gait biomechanics and to larger multicentre studies.

REFERENCES

[1] Louie DR, et al. Journal of neuroengineering and rehabilitation, 2016;13(1):53.

[2] Goffredo M, et al. European journal of physical and rehabilitation medicine, 2019;02(4).

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POSTURAL BALANCING TRAINING USING THE INTELLIGENT MOTION-HIROB: CASE REPORT.

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INTRODUCTION

In literature is reported that the Horseback therapy can be a valid instrument for working on balance control which favors greater control of the upright position [1],[2],[3].

The objective of this study is to evaluate if the Hirob robot, that reproduce the movement of the horse with more possibilities to control the stimulus in relation to the patient, is able to work, safely on the same goals of the horseback therapy, in neurological paediatric patients.

METHODS

We analysed the case of one child (12 years old), affected by tetraplegia, cognitively adequate, with axial control difficulties and impaired vestibular perception. The child made the Hirob training that consisted on one session of therapies of 45 minutes for three consecutive weeks. The exercises done on the robot had as objective: to improve the postural balance and the control of the trunk in relation to the pelvis; to favor the functional integration between the two bodily hemilates; to consolidate the adaptive postural reactions [4],

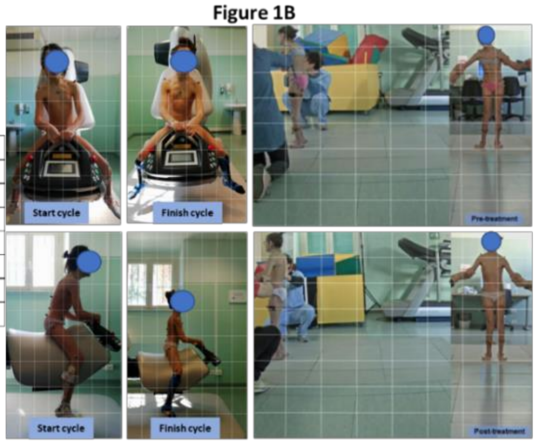
The evaluation tools used, before and after treatment, were: Static Analysis (BTS Smart-DX-1000, IT), Paediatric Balance Scale (PBS) and a video recording protocol.

RESULTS

The Static analysis showed significative changes (figure 1A). The PBS didn't show significative changes before and after the treatment cycle. At the video recording protocol was observed a better postural alignment in upright position and on the robot (Figure 1B).

Figure 1A	Pre-treatment			Post treatment		
STANDING ANGLE	Right	Left	Normal index	Right	Left	Normal index
Pelvic tilt	17.3±0.9	17.3±0.9	10±4	7.9±1.5	7.9±1.5	10±4
Pelvic rotation	-14.3±1.7	14.3±1.7	0±5	4.4±0.9	-4.4±0.9	0±5
Hip abd/adduction	4.5±0.8	5.9±1.7	0±3	0.8±1.3	4.1±1.7	0±3
Hip flex/ext	35.9±1.7	29±3.1	10±4	21.9±3	13.3±2.3	10±4
knee flex/ext	26.1±3.6	18.6±4.1	5±5	24.6±2.4	10.7±1.6	5±5
knee rotation	19.8±1	3.9±1.7	-10±5	6.6±1.3	9.1±0.8	-10±5

Figure 1B



DISCUSSION

The results found suggest that, the Hirob robot, can be a valid rehabilitation tool to work on postural balancing in accordance with the principles of horseback therapy. There are also different works that show how this type of therapeutic activity can support the reduction of muscular hypertonicity of some muscle groups in particular: adductors, ileopsoas, ischiocrural and triceps sural [5],[6].

The future perspectives are the increasing of the sample and the establishment of a control group that carries out a different approach with the same Hirob therapeutic objectives. Another possible future study can be based on the assessment about the muscle benefit.

REFERENCES

[1] Tim L. Shurtleff et al. Arch Phys Med Rehabil Vol 90, July 2009
[2] *Jeong-Yi Kwon et al.* Arch Phys Med Rehabil Vol 92, May 2011
[3] Martı´n-Valero R, et al. European Journal of Paediatric Neurology (2018)
[4] S.L. Pava˜o 1368 et al. Research in Developmental Disabilities 34 (2013) 1367–1375
[5] D. Lucena-Ant_on et al. Complementary Therapies in Clinical Practice 31 (2018) 188e192
[6] M.F. Ribeiro et 2 al. Journal of Bodywork & Movement Therapies xxx (2017) 1e9

http://doi.org/10.6092/unibo/amsacta/6260

THE OSTHEOPATHIC MANIPOLATIVE TREATMENT (OMT) IN THE MULTIDISCIPLINARY MANAGEMENT IN PAEDIATRIC PATIENTS WITH CEREBRAL PALSY: PRELIMINARY RESULTS.

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INTRODUCTION

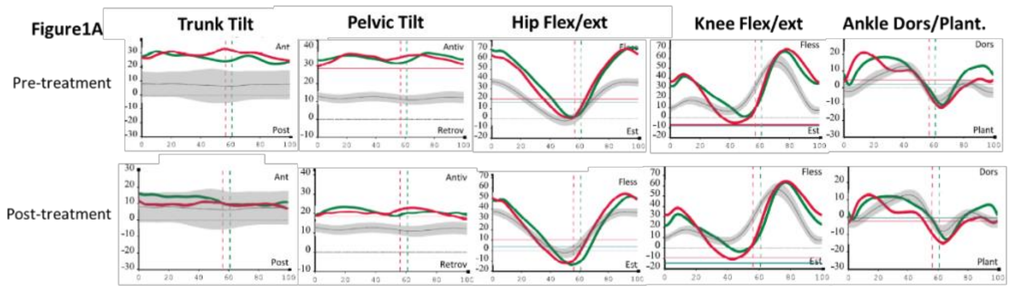
Until now, OMT didn't produce evidence of treatment efficacy in patients with cerebral palsy. There are different muscular-articular dysfunctions, typical of diplegic patients, which affect the neuro-motor development of children [1]. the objective of this study is to evaluate the impact, on patients care, of an integrated treatment based on physiotherapy and osteopathy, in promoting a biomechanical change.

METHODS

We analysed the case of two children (5 and 8 years old), affected by diplegia, cognitively adequate. The two children had the same neuro-motor treatment aimed at: walking exercises, postural balance and selective control of joint movement by promoting greater kinaesthetic representation of one's body. The control child performed neuro-motor treatment for seven consecutive days, two sessions a day; the study child performed one session of the same neuro-motor treatment and one OMT session aimed to promote the proper postural alignment and to correct the dysfunctions found that limited the patient's functionality through different osteopathic techniques such as those concerning osteoarticular, myofascial release and muscle energy [2]. The evaluation tool used, before and after treatment, was Gait Analysis (BTS Smart-DX-1000, IT).

RESULTS

The Gait analysis of the control child didn't show changes in kinematic and dynamic analysis; on spatio-temporal parameters we observed: a reduction of double support (14,05±0,79 – 11,31±1,34) with an increase of single support (35,54±2,35 – 38,52±1,35), of step length (0,53±0,03 – 0,63±0,02) and step velocity (0,5±0 – 0,7±0). The Gait analysis of the study child showed significative changes in kinematic and dynamic analysis observable on figure 1A; on spatio-temporal parameters we observed a reduction of the double support (9,91±1,50 – 8,84±0,99) and step length (0,91±0,06 – 0,88±0,02). On the study child we also performed X vertebral ray which showed significant changes in the structure of cervical and lumbar lordosis such as pelvic alignment (figure 1B).



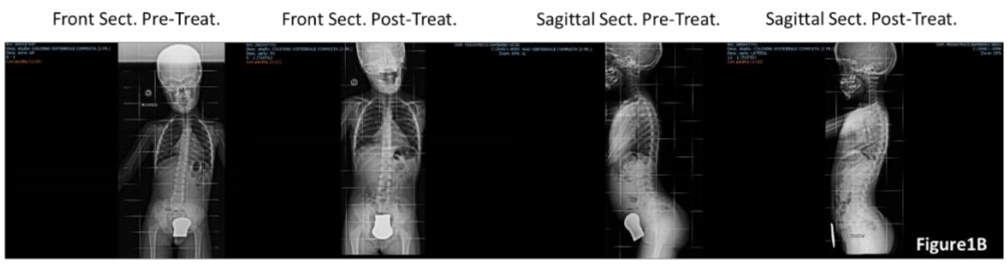


***Figure1A: we observed to trunk tilt and Hip flex/ext that were part of the normal trend; an important reduction of pelvic tilt, a reduction of knee cushioning curve and of the first ankle rotation.**

DISCUSSION

The results found suggest that an integrated work can predispose patients to a new window of neuro-motor learning through a structural biomechanical change that influences the motor function of walking. the future prospects are to increase the number of patients analysing and to verify if the biomechanical change lasts over time.

REFERENCES

[1] Mariorie H.Woollacott et al., Neural plasticity vol. 12, NO. 2-3, 2005

[2] Melinda F. Davis et al., JAOA • Vol 107 • No 6 • June 2007

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THE NEUROREHABILITATION DEVICE EQUISTASI® CAN INDUCE CHANGES IN PARKINSON'S DISEASE PATIENTS' ANKLE JOINTS KINEMATICS AND KINETICS

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INTRODUCTION

Gait alterations (rigidity, postural instability and camptocormic posture [1]) are among the most invalidating symptoms in Parkinson's Disease (PD) [2]. The aim of this study was to investigate the effects of Equistasi®, a wearable device based on focal mechanical vibration which stimulate proprioception.

METHODS

Twenty five patients participated in a randomized double-blind study. Out of them 21 completed the study (age 64±11 years, BMI 26.2±3.3 kg/m²). At T0, all subjects randomly received 3 active or 3 placebo devices applied in correspondence of C7 and of the gastrocnemius, bilaterally [3]. After 8 weeks of treatment, a washout month was taken before subjects received the other device and underwent other 8 weeks of treatment. The subjects were assessed walking barefoot at their preferred walking speed at the BioMovLab (University of Padova) before and after the first 8 weeks (T0-T1), and before and after the following 8 ones (T2-T3). Gait analysis was performed with 6 cameras stereophotogrammetric system (BTS) synchronized with 2 force plate (Bertec). The kinematic protocol reported in [3] was adopted and 3D joint angles and moments, ground reaction forces together with space-time parameters were estimated. PD data were compared with a sample of healthy subjects (age 50±2.9 years, BMI 24±2.8 kg/m²). Statistical analysis was performed using Student's paired T-test or non-parametric Kruskal-Wallis test ($p<0.05$): comparisons between respectively pre and post Equistasi treatment, pre and post Placebo and controls were performed.

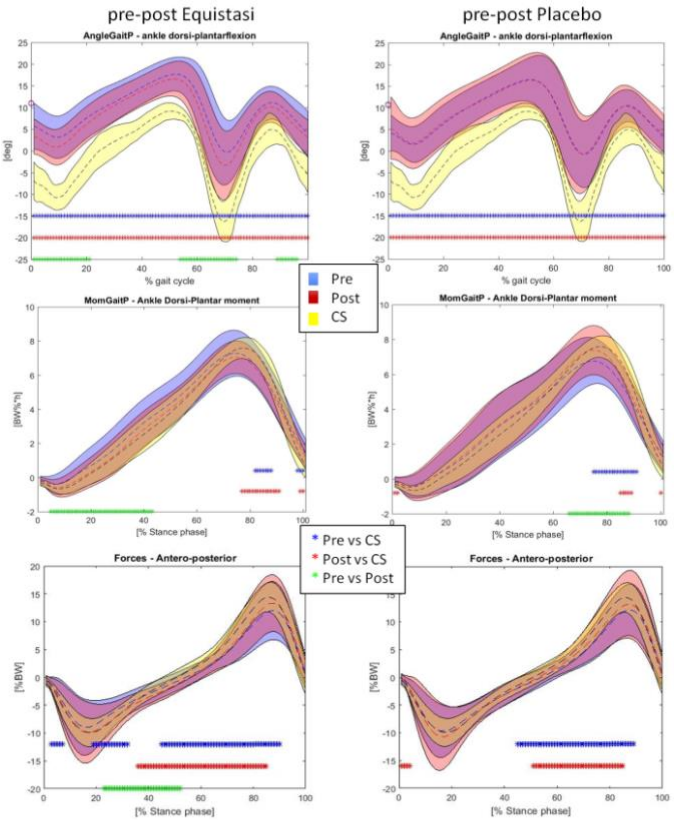

Figure 1. Angles, forces and moments in ankle dorsi-plantarflexion. Colored bands represent the mean value ± 1 SD. * means a significative difference

RESULTS

The most relevant results were reported in Figure 1. The ankle joint displayed the major changes induced by the Equistasi treatment, in particular on the dorsi-plantarflexion angle.

DISCUSSION

Results suggest that Equistasi leads to changes in the dynamic of gait in PD patients. The stimulation applied by the Equistasi device on the gastrocnemius could be associated to the changes observed at both ankle joint angles and moments.

REFERENCES

[1] Carpinella I, et al, *Trans Neural Syst Rehabil Eng* 2007; 15(4):543-5.
[2] Cova I, et al, *Parkinsonism Relat Disord.* 2010; 34:38-42.
[3] Volpe D, et al, *PLoS One.* 2014; 17;9(11):e112065.
[4] Sawacha et al, *Clin Biomech*. 2009*; 24(9):722-8.*

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ELECTROMYOGRAPHY GUIDED - TREATMENT WITH BOTULINUM TOXIN OF HEAD DROP IN PARKINSON'S DISEASE

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INTRODUCTION

Head drop results from weakness of the neck extensor [1], or increased tone of the flexor muscles [2]. A reconciling hypothesis combines both mechanisms, postulating anterocollis to be a consequence of axial rigidity of the flexor muscles, which may lead to under-use and weakness of the erector spinal muscles. 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

23 patients (11 females and 12 males; the average age was 69 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 (SCM), splenius capitis (SPC), trapezius, cervical paravertebral (CP) and needle EMG signals from longus colli, anterior scalenus, semispinalis capitis, 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. Under EMG and ultrasound-guidance, we injected botulinum toxin (Dysport) into the dystonic muscles using 20 U per muscle. In addition the patients underwent a rehabilitation programme consisting of individual 90-minute daily sessions, 5 days a week for 4 weeks.

RESULTS

We identified three EMG distinct patterns within the patient group (Fig. 1): 1) the overactivity in the neck flexor with potential of more than 100 µVolts/sec. for more than 500 msec at rest and during movements; 2) coexistence of focal neck extensor myopathic potentials and neck flexor abnormal tonic hyperactivity;

3) generalized myopathic changes with short duration, rapidly recruited motor units, plus fibrillation potentials, in absence of neck flexor dystonic patterns. 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. After the treatment, the score of Tsui showed a mean significant improvement of 8 points. Significant decrease of X-ray degree of cervical kyphosis (34.2° $\pm$ 5.6° vs. 46.1° $\pm$ 9.7°) was observed. Dynamic electromyography: reduction of abnormal tonic hyperactivity of the inoculated muscles, associated with an increase in cervical spine strength.

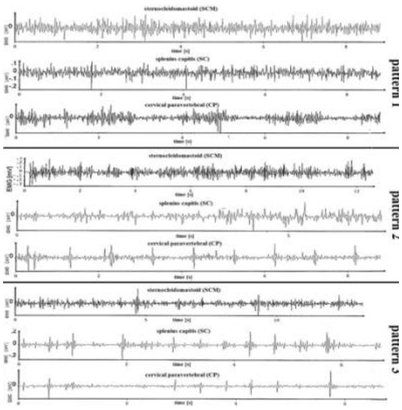

Fig.1: EMG patterns

DISCUSSION

Our electrophysiological findings suggest that anterocollis may be differentiated into three subtypes; dystonia-alone without associated myopathy; myopathy-alone; dystonia and myopathy [3]. In PD patients with antecollis without weakness, electromyography findings may be abnormal, if the patients have both dystonia and myopathy underlying their abnormal head positioning. Anterocollis with an underlying dystonic pattern would be treatable with botulinum toxin injections, while may secondarily predispose to focal myopathy, perhaps via local muscle compression [3].

REFERENCES

[1] Margraf NG et al. Mov Disord 2010; 25(5):542-51.
[2] Jankovic J. Mov Disord 2010; 25(5): 527-528.
[3] Savica R et al. Parkinsonism Relat Disord 2012; 18(1): 30-4.

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SIX MINUTE WALKING TEST (6MWT) IN THE ASSESSMENT OF THE REHABILITATION OUTCOME IN PATIENT WITH PARKINSON'S DISEASE

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INTRODUCTION

The evaluation of rehabilitation outcomes is of primary importance in clinical practice. Modern biomedical technologies are replacing the old qualitative methods based on clinical scales. Although the gold standard in gait analysis is the stereophotogrammetry, wearable inertial systems are spreading in clinical practice thanks to their lower complexity of the experimental setup and data processing procedures, to their lower cost of the instrumentation and the limited time required for the examinations. Aim of the study has been the evaluation of rehabilitation outcome in terms of distance covered in 6 minute (6MWD) from patients with Parkinson's disease following a monthly pharmacological and physiotherapeutic treatment.

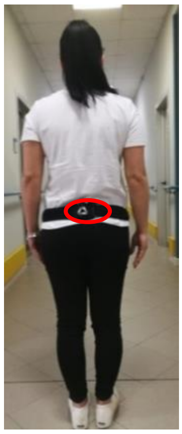

Figura 4 - G-sensor of G-Walk System

METHODS

Study population is composed of 19 patients with Parkinson's disease admitted for rehabilitation treatments at S. Maugeri Foundation IRCCS of Telese Terme (BN); they signed an informed consent form for gait analysis. All patients underwent a gait analysis session instrumented by G-WALK (Figure 1), a wearable inertial system produced by BTS Bioengineering. The gait analysis protocol (6MWT) consisted in a single trial consisting in a six minute walk along a 30 m repeatedly straight path, widely used in the clinical practice [1]. The gait kinematic parameter considered in the study is the 6-minute walk distance 6MWD (m). Statistical analysis of results has been first performed testing and making sure about the Gaussian distribution of the 6MWD parameter by D'Agostino-Pearson omnibus normality test; afterward differences about the 6MWD between pre and post treatment have been studied by paired parametric t-test.

RESULTS

T-test result about 6MWD is shown in Table 1; Figure 2 shows the graph related to 6MWD in the pre-treatment phase and post-treatment phase.

Table 1. Paired t-test between pre and post treatment about 6-minute walk distance parameter

Gait Kinematic Parameter	Pre-treatment	Post-treatment
6-minute walk distance (m)	292.80 ± 93.86	314.60 ± 108.60**

* p<0.5, ** p<0.01, *** p<0.001, **** p<0.0001 at ANOVA test

DISCUSSION

Results described in the Table 1 and showed in the Figure 2 allow to highlight the following findings.

There is a significant difference about the gait parameter 6WMD between pre-treatment and post-treatment, the related mean values are quite different with an about 7.5% mean percentage increase after the treatment. Study results suggest that there is an improvement in terms of distance covered in 6 minutes after only a month of pharmacological and physiotherapeutic treatment underlining the importance of neurorehabilitation in the clinical practice about the treatment of patients with Parkinson's disease.

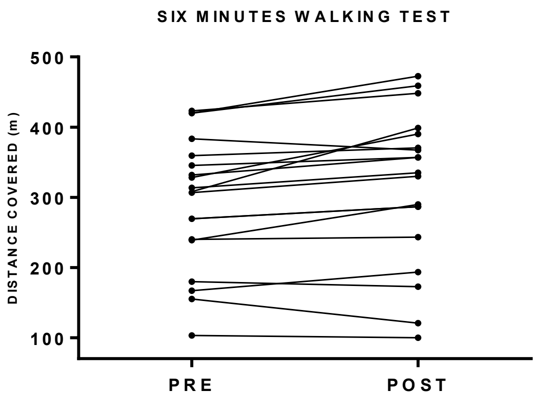

Figura 5 - Plot of parameter value pre and post treatment

REFERENCES

[1] Falvo, M. J., & Earhart, G. M. (2009). *Archives of Physical Medicine and Rehabilitation*, *90*(6), 1004-1008.

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'AEGON' PROJECT: AUDITORY-EMOTIONAL STIMULI AND GAIT IN PARKINSON'S DISEASE

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INTRODUCTION

Freezing of Gait (FOG) is an episodic inability to generate effective stepping. FOG affects more than 50% of subjects with Parkinson's Disease (PD) and is one of the most disabling symptoms during walking [1]. Although FOG has been intensely studied, its pathophysiology is not well understood and current therapies for PD symptoms are poor effective on FOG symptoms. Increasing evidence suggests that non-motor systems (i.e. limbic system), related to emotional behaviors, are involved in its underlying mechanism [1], hypothesizing that emotions could play a role in triggering FOG in PD. Under this assumption, gait characteristics should be different between PD patients with FOG and without FOG in response to emotional stimuli. Goal of the present work is the presentation of the project "AEGON" (Auditory-Emotional stimuli and Gait in parkinsON's disease) to investigate possible relationship between emotional stimuli and FOG during walking in PD.

METHODS

The project consists in two main phases: 1) experimental protocol set up; 2) implementation of a pilot study aimed at evaluating the role of auditory-emotional stimuli on gait in a cohort of 30 PD (15 with FOG (+) and 15 without FOG (-)). To date, phase 1 was completed. Fifteen sounds that we usually hear/feel in our life has been chosen from IADS (International Affective Digitized Sounds) database [2] as emotional stimuli. During the experimental protocol PD will be required to walk in the laboratory space unconstrained while wearing Bluetooth headphones, markers and two footswitches under the feet heels. Participants will be asked to stop with both feet on the ground as soon as they hear one of the sounds. Then, subjects have to restart walking whenever he/she feels to. The optoelectronic system will record the coordinates of 15 markers: 6 for each foot (heel, toe, lateral and medial parts) and 3 on the pelvis (psis and asis). The auditory-emotional will be delivered in a random sequence at heel strikes and after 300 ms from heel strikes [3]. As concerns phase 2, we tested the experimental protocol on 3 subjects: 1 healthy subject (HS), 1 PD FOG- and 1 PD FOG+. Spatiotemporal and kinematic gait parameters were calculated.

RESULTS

All the participants included in this preliminary phase were able to complete the experimental protocol and all data were recorded correctly. According with our a priori hypothesis, auditory-emotional stimuli were able to influence gait performance and to provoke a FOG episode in a PD FOG+ (Figure 1).

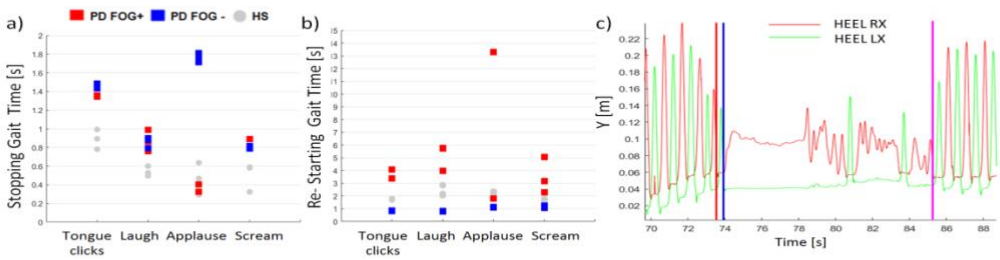

Figure 1. (a) Stopping and (b) Re-Starting times of the pilot walking trials are reported. In figure (c) the vertical trajectories of the heels during the FOG episode are reported. Vertical red, blue and purple lines correspond to the times of sound presentation, stopping and restarting, respectively.

DISCUSSION

Results from the testing phase support the feasibility of this experimental protocol. Preliminary results suggests that auditory-emotional stimuli could trigger FOG episodes supporting the key role of emotion on FOG pathophysiology, although the protocol has been tested in a small sample size.

REFERENCES

[1] Lagravinese G, et al. *Mov Disord.* 2018;33(4):609-617.
[2] Bradley MM, Lang PJ. The International Affective Digitized Sounds (2nd Edition; IADS-2). 2007.
[3] Tirosh O, Sparrow WA. *Gait Posture*. 2004; 19(3):243-251.

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ECOLOGICAL, OBSTRUCTED WALKING PARADIGM TO ASSESS THE EFFECT OF AUDIO-VISUAL SCANNING TRAINING (AVIST) IN HEMIANOPIC SUBJECTS

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INTRODUCTION

Homonymous hemianopia (HH) is a condition that originates from a visual field loss on the right or left side of both eyes (right HH, left HH) due to post-chiasmatic lesions on the contralateral retino-geniculo-striate pathway. This impairment compromise the ability to produce effective saccades leading to an increased difficulty in functional activities, like walking in a crowded environment [1]. For this reason, patients undergo to specific treatments; in this study we used Audio-Visual Scanning Training (AViST) to train subjects with HH to respond to audio-visual stimuli with more effective saccades, contributing to a better exploratory ability [2]. Usually, patients fill in questionnaires to judge their ability in carrying out such activities before and after the rehabilitation treatment. In this study, we used an ecological, obstructed walking paradigm to quantify the behavior of the subjects while walking avoiding vertical obstacles [3]. Our aims are to explore differences in movement between subjects with HH and healthy controls (HC) and to quantify the effect of AViST through a longitudinal analysis.

METHODS

Ten subjects with HH (7 right HH, 3 left HH) and six HC walked through a corridor (2x15,4 m) avoiding three vertical obstacles. Five subjects with HH performed the test before and after AViST. In our walking paradigm, the Gait Tutor system (mHealth Technologies, IT) was used without the need for an invasive set-up: two inertial sensors were applied to the feet to detect trajectories and spatio-temporal gait parameters, and one on the forehead to detect left-right movement of the head (yaw angle). In particular, we extracted: frontal and lateral distances between subject and obstacle during obstacle circumvention (semi-axes of the approximate ellipse [3]); maximum yaw angle between head direction and central line; yaw angle variance. We used unpaired non-parametric statistics to examine differences between HC and HH groups and paired non-parametric statistics to assess the effect of AViST.

RESULTS

The statistical analysis shows that HH group requires more time and takes smaller steps to perform the protocol than HC subjects, **Table 1**. Looking at the absolute median value, we achieve a greater variance and maximum yaw angle (Max_Angle) in HH compared to HC group. Instead, the semi-axes executed to circumvent the obstacles are similar between the groups, **Table 1**. Moving on the effect of AViST, the paired analysis shows that after the treatment the subjects require less time to perform the protocol (p-value = 0.047); in the other parameters we have no significant differences.

Table 1. Median and interquartile range (Q1-Q3) of the parameters evaluated between HC and HH groups. Bold numbers indicate significant differences (p-value < 0.05).

	Total Time [s]	Stride Length [m]	Minor axis [m]	Major axis [m]	Max_Angle [deg]	Variance [deg^2]
HC (n=6)	11.0 (9.4-13.1)	1.24 (1.16-1.26)	0.35 (0.24-0.38)	1.33 (1.19-1.38)	16.6 (13.6-19.0)	44.7 (25.5-66.3)
HH (n=10)	17.2 (15.9-18.6)	0.97 (0.91-1.12)	0.37 (0.31-0.40)	1.12 (0.78-1.30)	25.1 (18.1-34.7)	81.8 (50.9-109.2)
P-value	**p < 0.001**	**p = 0.003**	p = 0.713	p = 0.118	p = 0.116	p = 0.181

DISCUSSION

Differences in total time and stride length between HC and HH groups show that this walking paradigm is more difficult for HH subjects. In addition, greater variance and maximum yaw angle seem to support the hypothesis that HH subjects rely higher on head movements for scene exploration, resulting in a poor ocular-scanning efficacy. These parameters are potentially able to discriminate between the two groups, but the analysis should be performed on more subjects to reach statistical significance. Furthermore, the longitudinal analysis indicates that after the AViST treatment HH subjects require less time to perform the protocol. Other parameters failed to show changes, but more data is needed. These results are far from conclusive, but they are promising about finding new insights on HH condition.

REFERENCES

[1] Zihl J. *Pergamon* 1995;33(3):287-303.

[2] Bolognini N, et al. *Brain* 2005;128(12):2830-42.

[3] Gérin-Lajoie M, et al. *Motor Control* 2005;9(3):242-69.

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QUANTITATIVE ANALYSIS OF BLINK RATE IN PATIENTS WITH BLEPHAROSPASM

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INTRODUCTION

The benign essential blepharospasm is a focal dystonia characterized by involuntary closing of the eyelids. It is usually caused by an uncontrolled contraction of the orbicularis oculi muscle, but it can also be caused by a failed contraction of the flexor[1]. Diagnostic tools are of limited assistance for the diagnosis of dystonia, which remains based on clinical diagnostic skills. Therefore, there is an increasing need for more accurate and precise methods for both delineating the nature of abnormal movements and rating their severity. The aim of this research was to characterize the kinematic blinking in patients with blepharospasm, by assessing the amplitude, frequency and duration of the movement

METHODS

Twenty patients with blepharospasm and twenty healthy individuals were examined. All subjects performed three tasks: quiet rest with opened eyes looking at a point, located 230 cm away(rest); free conversation on trivial subjects, bearing no emotional impact or the use of the memory(conversation); reading a standardized text(reading). The data collection protocol used was a modified protocol of previous one developed by Sforza et al.[2]. Facial movements were recorded using an optoelectronic system with 9 infrared cameras with a sampling rate of 120 Hz (SMART, BTS Bioengineering). The kinematic parameters calculated for right and left eye were: blink rate, eyelid displacement and duration of closure and opening phase. Subjects were assessed in two different sessions: PRE phase (absence of the effect of the botulinum toxin) and the POST phase (presence of the maximum effect of the botulinum toxin). The kinematic parameters between the three groups of individuals (healthy, blepharo-pre, blepharo-post) were compared for the three conditions.

RESULTS

In patients with blepharospasm, a significant increase ($p<0.05$) of the frequency was found in all the tests and the blink rate during rest was higher than blink rate during conversation in comparison to the healthy group.

DISCUSSION

The results demonstrated the presence of differences in motor control of subjects with dystonia compared to healthy subjects. In the assessment of adults affected by blepharospasm we found a kinematic parameter characteristic of the disease: blink rate (rest>conversation). The observation of overlapping blink rate values between patients with blepharospasm and control group during reading is interesting since it may suggest some speculations on the pathophysiology of increased frequency in blepharospasm. From our point of view, these findings support the hypothesis that conversation may act as a “gestes antagonistes” towards a pathologically increased blink rate[3]. Utilizing the optoelectronic system to evaluate the blepharospasm allowed us to assess the kinematic movement of the blinking in a detailed manner, by identifying the parameters that objectively illustrate the pathology’s characteristics and the effects of the therapeutic treatment.

REFERENCES

[1] Albanese A, et al. *Movement Disorders* 2013 Jun 15;28(7):863-73
[2] Sforza C, et al. *Ophthalmic and Physiological Optics* 2008 Jul;28(4):345–53
[3] Bentivoglio AR, et al. *Movement Disorders* 2006 Aug;21(8):1225-9

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SARA-HOME: PRELIMINARY DATA OF KINECT BASED TELE-ASSESSMENT OF YOUNG PATIENTS WITH ATAXIA.

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INTRODUCTION

Genetic ataxia is a degenerative disease involving cerebellum and spinal cord in which gait and limbs ataxia are key clinical features requiring frequent follow up. During clinical trials, specific evaluation tools and outcome measures are needed. In fact, the reliability of the Scale for Assessment and Rating of Ataxia (SARA), the most used clinical score for ataxia, is age-dependent, loosing accuracy below the age of 11 years, and is also affected by concurrent neurological disturbances (e.g. movement disorders). The aim of the study is to automate and digitalize the SARA Scale [1] by means of a software for home assessment (SARA-home) based on low cost tracking devices.

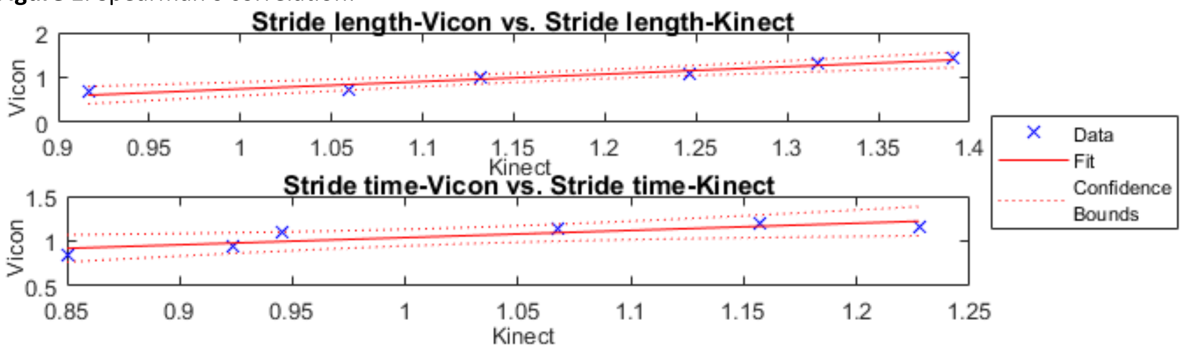
METHODS

We use a Kinect 2.0 and Leap Motion connected to a personal computer to acquire biometric data of SARA tasks (speech fluency, body movement of upper and lower limbs). These devices were identified for their reliability, availability and low cost [2]. Ad hoc software (SARA-Home) was written to acquire the digitalized tasks. The digitalized tasks are: gait, stance, sitting, speech disturbance, finger chase, fast alternating hand movements. Gait, stance and sitting were evaluated with Kinect on frontal plane. The speech disturbance task was evaluated through PATA repetition rate test, recorded with Kinect's microphones. Finger chase and fast alternating hand tasks were acquired with Leap Motion. Visual feedback (e.g. target color change) were used to improve patient's attention on the task. Acquisitions were conducted on six patients with ataxia (5 males, 1 female, mean age 12.8±4) in a space of 4.15m length x 1.80m width x 2m height. We acquired also the full body model by an optoelectronic system (Vicon MX). Here, we analyzed the gait spatial and temporal parameters.

RESULTS

We examined spatio-temporal parameters: stride length (m) and stride time (s). We conducted the Spearman's correlation (Figure 1) between these two variables recorded with Vicon system and those recorded with Kinect. Spearman's rank correlation coefficient (rho) and p value are: stride length rho=1, pvalue<0.01; stride time rho=0.94, pvalue<0.05.

Figure 1. Spearman's correlation.



DISCUSSION

Sara-home may increase the sensibility of the SARA scale. Moreover, patients are compliant and motivated to complete tasks by the reproduction of his skeletal joint structure on a screen. Sara-home seems to be a useful tracking system to monitor patient's motor performances in a domestic environment. These preliminary data encourage us to use an automatic evaluation that could be perform remotely. Studies are necessary to analyze the relationship between Kinect-Leap Motion data sequences and clinical SARA scale assessment.

REFERENCES

[1] Schmitz-Hübsch T, et al. *Neurology* 2006, 66(11):1717-1720.

[2] Mousavi Hondori H, Khademi M. *Journal of medical engineering* 2014, 2014:16 pages.

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THE SMARTPHONE AND THE BIOMECHANICAL RISK: THE PROPOSAL OF AN ELECTRONIC BASED SURVEY ON YOUNG SUBJECTS

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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 designed to explain the consequences of repeated solicitations to the human body, caused by the excessive use of portable devices of all kinds, such as 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.,• With the passing of the years to these pains of neuropathic and musculoskeletal origin, other problems such as gastrointestinal and respiratory difficulties can be added. 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 inclination of the neck (Figure 1).

METHODS

The general idea was to focus on the young subject and to set-up an investigation methodology based on an electronic survey to explore their knowledge and predisposition to the above described risks.
The tool was based on a dedicated questionnaire that generally was divided into two sections:
Section 1) The smartphone addition. *Section 2)* Knowledge and predisposition to the biomechanical risk.

RESULTS AND DISCUSSION

The questionnaires were organized using an electronic methodology based on Forms (Microsoft,USA). This methodology is particularly useful for the electronic surveys: it allows an easy sending of the questionnaire using for example WhatsApp or other messengers
The data are automatically stored in a database, a report is automatically updated with graphics and statistics. This is the link to the *section 2* of the electronic form developed using Forms https://forms.office.com/Pages/ResponsePage.aspx?id=DQSIkWdsW0yxEjajBLZtrQAAAAAAAAAAAAZ__ghPqE5UREtDQTVUMURTQklUWE8wU1ZGNDlDUDlPMC4u .The survey was at the moment submitted to 150 subjects with an age comprised between 14 to 21 years. All of them were smartphone owners. The mean time spent with the smartphone was equal to 3,18 h in mean value. The principal activities were WhatsApp and social networks. The questions related to the knowledge on postural risks received an assessment of 2,73 in mean value (<3).

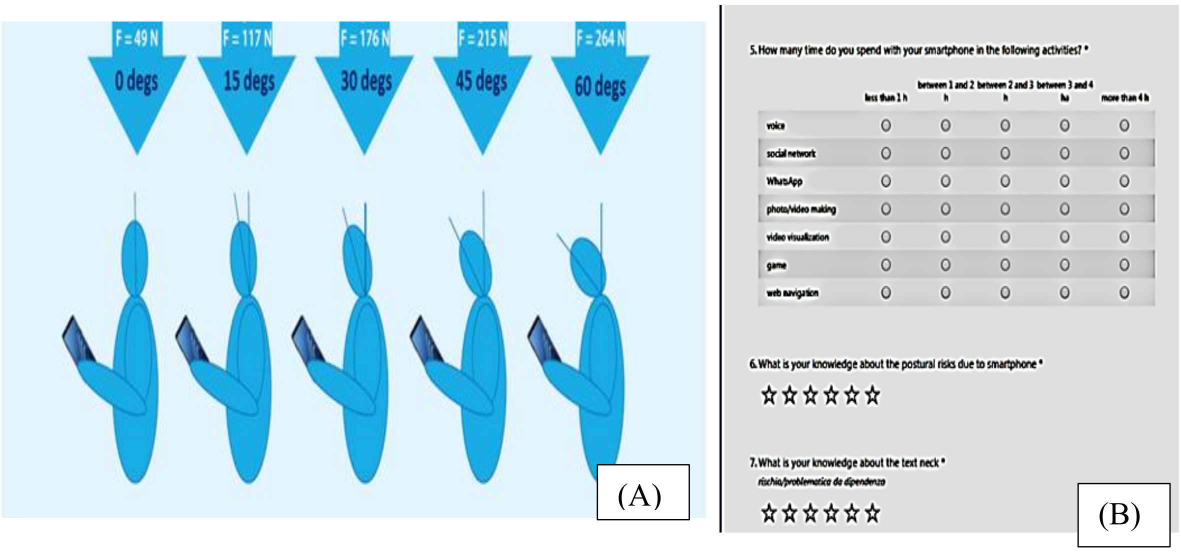

Figure 1. (A) Biomechanical risk when the neck angle increases (B) A piece of the survey

REFERENCES

[1] Giansanti D., *Istisan* Report 18/21, ISS, 2018, Rome.
[2] Giansanti D et al., Notiziario ISS, Vol 31, n. 7-8, 2018, Rome

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KINEMATIC CHARACTERIZATION OF GAIT IN COSTELLO SYNDROME: PRELIMINARY FINDINGS

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INTRODUCTION

Costello syndrome is a rare genetic condition caused by heterozygous alterations in HRAS and characterized by multi-system abnormalities. Individuals with Costello syndrome usually present with severe feeding difficulties in infancy, short statur, coarse facial features, increased tumor risks, cardiac and neurological complications, intellectual disability and orthopedic complications including: ulnar deviation, hip dysplasia, tight Achilles tendons, and unusual kyphoscoliosis [1,2]. Orthopedic manifestations are very common and result in significant morbidity. In particular, lower extremity disorders may affect ambulation and quality of life and should be properly assessed and addressed [3]. However, at the best of our knowledge no description of gait pattern is available.

METHODS

We enrolled 5 patients with Costello Syndrome (3M, 2F; 19±8.8 mean age, years). Gait analysis was performed using the SMART-DX optoelectronic system with 8 infrared cameras (BTS Bioengineering, Milano, Italy) sampling at 200 Hz. We used the Davis model that includes 22 markers. In this experimental procedure, subjects were required to walk barefoot along 6 meters walkway. All spatio-temporal parameters were calculated. To assess kinematics of the lower limb joints we also calculated hip, knee, and ankle range of motion (ROM) in the sagittal plane.

RESULTS

Spatio-temporal parameters show an increase of the stance phase and the double support phase with a decrease of the swing phase and the cadence. Moreover, there is a reduction of the step length and the mean speed. ROMs of the lower limb joints are smaller than healthy subjects and typically these patients show a posture characterized by flexed knees and dorsiflexed ankle during the gait cycle. Pelvis and hip show a variable behavior in our sample.

Table1.Spatio-temporal and kinematic parameters.

Spatio-temporal parameters		**Patients Mean (SD)**	**Controls Mean (SD)**
	Cadence (step/min)	94.9 (15.4)	132.6 (4.3)
	Gait cycle duration (s)	1.3 (0.2)	0.98 (0.1)
	Stance time (% gait cycle)	65 (5.4)	58.6 (2.4)
	Swing time (% gait cycle)	34.9 (5.4)	41.2 (1.5)
	Double support time (% gait cycle)	24.4 (14.7)	5.5 (0.7)
	Step length (m)	0.3 (0.1)	0.5 (0.02)
	Step width (m)	0.2 (0.05)	0.1 (0.02)
	Mean speed (m/s)	0.4 (0.2)	1.2 (0.2)
Kinematic parameters			
	Hip ROM (deg)	27.9 (10.4)	48.8 (3.0)
	Knee ROM (deg)	21 (5.7)	59.0 (1.4)
	Ankle ROM (deg)	16.5 (8.2)	25.8 (8.5)

DISCUSSION

Our preliminary results represent the first kinematic characterization of patients affected by Costello syndrome. The main features of Costello gait are the stiff flexed knee associated to a dorsiflexed ankle while pelvis and hip pattern is not consistent among our patients probably because of a different degree of kyphoscoliosis. A more numerous sample could contribute to better describe the kinematic pattern.

REFERENCES

[1] Yassir W, et al. *J Pediatr Orthop* 2003; 23(1):94-8.

[2] Aoki Y, et al. *Nat Genet* 2005; 37(10):1038–1040.

[3] Detweiler S, et al. *Am J Med Genet A* 2013; 161A(8):1940-9.

http://doi.org/10.6092/unibo/amsacta/6260

EFFECTS OF INTENSIVE NEUROREHABILITATION TREATMENT ON THE GAIT PATTERNS OF A SUBJECT WITH INCLUSION BODY MYOSITIS

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INTRODUCTION

Inclusion body myositis (IBM) is a progressive idiopathic inflammatory myopathy characterized by chronic progressive muscle inflammation. Muscle weakness in IBM results in the loss of independence and the need for assistive device and supportive care. IBM has a prevalence ranging from 5 to 10 cases reported per million adults [1]. Several published reports on IBM focus on disease epidemiology or drug trials, others outline the efficacy of physical treatment [2-3]. The gait pattern of IBM patients was described by Bernhardt [1]. The aim of this study was to describe the gait pattern modification, after an intensive neurorehabilitation treatment, in a subject with IBM.

METHODS

For the present study a 75-year-old female patient with IBM, confirmed through muscle biopsy, was enrolled. The patient referred a 2-year history of proximal extremity weakness and pain. Neurorehabilitation treatments consisted of aerobic exercises focused on balance and lower limb training. Muscles reinforcement was aimed at the improvement of gait, posture and locomotor activities related to ADL. The treatment was 5-weeks long, 6 day per week, two 45-minutes long periods per day. The clinical evaluation (pre and post) consisted of FIM, FAC and Conley Scale. The patient was evaluated at the Motion Lab of Casa di Cura del Policlinico using an optoelectronic system with 6 cameras (VICON, Oxford, UK) with a sampling rate of 100 Hz. Markers were positioned according to modified Davis marker set (Plug-In-Gait). Instrumental evaluation, pre and post treatment, consisted of spatiotemporal parameters and kinematics analysis (lower limb joints ROM). Pre and post evaluation were compared using t Student test (with $p<0.05$ threshold).

RESULTS

The patient did not present adverse effects (e.g., muscle pain, excessive fatigue) during the intensive neurorehabilitation treatment. The analysis showed significant modifications ($p<0.0001$) in spatiotemporal parameters between pre and post rehabilitation. Walking speed (m/s) increased of 0.2 (0.48 (0.03) vs.0.68 (0.05); mean (standard deviation) pre vs. post) while the duration of stance phase (% of gait cycle) was reduced (69.76 (1.90) vs. 64.55 (3.15)). Step and stride length (m) increased significantly of 0.14 and 0.29, respectively (0.34 (0.03) vs. 0.48 (0.03); 0.67 (0.04) vs. 0.96 (0.05)). The kinematic analysis (ROM, °) showed a significant ($p<000.1$) modifications for hip and knee flex-extensions, both right and left limb. In addition, a significant modification ($p<0.05$) was reported for the ankle dorsi-plantarflexion ROM. The clinical evaluation showed a higher score for FIM scale (108 vs. 121). FAC and Conley scale did not show any modification (2 and 5 points, respectively).

Table 3: Spatiotemporal and kinematic parameters (mean and standard deviation) for the two analyzed periods. Statistical significance differences (pre vs. post) are reported in bold ($p<0.0001$) or underlined ($p<0.05$). ROM: Range of Motion

	Right ROM Pre treatment	Right ROM Post treatment	Left ROM Pre treatment	Left ROM Post treatment
Pelvic tilt (°)	3.39 (3.34)	3.70 (1.41)	3.02 (0.53)	3.15 (0.86)
Hip flex-extension (°)	**43.87 (1.26)**	**52.77 (1.57)**	**41.82 (0.96)**	**49.82 (3.87)**
Knee flex-extension (°)	**64.69 (1.51)**	**73.58 (2.97)**	**63.91 (2.52)**	**74.27 (3.22)**
Ankle dorsi-plantarflexion(°)	<u>26.38 (2.38)</u>	<u>31.35 (3.04)</u>	<u>22.32 (2.33)</u>	<u>18.62 (1.70)</u>

DISCUSSION

At the best of our knowledge, this is the first case-report describing the effect of intensive neurorehabilitation in a patient with IBM through the analysis of gait. As reported in results, the subject showed a general improvement of gait. The findings of this study support that, beyond a multidisciplinary therapeutic approach for IBM patients, a neurorehabilitation intensive treatment could be beneficial for the recovery of locomotion and, therefore, for an improvement of ADL and a better lifestyle. This study has several limitations. IBM is a rare disease, and due to geographic limitation on recruitment, only one subject was analyzed. Further work is needed to better describe the evidences of this preliminary study.

REFERENCES

[1] Bernhardt K.A., Oh T.H., Kaufman K.R. *Gait and Posture* 2011; 33: 442-446
[2] Wiesinger G.F, Quittan M., Graninger M et al. *Br J Rheumatol* 1998; 37: 1338-42
[3] Alexanderson H. *Journal of Internal Medicine* 2016; 280: 75-96

DOES GAIT KINEMATIC PARAMETERS CHANGE AS FUNCTIONAL OUTCOME SCALES IN TOTAL HIP ARTHROPLASTY SUBJECTS AFTER REHABILITATION?

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INTRODUCTION

Total hip arthroplasty (THA), is a routine, common surgical intervention; following surgery is usual practice a period of rehabilitation to recover strength, range of motion and walking ability of the operated limb. Many functional outcome scales (FS) have been developed to assess the improvements of the patients, but gait parameters have not been studied as extensively[1] as possible outcome. This study aims to evaluate the effectiveness of rehabilitation through gait analysis (GA), and to compare the improvements detected with FS are related with those detected by GA.

METHODS

Subjects were recruited in a rehabilitation unit after receiving THA. Inclusion criteria were stable clinical conditions, and no other neurological or rheumatic pathologies or previous surgeries at the lower limbs. Merle D'Aubignè-Postel scale (MDS), Barthel Index (BI), Numerical Rating Scale (NRS) and GA were assessed at admission (T0) and discharge (T1). For the GA, a BTS® DX-400 system with 8 optoelectronic cameras and 2 force platforms was used, implementing the Davis-Heel markerset protocol with 22 passive markers[2]. For each subject, at least 3 walks were performed, with one or two crutches according to needs. Data were processed using BTS® software SMART-Analyser, as the software normally used to produce clinical reports, and the whole gait analysis was performed by an expert operator. For the descriptive analysis, mean and standard deviation were used. A Student T test was performed to test the null hypothesis of samples drawn from the same population; the improvement variation between T0 and T1 and the relative Pearson's coefficient R were calculated to investigate a possible relationship between some FS (BI and MDS) and gait kinematic parameters. Ethical committee approval has been obtained.

RESULTS

8 subjects (2 females, 4 left hips) mean age 66±10 were included. The FS scores improved significantly ($p<0.01$) except for NRS ($p=0.18$). Some of the GA kinematic parameters (cycle duration and length, stance, swing and double support phase, cadence and speed) improved significantly, the significant parameters are illustrated in Table 1a. The Pearson's coefficient R between FS and the significant parameters of GA showed some strong correlations, in particular MDS (Table 1b).

Table1. ***a*** *Significant Gait kinematic values at Hospitalization T0 and discharge T1;* ***b*** *Values of Pearson's coefficient R between BI, MDS and the significant gait parameters [OL= Operated Limb; NL= Non operated Limb]*

a				b	
Kinematic Parameters of gait	Mean (SD) T0	Mean (SD) T1	pValue	BI	MDS
Cycle duration(s) OL	2.27 (0.73)	1.82 (0.62)	0.02	-0.21	-0.53
Cycle duration (s) NL	2.27 (0.69)	1.83 (0.53)	0.00	-0.07	-0.45
Stance duration (s) OL	1.59 (0.60)	1.22 (0.52)	0.00	-0.24	-0.27
Stance duration (s) NL	1.62 (0.62)	1.23 (0.53)	0.02	-0.06	-0.54
Swing duration (s) NL	0.70 (0.13	0.63 (0.11)	0.04	-0.64	0.43
Double support phase (%) NL	30.29 (13.32)	14.69 (10.28)	0.02	0.28	-0.51
Mean speed (m/s)	0.36 (0.19)	0.53 (0.24)	0.01	0.25	0.24
Cadence (steps/min)	59.35 (21.59)	70.83 (17.74)	0.03	0.50	0.18
Lenght of cycle (m) OL	0.76 (0.17)	0.87 (0.20)	0.01	0.07	0.15
Lenght of cycle (m) NL	0.76 (0.18	0.91 (0.21)	0.01	-0.11	0.42

DISCUSSION

Both FS and temporal and spatial GA parameters show meaningful improvements between T0 and T1; these improvements have been clearly detected also with GA, that has rarely been performed before in such an acute phase. The correlation detected between the FS and the aforementioned GA parameters, suggests a wider use of GA in this clinical contexts, as a useful tool to assess the function and improvements of this kind of population[3]. The study is still ongoing: we expect to extend the evaluation to a larger sample size in the next future.

REFERENCES

[1] A.M. Ewen, et al. Gait Posture. 36 (2012) 1–6. doi:10.1016/j.gaitpost.2011.12.024.
[2] J. Pollet, et al. Gait Posture. 65 (2018) 513–514. doi:10.1016/j.gaitpost.2018.07.086.
[3] S. Zhao, et al. Orthop. Surg. 2 (2010) 94–99. doi:10.1111/j.1757-7861.2010.00070.x.

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THE ADDITION OF AEROBIC TRAINING TO CONVENTIONAL REHABILITATION AFTER PROXIMAL FEMUR FRACTURE: A RANDOMIZED CONTROLLED TRIAL

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INTRODUCTION

Femur fracture is an important cause of morbidity, premature institutionalization and mortality in older adults [1]. Elderly people with proximal femur fracture do not recover the status before surgery [1,2]. Recent studies state that one of the reason that can lead to unsatisfactory recovery of motor skills could be the low level of physical activities during inpatient hospitalization [3]. The purpose of this study is twofold: (a) examine the feasibility of aerobic exercise in people with recent proximal femur fracture surgically treated and (b) verify the effectiveness of aerobic training in addition to conventional rehabilitation.

METHODS

25 elderly with proximal femur fracture were randomized in 2 groups: experimental (EXP: n= 12; Age 82.3 ± 4.7) and control (CNT: n= 13; Age 84.8 ± 9.6). All patients underwent conventional rehabilitation once/day for 5 times/week for 3 weeks. In addition to conventional rehabilitation, EXP patients underwent 30 min of aerobic training with an arm cycle ergometer 5 times/week for 3 weeks. Both groups were evaluated pre- and post- training with the following outcome measures: Cumulated Ambulation Score (CAS), Verbal Ranking Scale (VRS), strength of knee extensors and Activities-Specific Balance Confidence Scale (ABC). Timed Up and Go Test (TUG) and 10 -Meter Walking Test (10mwt) were administered only at the end of the training due to inability of patients to perform both tests at admission.

RESULTS

No adverse effects were recorded. 11 on 12 patients of EXP group have completed the aerobic training treatment. Patients in EXP group reached a training volume of 75 minute/week at an intensity of 1.6 metabolic equivalent of task (MET), that correspond to a light-intensity aerobic activity. Both groups improved after training in all variables (Wilkoxon test, $p<0.03$), with the exception of CAS-I in the CNT group (Wilkoxon test, $p<0.08$). At discharge EXP group improved more significantly at the TUG and 10mwt than CNT group (ANCOVA, $p<0.0001$). Also the strength of the fracture leg increase more in EXP than in CNT at discharge (ANCOVA, $p<0.0001$).

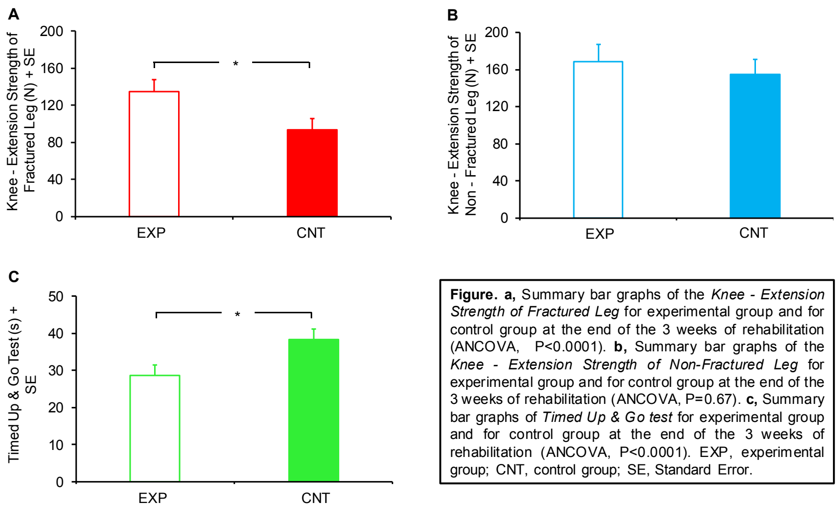

Figure. a, Summary bar graphs of the *Knee - Extension Strength of Fractured Leg* for experimental group and for control group at the end of the 3 weeks of rehabilitation (ANCOVA, P<0.0001). **b,** Summary bar graphs of the *Knee - Extension Strength of Non-Fractured Leg* for experimental group and for control group at the end of the 3 weeks of rehabilitation (ANCOVA, P=0.67). **c,** Summary bar graphs of *Timed Up & Go test* for experimental group and for control group at the end of the 3 weeks of rehabilitation (ANCOVA, P<0.0001). EXP, experimental group; CNT, control group; SE, Standard Error.

DISCUSSION

Aerobic training performed with an arm cycle ergometer, in addition to conventional rehabilitation, is safe, feasible and it provides positive effects on gait and strength in elderly people with proximal femur fracture. Our study confirms that low-intensity physical activity performed at about 1.6 MET can induce positive effects in currently inactive elderly population [4].

REFERENCES

[1] Roche et al. BMJ 2005, 331(7529),1374.
[2] Lin et al. JNR 2004; 12(1),72-82.
[3] Davenport et al. Physiother Res Int 2014; 20(3),174-181.
[4] Fuzeki et al. Sports Med 2017; 47: 1769-1793.

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ANALYSIS OF THE BALANCE IN STATE OF STATIC AND PARAMETERS SPACE-TEMPORALS IN WALKING IN PATIENTS WITH IDIOPATHIC NORMAL PRESSURE HIDROCEPHALUS PRE AND POST-SUBSTRACTION OF CEREBROSPINAL LIQUID (TAP-TEST)

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INTRODUCTION

This study wanted to measure the qualitative/quantitative variations concerning balance and gait disturbances, present in 94-100% of cases [1], on patients with NPH subjected to *tap- test* by carrying out biometric tests (static stabilometry and dynamic baropodometry).

The patients were chosen starting from the PDTA [2] drawn up between 3 structures (SSD of RRF, SC of Neurosurgery and SC of Neurology) of the A.S.O.S. Croce and Carle, Cuneo (CN),Italy.

The examinations took place at the Digitized Biometrics Laboratory of the SSD of RRF.

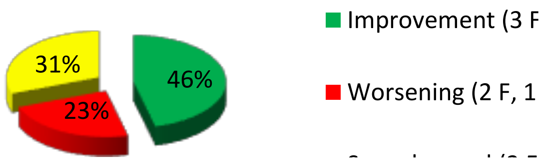
METHODS

13 patients (7 F,6 M). A first evaluation took place before subtraction of cerebrospinal fluid (T0), the second measurement at 2-48 h from surgery (T1).The clinical and instrumental examination took place with a static stabilometry for the study of the erect station with open eyes (OE) for 30 seconds and closed eyes (CE) for 30 seconds and a walking on the baropodometric platform for a duration of 60 seconds.

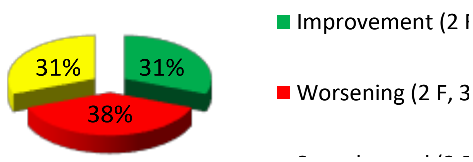
RESULTS

The stabilometric indicators (**sway area**;**path length**) [3] at T1 recorded an improvement in 46.15%, a worsening in 23.07% and a situation unchanged in 30.76% of cases . The gait parameters (**length of the half-pass, average speed, step's cadence , interstep away, support time, double support time**) [4] at T1 they recorded a positive change in 30.76% of cases, a worsening in 38.46% and a situation unchanged in 30.76%. The results obtained denote that no changes in the parameters were recorded , especially the dynamic ones , which suggested an objective improvement after the tap- test in the short period.

STABILOMETRY



BAROPODOMETRY



DISCUSSION

The reports of the Laboratory, according to parameters from literature, were able to help in the evaluation of a possible second subtraction of cerebrospinal fluid.

REFERENCES

[1] Yasutaka Nikaido, et al. Gait & Posture n. 63, year 2018, 5-9.

[2] SSD of RRF, SC of Neurosurgery, SC of Neurology, ASO S. Croce and Carle , Cuneo (CN), Italy, 2018.

[3] Riccardo Schiffer, Stabilometria Clinic, Edi.Ermes, Milan (MI), Italy, 2015, 54.

[4] Riccardo Schiffer, Clinical Baropodometry, Medea srl, Nonveta Padovana (PD), Italy, 2019, 18.

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MOTOR DESCRIPTORS OF LOCOMOTOR PERFORMANCE IN CHILDREN AND YOUNG ADULTS WITH DEVELOPMENTAL COORDINATION DISORDER.

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INTRODUCTION

Developmental coordination disorder (DCD) is an innate motor coordination impairment that affects basic locomotion and balance [1]. A quantification of DCD locomotor characteristics is still missing in the literature, probably because of the variability of the observed alterations [1]. Inertial sensors and nonlinear analysis of trunk acceleration has been demonstrated to provide novel insight in motor control development [2,3]. Thus, this approach could support the understanding of motor control alterations, potentially integrating monitoring and interventions in this population. The aim of this study was the preliminary characterization of DCD locomotor performance, through a quantitative analysis of natural- (NW) and tandem walking (TW) [2,3].

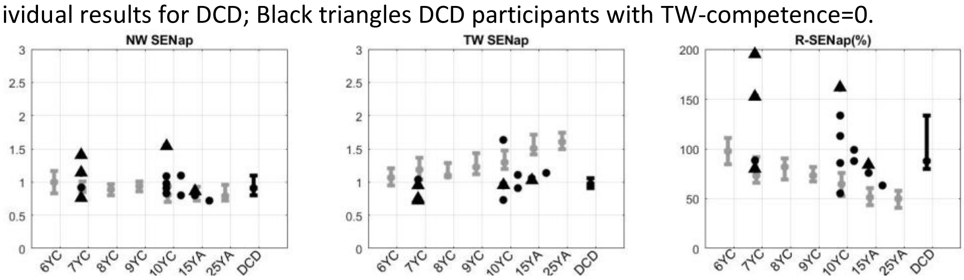
METHODS

15 participants (2F/13M, median 11y, min-max 7-19y; 150cm, 120-170cm; 38kg, 22-80kg) with DCD walked in NW and TW. 3D acceleration and angular velocity of lower trunk and shanks were collected (Opals, APDM, USA). For each participant, 14 strides of NW and TW were analyzed. Number of correct consecutive steps [2] was assessed (TW-competence), as conventional measure. Stride-, stance- and double support time, and their variability were estimated from shank angular velocities [3]. Recurrence quantification analysis (RQA), associated with pattern regularity, and multiscale entropy (MSE, SEN for τ=1..6), associated to motor complexity, were calculated on trunk acceleration components (V, AP, ML) [2]. To evaluate the concurrent development of automaticity and complexity, each SEN value in NW was expressed in percentage of the corresponding TW value (R-SEN) [2]. Results were compared to typically developing groups (TD) (6-25 years) [3] and analyzed with respect to TW-competence.

RESULTS

In NW, no significant difference was found between DCD and TD for all the parameters. In TW, DCD showed longer stance and double support phases, increased stride time and variability. DCD participants showed higher RQA and lower SEN values in AP direction. When considering R-SEN, differences between DCD and TD resulted more evident. When analyzing results with respect to TW-competence, participants showing the lowest score tended to have the highest R-SEN in AP.

Figure 1. Fig.1 SENap results (25th, 50th and 75th percentiles) for TD (grey lines) [3] and DCD (black line). Black circles indicate individual results for DCD; Black triangles DCD participants with TW-competence=0.



DISCUSSION

Preliminary results allowed differentiating DCD TW performance from that of all considered TD populations. Variability of temporal parameters resulted the highest in DCD participants regardless their age. Trunk motor pattern resulted less complex and more regular in AP direction, suggesting that DCD use simple motor solutions to solve a new challenging motor task (TW), instead of exploring and manifesting motor complexity.

REFERENCES

[1] J. Gibbs et al., *Arch. Dis. Child*. 2007
[2] Bisi MC et al., *J Biomech Eng*. 2018
[3] Bisi MC et al., *Gait Posture*. 2019

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USE OF GAITRITE SYSTEM TO INVESTIGATE WALKING ABILITY IN CHARCOT MARIE TOOTH PATIENTS

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INTRODUCTION

Charcot Marie Tooth (CMT) neuropathy is the most common inherited neurological disorder. In CMT, symptoms usually start in the 1st-2nd decade of life with slowly progressive distal muscle weakness and atrophy. As ankle and toes dorsiflexors are the most affected muscles, these patients often complain of gait disorders with frequent falls and difficulties in running. In addition, joint tightness and deformities, and altered proprioception further impair muscle function, gait and balance. To date there is no effective therapy for the different forms of CMT and the efficacy of rehabilitation is unclear.

Here we present the results of the clinical and instrumental assessment, to investigate the possible usefulness of the GAITRite system in identifying gait disorders in CMT patients.

METHODS

We recruited 24 subjects affected by CMT. Inclusion criteria: clinical and genetically confirmed diagnosis of CMT; age between 18 and 75 years; score at the Short Physical Performance Battery (SPPB) between 2 and 10. All subjects underwent an evaluation by means of clinical scales (10 Meters walk test-10MWT; 6 minutes walk test–6MWT; Berg balance scale–BBS; SPPB; MRC strength evaluation; CMT examination score – CMTES; Walk12) and an instrumental gait assessment by means of the GAITRite system. We also collected both instrumental and clinical data of a control group of healthy age-matched subjects (HS). The GAITRite System is a 7 meters long electronic portable walkway able to measure the temporal and spatial gait parameters. As the subject ambulates across the walkway, the pressure exerted by the feet onto the walkway activates the sensors. Subjects were asked to walk on the carpet for one minute at normal speed (Normal Walk–NW), at fast speed, but not running (Fast Walk – FW), at normal speed enunciating aloud all possible words beginning with a chosen letter (Dual Task – DT). The clinical and instrumental measures were compared between the 2 groups using unpaired t-test. Pearson's correlation coefficients were calculated between all continuous characteristics (i.e.: 6MWt, 10MWt) while Spearman's correlation coefficient was adopted for ordinal outcomes (CMTES, WALK 12, BBS, SPPB).

RESULTS

To date we completed the evaluation of 15 subjects (mean age 57,5±15,3). The study is still ongoing. The mean score of 8,36 at the CMTES, confirm the fact that our subjects fall within the mild to moderate degree of disease. Concerning the balance assessment, at the BBS we found a mean score of 45.29±10.1 while at the SPPB 7.1±2.1, so highlighting the risk of fall of these subjects. At the walking tests, they spent a mean time of 9,9 seconds performing the 10MWT and they paced a mean of 361,9 meters at the 6MWT. Comparing the GAITRite data of CMT and HS, we found significant differences in velocity and Step Length ($p<0.001$) at NW; at FW and DT all parameters are significantly different ($p<0.05$). In all task no difference was found in step width.

We also investigate the possible correlations between the clinical assessment and the instrumental data at the NW, finding a strong negative correlation between speed and age (-0,6), speed and 10MWT (-0,91) e CMTES (-0,5) and a strong positive correlation between speed and balance tests (BBS 0,6; SPPB 0,9) and between speed and 6MWT (0,9). No correlation was found between speed and Walk12.

DISCUSSION

The present data allow us to suggest the use of the GAITRite system as a useful and rapid tool in the walking evaluation of CMT subjects, able to assess gait modifications both in spatial or temporal parameters.

REFERENCES

[1] Reynaud V Et al. Am J Phys Med Rehabil. 2018.
[2] Vo ML et al. Clin Neuromuscul Dis. 2015 Sep;17(1):22-6.
[3] Mori L et al.; TreSPE Study Group Eur J Phys Rehabil Med. 2019 Feb;55(1):47-55.

http://doi.org/10.6092/unibo/amsacta/6260

THE BACKPACK INFLUENCE ON KINEMATIC PARAMETERS DURING THE WALK AND ITS POTENTIAL INFLUENCE DURING THE DEVELOPMENT AGE IN TERMS OF MUSCOLO-SKELETAL DISORDERS.

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INTRODUCTION

Idiopathic scoliosis, hyperkyphosis and rachialgie are the most common pathologies of the spinal column in children and adolscents. Although at the root of these pathologies there are genetic, family, behavioral and psychological components, biomechanical factors as load on the shoulders due to school backpack could play an important role in their evolution; the load daily carried by schoolchildren was estimated 9.3 kg [1]. Aim of the paper has been the investigation of the role of the school backpack during the walk trying to identify if and how much it affects walking in terms of space-time parameters and detachment from normal values considering whether it might be correlated to potential musculo-sketal disorders.

METHODS

The study has been carried out on a population of 100 normal secondary school students, aging from 14 to 15 years old (60% males). All subjects underwent a gait analysis session instrumented by the inertial device G-Sensor (BTS Bioengineering) placed in the pocket of a belt in a lumbosacral position between S1 and S2 vertebrae. The gait analysis protocol consisted in two different sessions: a free walking session and a second one walking with a backpack of 9.3 kg; each session consisted in four consecutive trials of a 15 meters walk along a straight path, spaced by a pause of at least 1 minute. The main parameters calculated by the device and considered in the study are shown in Table 1 considering for each subject the mean values between the four trials. Differences in mean values of all parameters between the two different study condition have been studied by appropriate (paired t-test or Wilcoxon matched-pairs signed rank test) two tailed ANOVA test. The test has been performed with a 95% confidence values by GraphPad Prism Software version 7.0 for Windows.

RESULTS

ANOVA results for each parameter analyzed in the two different condition are shown in Table 1.

Table 1. Anova Test between free walk and walk with backpack for each parameter

Parameters	Free Walk	Walk with Backpack
Stance Phase (%)	59.22 ± 1.41	61.50 ± 1.35****
Swing Phase (%)	40.78 ± 1.41	38.50 ± 1.35****
Initial Double Support Phase (%)	9.22 ± 1.38	11.53 ± 1.35****
Single Support Phase (%)	40.78 ± 1.40	38.44 ± 1.37****
Cadence (steps/min)	114.70 ± 9.32	113.80 ± 8.64**
Propulsion	9.69 ± 1.79	9.15 ± 1.57****

* p<0.5, ** p<0.01, *** p<0.001, **** p<0.0001 at ANOVA test

DISCUSSION

Normal values for Stance, Swing, Initial double Support, Single Support Phases are respectively: 60,40,10,40%, as can be seen in the Table 1 there is a bigger detachment from normal values in the case of walk with backpack and a significant statistical difference between the two different walking condition with a percent change of approximately 2%. We can observe a significant variation for the cadence too. Finally, the propulsion index value in the case of walk with backpack is significantly lower than during free walk; representing the slope of the straight line that follow the rising edge of the antero-posterior acceleration pattern during the single support phase, its higher value during free walk indicate a greater capacity during advancement in the single support phase. We can conclude that all parameters values are significantly negatively affected by the backpack letting to suppose a potential biomechanical overload on skeletal-muscle structures in students wearing backpack.

REFERENCES

[1] Negrini, S., Carabalona, R., & Sibilla, P. (1999). The Lancet, 354(9194), 1974.

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SURFACE EMG DURING GAIT IN CHILDREN WITH FRAGILE X SYNDROME: COULD THIS BECOME A MEASURABLE OUTCOME?

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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]. In these subjects, the most frequent musculoskeletal manifestations include severe flexible flat feet, excessive laxity of the joints, and possible scoliosis [1], that justifies a referral for gait analysis evaluation in FXS children. Management of gait deviations is complex and requires identification and understanding of the underlying causes [1]. The aim of the present study was to identify the relationship between observed musculoskeletal manifestation and altered motor control in FXS children. For this purpose, surface electromyography (sEMG) was acquired together with gait time space parameters within standard clinical ambulatory assessment conditions.

METHODS

After appropriate informed consent by the parents, 7 FXS children (mean(±SD) age and BMI respectively of 9.74(±4.18) years and 18.56(±3.32) Kg/m^2) were evaluated at the Paediatric Department, and 10 controls ((CS) mean(±SD), age of 9.09(±2.51) years and BMI of 18,11(±2.14) Kg/m^2), were evaluated at the Bioengineering of Movement Laboratory of the Department of Information Engineering (University of Padua). Kinematics and sEMG data were simultaneously acquired through four synchronized cameras (GoPro Hero3, 30fps) and 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. Time and space parameters were computed together with duration of muscle contraction, onset and offset activation timing [2] and peak of the envelope [3].

RESULTS

Despite the small sample subjects, preliminary results consistently showed the presence of an altered gait pattern associated with abnormal muscle activity: joints kinematics results showed a reduced knee flexion/extension range of motion and an excessive hip flexion over the whole gait cycle, an excessive ankle flexion at loading response and push off phases; in terms of sEMG (*Fig. 1*), FXS displayed a longer duration of right TA and right BF contraction together with a delayed activity onset.

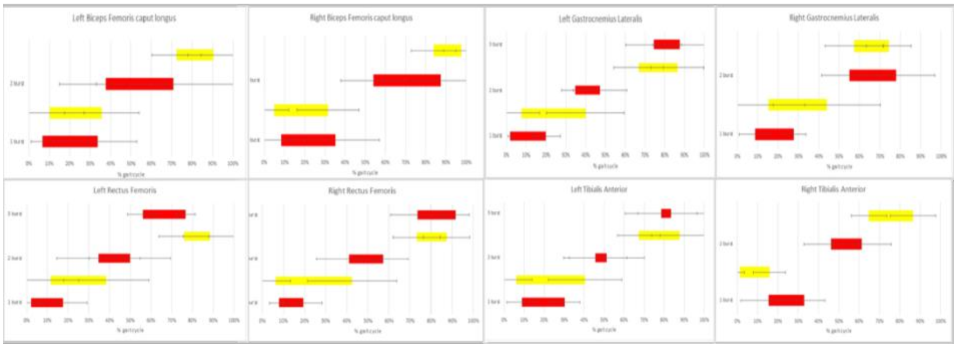

Figure 1. Duration of muscle contraction and on-off muscle timing as a function of the % of the gait cycle (yellow CS, red FXS) mean(SD).

DISCUSSION

The objective assessment of the affected individual's muscle activation timing will be useful to plan intervention aiming at restoring a more functional motor control. This information can help to determine the degree of improvement in FXS children walking ability.

REFERENCES

[1] Hagerman RJ, et al. *Nat Rev Dis Primers* 2017;Vol(3):17065.
[2] Bonato P, et al. *IEEE Trans Biomed Eng.* 1998:Vol(45(3)):287-99.
[3] Sawacha Z, Spolaor F, et al. *Gait Posture* 2012;Vol(35(1)):101-105.

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TASK-DEPENDENT ABNORMAL MUSCLE ACTIVITY IN DIABETES SUBJECTS WITH AND WITHOUT NEUROPATHY: COMPARISON AMONG OVERGROUND AND TREADMILL WALKING, STAIR NEGOTIATION.

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INTRODUCTION

Peripheral neuropathy (DPN) leading to plantar foot ulcers occurrence, loss of motor units and reduction of muscle volume is one of the most severe complications of diabetes [1]; one of the most widespread chronic diseases [1]. Several studies analyzed surface electromyographic (sEMG) signal in diabetic subjects with and without DPN, but still there isn't an agreements in terms of which are the most impaired muscles [2-4]. In the literature, the studies varied in term of either type of task or sEMG parameters analyzed (i.e. peak of the envelope, onset-offset activation timing, duration of the activation, spectral frequency analysis) [3-5]. The aim of this work was to verify the impact of different activities and type of sEMG analysis on the detection of lower limb muscle impairments in diabetic subjects (DS) with and without DPN. For this purpose 3 activities were compared: stair negotiation (SN), overground (OW) - treadmill walking (TW).

METHODS

Sixty subjects took part in the study, after signing informed consent : 20 controls ((CS) mean(± SD) age and BMI respectively of 59.8±6.3 years and 26.1±7.7kg/m²); 20 DS (mean(± SD) age and BMI respectively of 61.6±9.0 years and 26.3±2.4kg/m²); 20 diabetic subjects with DPN ((DNS) mean (± SD) age and BMI respectively of 62.0±7.8 years and 27.4±5.8kg/m²). Two sEMG systems (BTS POCKETEMG-1000Hz–OW/SN; BTS_FreeEmg-1000Hz–TW), stereophotogrammetry (6 cameras, 60-120 Hz BTS), 2 webcam (Logitech 30 Hz), 2 force plates (Bertec FP4060), plantar pressure insoles (Novel Pedar, 100 Hz) were used. During OW and SN six muscles were recorded bilaterally - Rectus Femoris (RF), Tibialis Anterior (TA), Peroneus Longus (PL) Gastrocnemius Lateralis (GAL), Gluteus Medius (GM), Extensor Digitorum Communis (EXD); during TW 4 of the 6 muscles were acquired (RF, TA, GAL, EXD). sEMG activity duration, onset-offset, envelope peaks were determined [3,5].

RESULTS

During OW shortened interval of activation on TA and differences in duration of RF and GM were detected in both DNS and DS, while prolonged duration of left PL activity was observed only in DS. During TW a shorter duration of both EXD and GAL's activity was observed. SN revealed differences in PL and GM duration of contraction.

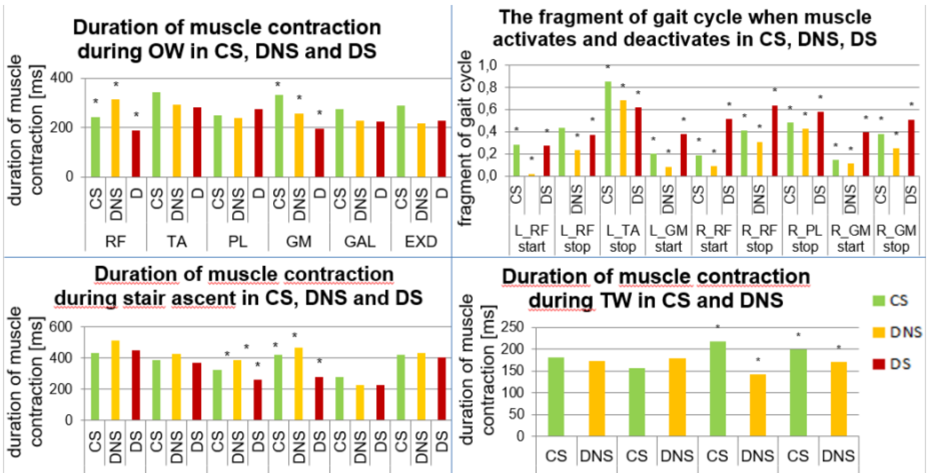

Figure 1. Duration of muscle contraction, onset and offset activation during gait; duration of muscle contraction stair ascent (in CS, DNS and DS) and treadmill exercise (CS, DNS) (*-significant difference)

DISCUSSION

The key finding of this study should be considered that the alterations detected in lower limb muscles activity on both DS and DNS with respect to CS varied across the different tasks. This should be taken into account when adopting sEMG as a screening for detecting muscle impairments in these subjects.

REFERENCES

[1] Boulton AJM (2015). Medicine; **43**: 33-37
[3] Sacco ICN et al. (2003). Clinical Biomechanics **18**, 426–434
[4] Spolaor F, and Sawacha Z, et al. (2016) Journal of Electromyography and Kinesiology **31**, 32–3
[5] Handsaker JC, et al. (2016) Diabet Med. **33**(1):97-104

EFFECTS OF HEAVY SLOW RESISTANCE TRAINING AND SUPERIMPOSED NEUROMUSCULAR ELECTRICAL STIMULATION ON QUADRICEPS STRENGTH AND PAIN IN ATHLETES WITH PATELLAR TENDINOPATHY: A PRELIMINARY INVESTIGATION.

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INTRODUCTION

Heavy slow resistance exercise (HSRE) is the most recommended treatment for patellar tendinopathy [1] as it allows to gradually increase tendon load and neuromuscular activation during a training program. It has recently been shown that superimposing neuromuscular electrical stimulation (NMES) is effective to address tendon pain in subjects with surgically damaged patellar tendon [2]. The aim of this study was to compare the effects of HSRE and NMES superimposed to voluntary movements on muscle strength and pain of athletes with diagnosed patellar tendinopathy.

METHODS

Ten athletes diagnosed with patellar tendinopathy were recruited and randomly allocated to either the NMES group or HSRE group. Both groups were trained 3 times a week for 8 weeks. NMES group participants performed a training protocol involving NMES of the quadriceps muscle superimposed on repeated sit-to-stand-to-sit exercises, whilst HSRE group participants performed a training protocol involving repeated knee-extensions and flexions on a leg-press machine. For both groups the eccentric contraction of the quadriceps lasted 6 s and the concentric action lasted 2 s. NMES group exercise intensity was increased throughout the programme by increasing current intensity, from 0 to 120mA, and frequency, from 35 to 85 Hz. In the HSRT group exercise intensity was increased by increasing loads, from a load corresponding to 10 repetition maximum to a load corresponding to 4 repetition maximum.
Knee extensor muscles strength was measured during a maximal voluntary isometric contraction at 30° and 90° knee angle. Peak forces exerted by each limb during the assessments were recorded and normalized by body weight. Knee pain was assessed using the Victorian Institute Sports tendon Assessment questionnaire for Patellar tendon (VISA-P). Assessments were performed at the beginning of training (T0), after two weeks (T1) and at the end of training (T2).

RESULTS

In the NMES group quadriceps strength increased at 30° in the right limb from T0 to T1 (0.52 ± 0.15 vs. 0.72 ± 0.15, $p<0.05$), and from T1 to T2 (0.72 ± 0.15 vs. 0.90 ± 0.14, $p<0.05$), and in the left limb from T0 to T1 (0.58 ± 0.15 vs. 0.79 ± 0.08, $p<0.01$), and from T1 to T2 (0.79 ± 0.08 vs. 0.92 ± 0.12, $p<0.05$). A tendency towards significance was observed in the HSRT group at 30° from T0 to T1 in the right (0.80 ± 0.26 vs. 0.97 ± 0.17) and the left limb (0.84 ± 0.24 vs. 0.97 ± 0.14). At 90° knee angle the NMES group increased in the right limb from T0 to T1 (0.58 ± 0.15 vs. 0.71 ± 0.11, $p<0.01$), and from T0 to T2 (0.58 ± 0.15 vs. 0.89 ± 0.21, $p<0.01$), and in the left limb from T0 to T2 (0.67 ± 0.17 vs. 0.94 ± 0.34, $p<0.05$).
For the VISA-P score no significant differences between the two groups were observed at all time points, but there was a significant increase across time from T0 to T2 in both NMES group (from 45.2 ± 17.2% to 80 ± 13.9%, $p<0.01$) and HSRT group (from 61.6 ± 29.9% to 86.8 ± 13.4%, $p<0.05$).

DISCUSSION

HSRT and superimposed NMES were both effective in increasing quadriceps muscle strength and decreasing knee pain in athletes with patellar tendinopathy. These preliminary results suggest that NMES superimposed during an easy unloaded functional movement has similar effects on quadriceps muscle strength and knee pain of resistance training with high heavy loads, thus suggesting that both exercises generate an adequate loading for tendon healing. In addition, it should be noted that knee pain decreased as quadriceps muscle strength increased. These preliminary results should be confirmed by including a higher number of participants.

REFERENCES

[1] Kongsgaard M, et al. *Scand J Med Sci Sport* 2009;19:790-802.
[2] Labanca L, et al. *Med Sci Sport Exerc* 2018;50:407-416.

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EFFECT OF DIFFERENT RUNNING SHOES ON RUNNING KINEMATICS AND PLANTAR SKIN TEMPERATURE

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INTRODUCTION

Foot and ankle injuries are estimated to account for 31% of total running injuries sustained by recreational runners. Running shoes affect the risk of foot injuries and pathologies (e.g. plantar fasciitis, diabetic foot…), because of their influence on biomechanics and thermoregulation during running[1]. Local thermoregulation modifies the thermographic profile of the foot, that can be evaluated by the use of infrared thermography (IRT).

The aim of this study was to investigate the effect of three different running shoes on running biomechanics (spatio-temporal parameters and foot strike patterns) and on the skin temperature of the rearfoot (RFOOT) and forefoot (FFOOT).

METHODS

Ten experienced male middle-distance runners (age 24±4 years, BMI 20,9±1,8) participated in the study. Each participant performed three treadmill running trials (15 minutes each, three times/week) at 13 km/h. Three models of shoes for long distance run were used randomly in each trial: a neutral one (Nike Pegasus 34 - PE), a model for over-pronation (Nike Structure 21 – STR), a lightweight model (Nike Flex 2017 - FL). Running spatio-temporal parameters (Contact Time, Flight Time, Stride Length and Cadence) and foot strike patterns (rearfoot/forefoot strike pattern at Initial Contact and overpronation/pronation during mid-stance) were observed during the last five minutes of the trial, while the skin temperature of rearfoot (Tr) and forefoot (Tf) were recorded at the beginning and at the end of each trial[2]. Spatio-temporal parameters and foot-strike patterns were registered with an optoelectronic system (Optogait, Microgate) and a 90Hz camera (Logitech) used for manual digitation. The thermocamera used was a FLIR A320 with an image resolution of 320x240 pixels, image frequency set at 1 Hz, and emissivity set at 0.98. Thermographic acquisitions were performed in a climate controlled-room, with the subject placed two meters far from the camera. The athletes were required not to: use body lotions, smoke, or drink coffee before the thermographic examination. One-way repeated measures ANOVA and Bonferroni post-hoc test were carried out to analyse the influence of running shoes on spatio-temporal parameters and the difference of temperature (ΔT) of rearfoot and forefoot.

RESULTS

Between-shoes differences were not found in terms of spatio-temporal parameters, Foot-strike patterns at Initial Contact and Mid Stance and thermographic measures ($p>0,05$).

Differences in thermographic measures were not significant but a trend was observed: ΔT STR was lower compared to PE and FL both at rearfoot than forefoot ΔT STR. At rearfoot ΔT STR measured 4±2,08°C, ΔT PE was equal to 6,33±2,33°C and ΔT FL to 6,02±2,74°C. At forefoot ΔT STR was 8,59±2,32°C, ΔT PE and FL 9,22±2,46°C and 9,18±2,32°C respectively).

DISCUSSION

Spatio-temporal running parameters and foot-strike patterns did not change when different models of shoes are considered. Participants in the study appear to be able to keep unchanged their own running pattern in function of shoes' model, probably because they were all expert runners.

The absence of differences in foot skin temperature between-shoes could be to due to the fact that these shoes' model have similar insulation/breathability, that had been suggested to strongly affect foot temperature[3]. On the other hand, the slight lower value of ΔT STR compared to PE and FL, could became significant increasing the number of participants. Future studies may investigate the impact of different model of shoes in fatigue conditions, when it is more difficult to have a good control of running pattern.

It has be supposed that the technologies and the peculiarities of each shoes could come out when occurs the fatigue.

REFERENCES

[1] AS Tenforde et al. *Phys Med Rehabil Clin N Am* 2016 Feb;27(1):121-37.
[2] L Simoni et al. *Gait & Posture* 2017;57:31-32.
[3] JIP Quesada et al. *Applied Optics* 2017;56(19).

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HOW IMPAIRMENT AFFECTS WHEELCHAIR TENNIS SERVE MECHANICS: CASE STUDY FOR TWO ELITE PLAYERS BELONGING TO DIFFERENT DIVISIONS.

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INTRODUCTION

Success in wheelchair tennis (WCT) is greatly dependent on serve effectiveness. While hitting an optimal serve, lower and upper body segments follow the kinetic chain. However, in WCT, according to the impairment severity, a break in the chain occurs at different levels, with potential implications on the serve performance. Therefore, to improve service quality, knowledge of the stroke mechanics is essential to support evidence-based coaching and training programs. Eligible impairments are grouped in two divisions, open and quad, in accordance with the extent of mobility limitation they cause. The aim of this study was to quantify how the impairment severity influences serve outcomes; comparing ball, racket and upper limb joints kinematics between two elite WCT athletes playing in different classification, while performing their best serve.

METHODS

Two professional, male, WCT players belonging respectively to the Open and the Quad class were studied using high speed video cameras operating at 200 Hz and an optoelectronic motion analysis system (400Hz) while performing their favourite serve. Reflective markers were attached to the participant's bony anatomical landmarks, wheelchair, racket and tennis ball. National coaches identified, through a qualitative analysis of the video recordings, the best serve for each participant. Angles and angular velocities of racket, shoulder, elbow and wrist were calculated.

RESULTS

The ball speed straight after impact was higher for the Open athlete, as well as racket angular velocity and linear speed (132 Vs 104 Km/h; 46 Vs 37 rad/s; 36 Vs 30 m/s). The sequence of the joint's peak angular velocities just before impact were: elbow extension, wrist palmar flexion and shoulder internal rotation. As shown in Fig.1, at impact the maximal internal rotation was reached in both participants, with lower values for the Quad division (16 Vs 46 rad/s). The elbow was more extended in the Open participant (179° Vs 135°). Wrist palmar flexion was only slightly different between the two.

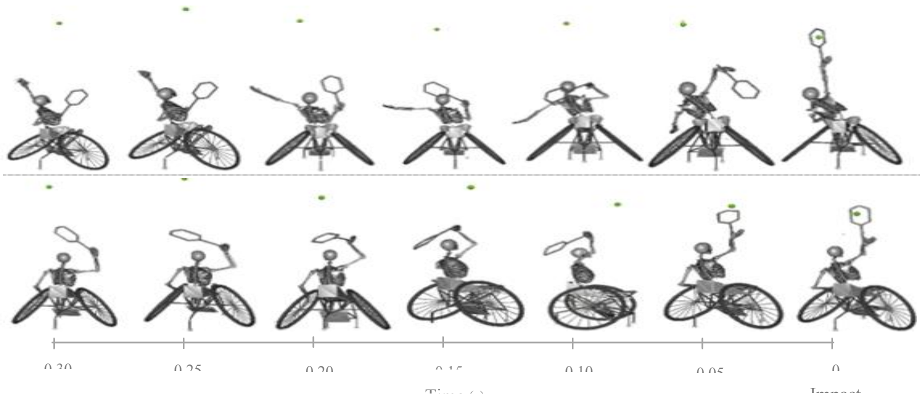

Fig.1 Visual pre-impact time history of the best serve analysed, respectively for the Open (top) and Quad

DISCUSSION

Speed and angular velocity of the racket, and subsequently of the ball, at impact, can be substantially changed through the movements of the upper limb segments. The impairment severity has a substantial impact on optimal serve performance.

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GAIT HARMONIC STRUCTURE OF WALKING IN PATIENTS WITH NEUROLOGICAL GAIT DISORDERS

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INTRODUCTION

Harmony is an important feature of physiological human gait warranting for efficient and smoothed movements during walking [1]. It has been found that the ratio between some gait elements (e.g. the ratio between the duration of the stance and that of the swing phase) was close to golden ratio (Φ=1.618) in healthy subjects, and far from it in several neurological gait disorders [1]. A recent study has suggested that gait harmony ratio may work as attractor that relates to some gait determinants including gait speed, variability and energy expenditure [2]. The aim of our study was to verify whether the changes of these gait features are responsible for the lost of gait harmony in several neurological gait disorders.

METHODS

A total of 192 patients [28 with cerebellar ataxia (CA); 49 with hereditary spastic paraparesis (HSP); 23 with hemiparesis (H); 12 with Charcot-Marie-Tooth (CMT); 80 with Parkinson's disease (PD)] and 67 healthy controls were included (C). Patients and controls walked barefoot at comfortable self-selected speeds along a 8-meter walkway with 22 passive spherical markers placed over prominent bony landmarks according to a validated biomechanical model [3]. Three golden ratios, stride/stance, stance/swing and swing/double support, and then the relative percentage errors (the ratio of the difference between Φ and the evaluated gait ratios and Φ) were evaluated. All the gait ratios of each patient groups were compared with those of the corresponding control groups, matched for gait speed, energy consumption, step-to-step variability, and anthropometric characteristics.

RESULTS

When matched only the gait speed, higher values of the relative percentage errors were found in all neurological gait disorder groups than control groups (see Figure 1 a). Conversely, at matched speed, energy consumption and step-to-step variability, almost all gait disoreders, with the exception of the hemiparetic patients, did not differ from the healthy controls (see Figure 1 b)

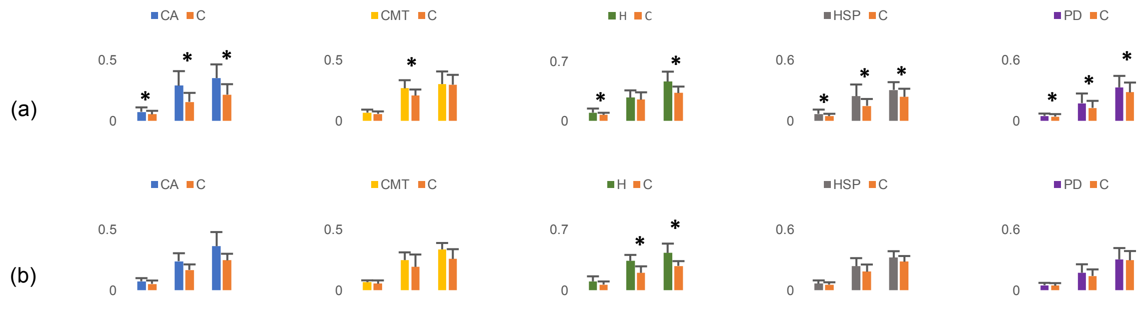

Figure 4: The relative percentage errors of the three golden ratios [(GC/St-ϕ)/ϕ, (St/Sw-ϕ)/ϕ and (Sw/DS-ϕ)/ϕ)] for each patients group and the relative healthy controls matched for only gait speed (a) or for gait speed, energy consumption and step-to-step variability (b). GC=gait cycle; St=stance; Sw=swing; DS=double support

DISCUSSION

These findings suggest that gait speed, balance-related gait variability and energy consumption are important features that determinate the divergence from the φ in neurological gait disorders possibly leading to the lost of gait harmony. Furthermore, we might speculate that the peculiar strong asymmetry of the hemiparetic gait may represent another important factor that moves the gait ratio away from the golden ratio.

REFERENCES

[1] Iosa M, et al. *Biosystems*. 2018;165:31-39.
[2] Serrao M, et al. *Clinical Biomechanics*. 2017; 48:15–23
[3] Davis III, et al. *Human Movement Science*. 1991;10:575–587.

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XX Congresso SIAMOC

LOWER LIMB TOTAL ABSOLUTE ANGLE AS INDEX OF BIOMECHANICAL INVARIANCE

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INTRODUCTION

The absolute angle is the angle of inclination of body segment relative to a fixed reference in the space [1]. This angle describes the orientation of a segment in space. Aim of this work is to study the absolute angle for exploring the biomechanical gait constraints. Four pattern of gait analysis were used to explore the biomechanical constrains: normal gait (healthy, H), Cerebral Palsy (CP), Charcot Marie Tooth (CMT) and Duchenne Muscular Dystrophy (DMD), that is, central peripheral and muscular disorders. The absolute angle for thigh, leg, and foot were considered.

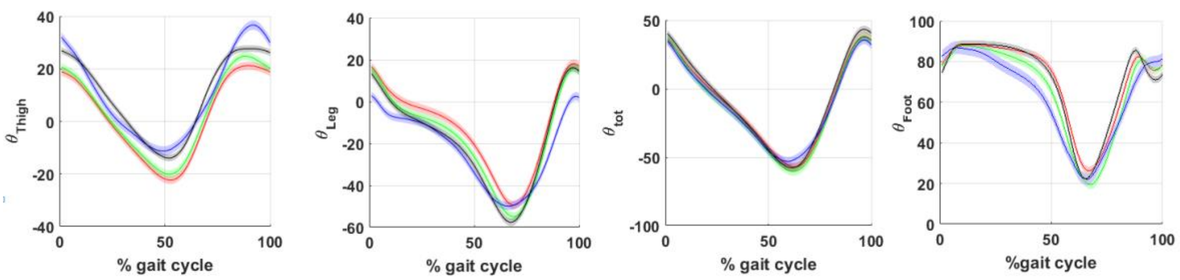
METHODS

Thirty children affected by CP (10 pts), CMT (10 pts), DMD (10 pts) and healthy (12 pts) underwent a gait analysis with eight-cameras motion capture system (Vicon MX, UK). Markers were located on anatomical landmarks of the subjects as indicated by Plug-in-Gait protocol to reconstruct a full body model. Three gait cycles were acquired for each patient, the kinematic parameters were collected for the lower limb to describe the biomechanical pattern. The absolute angle of thigh, leg and foot were calculated using the trigonometric relationship of the tangent [1]. For each absolute angle curve were calculated: mean, range, initial contact, maximum and the minimum. The Kruskal-Wallis test and a post – hoc with Bonferroni correction to determine if there were significant differences in the absolute angle parameters between the four pathologies (CMT, DMD, CP and healthy group) was used.

RESULTS

Absolute angle parametersof the thigh and the leg were statistically significant differences between H- CMT, H - DMD, CMT – CP, and DMD-CP. In the analysis of lower limb (thigh and leg), the max of shape between H and CP is statistically significant. The same result was returned in the analysis of the foot curve (Figure 1).

Figure 1. Absolute angle of thigh (Θ_{Thigh}), leg (Θ_{Leg}) , foot (Θ_{Foot}), and lower limb (thigh and leg, (Θ_{tot})). CMT = red, DMD = green, CP = blue and H = black.



DISCUSSION

From the analysis of the absolute angles it emerged how at local level the single segment (thigh and leg) behave differently depending on the pathology, instead if we study the lower limb at a global level (thigh more leg), a biomechanical constraint emerged. Each segments separately compensates for the disease deficit in order to maintain the global requisite, that is, a biomechanical invariance.

REFERENCES

[1] J. Hamill et al. Biomechanical basis of human movement: Fourth edition, 2014.

Sessione 8 – NEUROFISIOLOGIA DEL MOVIMENTO

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MY KINEMATICS AS A TEMPLATE TO DECODE YOUR ACTIONS: THE ROLE OF MOTOR RESONANCE IN INTENTION PREDICTION

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INTRODUCTION
Understanding the intention of others is an essential component of social behavior. The neural bases underlying this process have been identified in the motor system, specifically in the mirror mechanism [1,2]. Recent studies have demonstrated that the kinematics of an action is modulated by the underlying motor intention [3], and that difference in observed kinematic patterns explains the performance in the recognition of others' intents [4]. However, an open question is whether decoding others' intentions based on their kinematics depends solely on how much this varies across different actions, or rather it is also influenced by the similarly with the observer motor repertoire.

METHODS
We performed a kinematic study including two tasks on the same group of 21 volunteers. In the first, participants were asked to perform a series of reach-to-grasp and place actions, which differed for the final motor intention regarding the size of the target (i.e., put an object in a big or a small container) or the presence of a social content (i.e., put an object in a box or give it to another individual).
In the second task, participants were asked to observe and predict the motor intention of an actor executing one of the actions previously performed. During the observation, the placing phase was visually-occluded requiring the participant to predict the intention from the observation of the sole reach-to-grasp phase.
The reaching and grasping kinematics of the participants and of the actor were recorded with the 3D-optoelectronic SMART system (BTS Bioengineering, Milano, Italy). Wrist and fingers markers position was monitored time-wise to calculate reach trajectories ($R_{x\text{-FORWARD}}$, $R_{y\text{-VERTICAL}}$, $R_{z\text{-LATERAL}}$), reach velocity (R_{VEL}), grasp aperture (fingers distance, GA) and grasp velocity (G_{VEL}). Moreover, the vertical projection of the distance between the wrist and the elbow markers was calculated (WE_y). This variable may be considered as an indirect estimation of the wrist rotation during the reaching movement.
Repeated measures ANOVAs were carried out on kinematic variables including SIZE and CONTENT as within-subjects' factors. The Linear Fit Method (LFM), complemented with the Root Mean Square Error (RMSE), was selected to assess the waveform similarity between each participant and the actor. The correlation between R^2/RMSE values and the intention recognition accuracy was evaluated.

RESULTS
The results showed that reach and grasp kinematics was modulated by the different motor intentions. A main effect of factor SIZE was found for $R_{y\text{-VERTICAL}}$($p<0.04$), GA ($p<0.03$) and mean G_{vel} ($p=0.03$). A main effect of factor CONTENT was found for R_{VEL} ($p=0.04$, $p=0.03$) and WE_y ($p=0.005$; $p=0.04$).
Reach elevation was higher and fingers aperture resulted wider and faster when participants had to place the object in a big target compared to a small target. When the task required a social action, the reaching was slower and the vertical wrist-elbow distance resulted smaller.
Participants evidenced above chance accuracy in predicting the final intention of the action in the observation task, with higher performance for SIZE condition (85%) with respect to CONTENT condition (73%). Grasp Aperture R^2 and RMSE values significantly correlated with SIZE recognition accuracy (R^2-GA: $r = 0.64$; RMSE-GA: $r = -0.54$). Instead, the recognition accuracy in CONTENT condition showed a significant correlation only for one parameter, i.e. WE_y ($r = -0.53$), partially in line with the higher variability between the participants and the actor in terms of kinematic pattern .

DISCUSSION
The present study reveals that during action observation, low-level motor features provide cues for decoding the intentions of others and, more importantly, that their effect depends upon how similar they are to the observer motor repertoire. This provides further support to the view of action intention recognition as a visuo-motor process mediated by the motor mirror mechanism.

REFERENCES
[1] Rizzolatti G et al., *Physiological Reviews.* 2014; 94: 655–706.
[2] Rizzolatti G et al., *Functional Neurology.* 2007; 22, 205–210.
[3] Egmose I et al. *Journal of Motor Behaviour.* 2018; 50, 155–165.
[4] Cavallo A et al. *Scientific Report*. 2016; 6, 37036.

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GAIT INITIATION IN CHILDREN WITH JOUBERT SYNDROME

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INTRODUCTION

Joubert syndrome is a congenital cerebellar ataxia with autosomal recessive or X-linked inheritance. The diagnostic hallmark is the so-called molar tooth sign, a unique cerebellar and brainstem malformation recognizable on brain imaging [1]. Gait initiation is an interesting task for studying the impairment of balance and coordination caused by the cerebellum damage.

METHODS

We enrolled 5 children with Joubert Syndrome (JS group, mean age: 12±4 years), 5 affected by congenital cerebellar ataxia with slow and mild progression (CA, mean age:11± 2.3 years) and 5 healthy children (H group, mean age: 11±2 years). Kinematic data were optoelectronically recorded (SMART-E, BTS, Italy) using a full body 29 marker set [2]. A dynamometric force plate (KISTLER, Winterthur, Switzerland,) was used to measure the center of pressure (CoP) displacements. Surface EMG activity from Tibialis Anterior (TA) and Soleus (SOL) of each leg was recorded by wireless probes (FREEEMG 1000, BTS, Italy). A clinical evaluation with the SARA scale for ataxia was also performed. Subjects were asked to stand quietly on the force plate for 30 seconds, then start walking spontaneously after a vocal prompt, self-selecting the leading limb and feet position. For each recorded variable, the median value among the three groups was compared by a Kruskall-Wallis test, followed by Steel-Dwass post-hoc on each pathological group vs. the healthy one.

RESULTS

During the standing phase, preceding the first step, we found a larger confidence ellipse area and wider medial-lateral oscillations in pathological groups with respect to H group. These differences were found statistically significant just for CA group.

The main parameters characterizing APAs did not show significant differences among the groups.

CA children showed a significantly reduced first step length (Table 1). Finally TA and SOL EMG patterns were comparable among the three groups of subjects. The same was true for the timing of TA activation and of SOL inhibition in both legs.

Table 1. Gait initiation parameters shown as median (range). BoS: base of support; FL: foot length; BH: body height. * $p<0.05$, Steel-Dwass test.

	JS	CA	H
Medio-lateral range (%FL)	12.58 (6-15.02)	39 (15-41) *	7.5 (5.23-16.6)
Anterior-posterior range (%FL)	11.52 (8.22-17.09)	23 (15-26)	8.75 (7.33-29.60)
First step length (%BH)	32.39 (25.41-35.43)	25.09 (23.29-28) *	39.89 (29.94-45.05)
Ellipse Area (%BoS)	0.49 (0.23-1.62)	2.87 (0.88-4.93) *	0.23 (0.11-1.8)

DISCUSSION

The changes in CoP area and medial-lateral oscillations during standing confirm that CA is associated to an impaired control of balance and difficulties in maintaining the upright posture**.**

The comparable results between JS and H might be due to the compensatory strategies adopted since the earlier stages of their psico-motor development. Indeed, it might be argued that the non-progressive nature of the defect would have allowed a more efficient compensation.

REFERENCES

[1] Romani EM, et al. *Lancet Neurology* 2013;12(9):894-905.

[2] Ferrari A, et al. *Gait & Posture* 2008;28:207-216.

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SHUNT SURGERY EFFICACY IN IDIOPATHIC NORMAL-PRESSURE HYDROCEPHALUS: EVALUATION WITH INSTRUMENTED TUG

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INTRODUCTION

Idiopathic normal pressure hydrocephalus (iNPH) is a neurodegenerative, yet reversible, disease of the senile age, characterized by gait disturbances [1]. This condition is treatable via a cerebral shunt. CSF tap test (CSFtt) is the test commonly used to give indication to shunt surgery. Inertial sensors allow nowadays to accurately measure and analyze the modification of gait performances over screening tests or interventions in the clinical routine. In the present study the ability of the CSFtt to predict the outcome of shunt surgery was evaluated in terms of improvement in gait performance.

METHODS

Sixty-six patients suspected of iNPH performed a 3m instrumented Timed-Up and Go test (TUG) pre, 24 and 72 hours post the CSFtt (T24h; T72h) and 6 months after shunt surgery (T6m). The diagnosis of iNPH was assessed according to [1] via a clinical and neuroradiological evaluation. Patients were stratified in two groups: iNPH and iNPH with vascular encephalopathy (v-iNPH). The TUG was instrumented with mGait (mHealth Technologies, IT) a system based on a smartphone and 3 inertial sensors, two wore on the shoes and one on the trunk [2]. mGait was used to obtain accurate gait spatio-temporal and trunk posture parameters.

RESULTS

Patients (32.5% women; mean age 75 yo) were clinically divided in 46 iNPH and 20 v-iNPH. In Figure 1a the pre vs T24h and T72h and in 1b the pre vs T6m values for number of steps to perform TUG, are reported. The values obtained in T72h were preferred to the ones at T24h. Figure 1c reports the scatter plot of the stride length difference between pre vs T72h on x axis and pre vs T6m on the y axis.

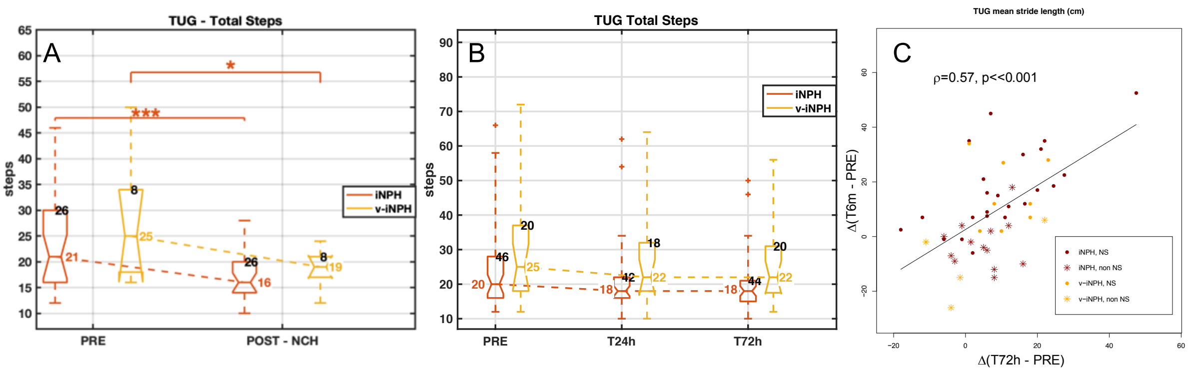

Figure 1. 1a: Pre vs T24h and T72h; 1b pre vs T6m for number of steps in TUG. Red box-plots report values of iNPH, and yellow of v-iNPH. Statistical comparisons are made with Wilcoxon signed rank test. p-values: *< 0.05; **< 0.01; ***< 0.001. 1c Pearson correlation coefficient of (T72h minus pre) vs (T6m minus pre). NS (non NS) refers to whether patients underwent (respectively, did not undergo) the neurosurgical intervention.

DISCUSSION

In this study, iNPH patients showed an improvement in gait performances post-CSFtt correlated with the outcome of shunt surgery treatment as testified by a Pearson correlation coefficient value of 0.73. In conclusion the use of instrumented motor test such as TUG is able to objectify performance modification due to CSFtt therefore strengthening its validity as indicator to surgery in iNPH.

REFERENCES

[1] Relkin N, et al. *Neurosurgery* 2005; 57(3): S4-16.
[2] Ferrari A, et al. *IEEE Trans Neural Syst Rehabil Eng*. 2016;24:764–73.

3D-GAIT ANALYSIS AND BRAIN CONNECTIVITY STUDY IN ON-OFF PARKINSONIAN PATIENTS

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INTRODUCTION

Motor impairment is the main cause of disability in patients with Parkinson's Disease (PD). Symptoms are typically controlled by dopaminergic therapy. The aim of our study is to evaluate how L-dopa modulates movement, topology of the brain network and the clinical profile of patients.

METHODS

20 PD patients (age 64+/-12.28, education 10.85+/-3.58 and BMI 26.61+/-2.76) underwent to clinical examination (UPDRS III, H&Y), Magnetoencephalography (MEG) evaluation and Gait Analysis (GA) assessment using stereophotogrammetric Qualysis system (120 Hz, 55 passive markers)[1]. We analyzed 2 experimental conditions: off and on antiparkinsonian medications[2]. Through the 3D-GA we examined Spatio-Temporal and Ankle, Knee and Thigh kinematic parameters, normalized for the 100% of gait cycle, calculating the Δs value as a difference between two consecutive peaks of gait cycle. We calculated the effect of L-Dopa of each parameter (*p*) as it follows: $X = [(pOn-pOff) / pOn] x100$. Than we correlated the X values of the significant parameters with the clinical data. Connectivity data were recorded in resting state condition with closed eyes for 2 intervals of 3.5 minutes.

RESULTS

Through GA, patients showed statistically significant improvements of velocity parameters (increased speed, cadence and stride length and a reduction cycle time) and stability (decrease of stride width, Stance time and its coefficient of variability (CV), double limb support time (DBL) and DBL/SLS (single limb support time). Kinematic parameters show an improvement of RoMs of Ankle (increased of plantar flexion during the phases of initial contact (IC), load response(LR) and pre-swing phase (PS), and a reduction of dorsiflexion in terminal swing (TSw)) and of the knee (increase of flexion during the phases of IC, LR, of terminal stance (TSt) and PS, and of the extension of TSw. Moreover, we found direct correlations between some spatio-temporal and kinematic data and clinical parameters. More specifically, UPDRS III correlates with speed ($p < 0.05$), Knee Δ1 ($p < 0.05$) and Δ4 ($p < 0.01$). H&Y correlates with speed, stride length ($p < 0.01$), Ankle Δ1 ($p < 0.05$), Knee Δ1 ($p < 0.01$), Δ3 ($p < 0.01$) and Δ4 ($p < 0.001$).

MEG evaluation does not highlighted statistically significant differences between the 2 conditions.

DISCUSSION

The data demonstrate the positive effect of L-DOPA treatment on walking performance. In fact the spatiotemporal parameters are improved after pharmacological assumption. The RoM of the ankle and knee increases in almost all phases of the gait cycle, indicating a lower joint stiffness. The gait analysis allows to observe the performance of the gait, supporting the clinical motor evaluations of PD patients. Unlike motor parameters, dopaminergic therapy does not seem to lead to differences between on-off conditions on brain connectivity.

REFERENCES

[1] Liparoti M et al. Mult Scler Relat Disord. 2019 Apr; 29: 100-107.

[2] Smulders K et al. Parkinsonism Relat Disord 2016 oct 31: 3-13.

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DOPAMINE-DEPENDENT MEASUREMENTS OF GAIT INITIATION IN SUBJECTS WITH PARKINSON'S DISEASE

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INTRODUCTION

Gait initiation (GI) has been intensively studied in subjects with Parkinson's disease (PD) being a task that greatly challenges the balance control system, which can be affected in these patients. Additionally, GI is characterized by anticipatory postural adjustments (APA), a *feedforward* motor program centrally activated with a possible contribution of the basal ganglia. Until now there is poor agreement on the alterations of GI in patients with PD and the contribution of dopamine in the production of APA at GI is unclear. This might derive also from the little attention given to the influence of the Base of Support (BoS) and the Anthropometric Measurements (AM) on the performance of the GI task [1]. Indeed, subjects with PD might increase their BoS to counteract a disease-related postural instability. In this study, we aimed to identify which GI alterations are PD-specific and dopamine-dependent, controlling for the influence of the BoS and the AM.

METHODS

Twenty-six PD subjects and 27 age-matched healthy subjects (HS) were instructed to stand on two dynamometric force plates (Kistler, 9260AA) and to start walking at their preferred speed after a vocal prompt. The BoS was self-selected by the subjects. All patients executed the task in the meds-off state (i.e. after overnight suspension of all dopaminergic drugs) and a subgroup of 13 patients also in the meds-on state (i.e. at 1h from the oral intake of 200/50mg of levodopa/benserazide). Each subject performed the task at least three times (range: 3-6). The phases of the APAs (i.e. Imbalance [IMB] and Unloading [UNL]) were identified by inspection of the Centre of Pressure (CoP) tracks. The main features of the BoS and the CoP during IMB and UNL were calculated with ad hoc Matlab algorithms. Results were averaged across trials. The main AM were measured for each subject. A partial correlation analysis was performed to investigate and disentangle the specific influence of the BoS and the AM on the GI parameters. The GI parameters dependent from the BoS were excluded from further analyses, while the ones influenced by the AM were normalized [2]. PD in meds-off condition and HS were compared with a Wilcoxon test. The effect of levodopa on the GI was evaluated with a matched pair test (i.e. meds-off vs. meds-on). For the statistical analyses, p-value was set at 0.05.

RESULTS

All IMB parameters were independent from the BoS. The IMB CoP displacement and velocity were altered in the PD in meds-off condition and ameliorated in the meds-on condition (IMB displacement [mm], HS: 62.5±20.3 PD-off: 45.8±22.3, PD-on: 49.5±19.5; IMB max velocity [mm/s], HS: 346.5±145.0 PD-off: 260.3±156.7, PD-on: 266.6±135.1). The majority of the UNL parameters were dependent from the BoS, especially in the mediolateral direction.

DISCUSSION

Of all APA measurements, the CoP parameters of the IMB phase showed to be independent from the BoS and therefore useful for the evaluation of the GI task. IMB measurements were altered in PD patients and ameliorated by levodopa assumption. This result suggests that the lack of dopamine can affect the *feedforward* motor control at GI. Of relevance, the UNL parameters were affected by the BoS and should be carefully considered in the evaluation of the GI performance especially in pathological conditions.

REFERENCES

[1] Rocchi L. et al. *Neuroscience Letters* 2006;406: 128–132
[2] O'Malley M. *J. Biomechanics* 1996;29(5): 619-425

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EFFECTS OF DUAL TASK ON BALANCE WHILE STANDING ON A MOVABLE PLATFORM DEPEND ON VISION BUT ARE SIMILAR IN YOUNG AND ELDERLY SUBJECTS AND IN PARKINSON'S DISEASE PATIENTS

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INTRODUCTION

During quiet stance, when subjects are required to perform a cognitive task, body sway may increase. This occurs in elderly subjects (E) and in patients with Parkinson's disease (PD), but not in young subjects (Y), suggesting that, in E and PD, postural control is an attention-demanding task [1,2]. Under dynamic conditions, as it occurs when subjects stand on a platform continuously and predictably moving in an anterior-posterior direction, balance maintenance becomes more difficult, particularly without vision [3]. We studied the effects of dual task under dynamic condition with and without vision, and their relationship with ageing and PD.

METHODS

We enrolled 14 Y, 14 E and 17 PD, aged 25.3 years ± 4.1 (standard deviation, SD), 67.8 ± 9.8 and 70 ± 8.5, respectively. Cognitive function scores (MMSE) were 28/30 in Y and 26.9/30 in both E and PD. Duration of PD was 5 years ± 3.7, UPDRS score 21 ± 9, and Hoehn and Yahr scale 2.5 ± 0.5. All PD were on medications and in on-state. In the single-task (ST) condition, subjects stood for 60 s on an anterior-posterior (A-P) (6 cm) moving platform (10 cm) at 0.2 Hz with eyes open (EO) or closed (EC) after a 10-s familiarization period. The SD of the head marker trace along the A-P direction, recorded through an optoelectronic system, was taken as a comprehensive index of head and body stability [4]. In the dual-task condition (DT), participants were required to count backward by 7 during the perturbation trial. All ST and DT trials were performed twice.

RESULTS

Single task. During postural perturbations with EO, head SD was larger ($p<0.05$) in Y than E. With EC, stability decreased in all groups (Y, $p<0.05$), mainly in E and PD ($p<0.0005$) with respect to EO; in particular, E reached larger ($p<0.05$) head SD than Y, with values similar to that of PD.

Dual task. Under this condition, with respect to ST, head SD decreased with EO but increased with EC. The changes were of similar extent under both visual conditions and in all groups.

DISCUSSION

The effects of DT on postural stability on a movable platform depended on the visual condition to a similar extent in the three cohorts. Increased stability with EO suggests that all subjects presumably reduced the visual flow to concentrate on the cognitive task. Conversely, increased body sway with EC suggests that DT reduced the capability of subjects to exploit afferent input (e.g., from the vestibule and muscle proprioceptors) to generate anticipatory postural adjstments (APA) [3]. At variance with results under static condition [1,2], no major impairment was observed in E and PD, presumably because APA were not particularly affected in these groups of subjects [5].

REFERENCES

[1] Melzer I, et al. Gerontology 2001;47(4):189-94.
[2] Marchese R et al. *Mov Disord* 2003;18(6):652-8.
[3] De Nunzio AM, et al. *Exp Brain Res* 2005;165(2):261-72.
[4] Nardone A, et al. *Arch Phys Med Rehabil* 2000;81(9):1217-23.
[5] Nardone A, Schieppati M. *Mov Disord* 2006;21(9):1515-20.

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A NEW METHOD TO DETECT DIFFERENCES IN START BEHAVIOURAL CONDITIONS OF ANTERIOR REACHING ACTIVITY.

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INTRODUCTION

Anticipatory postural adjustments (APA) are unconscious activities that precede voluntary movements and actively contribute to them. Previous studies have underlined the differences in APAs under different start behavioural conditions [1,2]; all these results have been obtained even without a defined method to differentiate between APA and focal voluntary movement [3–5]. Our aim is to detect differences in APAs under different behavioural conditions with a novel method to distinguish the onset of voluntary movement.

METHODS

We obtained informed consent and evaluated 9 healthy subjects (age 22±2; gender 5 females and 4 males). Subjects performed a standing anterior reaching of a cylinder at 117 cm of height from the ground and at the 100% of the arm length. The subjects performed 3 repetitions of the movement for each of the two behavioural conditions: a reaction-time start (external trigger), and a self-placed start (free start). The behavioural conditions were randomly given to the subjects. We used a BTS SMART-DX400 (with 8 cameras, 28 markers [3] and 1 on the cylinder) and a BTS FREEEMG 300, with 8 channels measuring bilaterally: tibialis anterior (TiAn), biceps femori, rectus of the abdomen and lumbar paravertebral muscles (ESLs). The voluntary movement onset is defined as the moment in which the hand starts moving for the last time towards the object, according to the evaluation of the displacement of the markers on hand and object. Data analysis was performed in MATLAB and R environment. For each identified variable we tested the statistical difference between free start- and external trigger-samples, testing the null hypothesis of samples drawn from a normally distributed population (Shapiro-Wilk normality test), and comparing their mean and variance (Welch t-test, F-test and Flinger-Killen test).

RESULTS

The results are shown in table 1.

Table 1. *Summary of the main results. Values expressed as pValue and t-value for Welch t-test, pValue and ratio of variances (F) for F-test, pValue for Flinger-Killeen test (⍰ = 0.05).*

		Welch t test	F test	Flinger-Killeen test
Δt (voluntary movement-hand movement, on markers displacement)		.008; 2.783	.001; 3.739	.011
EMG	Activation area on right Erector Spinae	.040; 2.151	.000; .076	.026
	RMS on right Erector Spinae	.026;-2.336	.000; .113	.034
	Maximal activation on right Tibialis Anterior	.003; -3.131	.001; .249	.001
	Maximal activation on left Tibialis Anterior	.044; -2.081	.016; .379	.012
	RMS on left Tibialis Anterior	.003; -3.245	.000; .092	.001

DISCUSSION

Data analysis depicts that trials with external trigger present: i) shorter APA (Δt) in markers signals then acquisitions with self placed start, ii) more stable performances as lower values of RMS on right ESLs and left TiAn muscles at rest, iii) higher maximal activations on both TiAn muscles, and iv) a higher area subtended by the right ESLs EMG signal during the activation period. These results are consistent with the current literature [1,2]. The method developed to identify the voluntary onset proved to be robust: it does not depend on external arbitrarily-imposed thresholds but is subject-dependant, and presents a relevant repeatability. The preliminary results suggest to apply this method in clinical context.

REFERENCES

[1] F. Benvenuti et al. Brain Res. 761 (1997) 59–70.
[2] W.A. Lee et al. Exp. Brain Res. 66 (1987) 257–270.
[3] H. Saito et al. Hum. Mov. Sci. 37 (2014) 69–86.
[4] A. Caronni et al. Acta Physiol. Oxf. Engl. 208 (2013) 111–124.
[5] M. Mezaour et al. Gait Posture. 30 (2009) 239–244.

ACTION OBSERVATION AND MOTOR IMAGERY IN PARKINSON'S DISEASE PATIENTS WITH POSTURAL INSTABILITY AND GAIT DISORDERS: A GAIT ANALYSIS AND FUNCTIONAL MRI STUDY

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INTRODUCTION

Previous studies suggested the efficacy of action observation training (AOT) and motor imagery (MI) in Parkinson's disease (PD) patients, especially in reducing bradykinesia, freezing of gait and improving autonomy in activities of daily living [1-3]. The aim of this study was to evaluate the effect of an AOT-MI training including dual-task gait and balance exercises on: 1) dual-task functional mobility parameters, 2) balance and 3) dual-task functional MRI (fMRI) plasticity in PD patients with postural instability and gait disorders (PIGD).

METHODS

Twenty PD-PIGD subjects were randomized into 2 groups: i) AOT-MI+DUAL-TASK group performed a 6-week training (1 hour session, 3 times a week) consisting of AOT-MI combined with practicing the observed-imagined gait and balance exercises; ii) DUAL-TASK-group performed the same exercises combined with landscape-videos observation. Exercises were increasingly difficult up to include dual-task during complex gait and balance tasks. At baseline (T0) and week 6 (W6) patients underwent Timed up and go (TUG), TUG with cognitive dual-task (TUG-COG) and with manual dual-task (TUG-MAN), MiniBESTest, Activities Balance Confidence (ABC) and PD quality of life (PDQ-39) questionnaires. Spatio-temporal parameters of straight and turn phases during TUG, TUG-COG and TUG-MAN were obtained using a six-camera SMART DX7000 optoelectronic system. Both at T0 and W6, patients also performed an fMRI dual-task consisting of foot anti-phase movements while counting backwards by threes starting from 100.

RESULTS

Both groups at W6 showed improvements of TUG total execution time and increased velocity during the straight phase of TUG. Only the AOT-MI+DUAL-TASK group showed improvements of TUG-COG and TUG-MAN total execution time, of straight velocity during TUG-COG and of peak turn velocity during TUG, TUG-COG and TUG-MAN. The AOT-MI+DUAL-TASK group showed also improvements of balance, self-confidence and quality of life. Improvements of gait speed during the turn phase of TUG and TUG-COG, of MiniBESTest, and ABC were significantly higher in the AOT-MI+DUAL-TASK group relative to the DUAL-TASK group. AOT-MI+DUAL-TASK relative to DUAL-TASK group showed reduced recruitment of frontal, occipital, temporal areas and of the right putamen during the fMRI dual-task.

Table 1. *Comparisons within groups and between groups in time. P* values referred to Wilcoxon test (within group in time); p§ referred to Mann Whitney test on delta values (between groups in time).*

	DUAL-TASK group (N=10)			AOT-MI+DUAL-TASK group (N=10)			p§
	T0	W6	p*	T0	W6	p*	
Peak turn velocity TUG (rad/s)	125.5 ± 26.3 (85.0 – 165.5)	127.5 ± 32.7 (88.4 – 189.3)	0.99	128.6 ± 20.0 (102.2 – 153.6)	155.9 ± 27.7 (107.4 – 195.4)	0.01	0.02
Peak turn velocity TUG-COG (rad/s)	105.6 ± 25.2 (73.3 – 145.1)	114.8 ± 33.0 (75.2 – 188.9)	0.40	111.9 ± 40.0 (44.2 – 185.5)	153.3 ± 40.8 (109.4 – 251.4)	0.01	0.02

DISCUSSION

At W6 both groups showed improvements of motor performance during TUG. However, only when gait and balance dual-task exercises were preceded by a motor-learning facilitation strategy (AOT-MI), patients showed functional mobility/balance improvements and increased brain efficiency during dual-task circumstances, which are among the most challenging for PD-PIGD patients.

REFERENCES

[1] Agosta F, et al. J Neurol 2017;264:88-101.
[2] Pelosin E, et al. Neurorehabil Neural Repair 2013;27:552-560.
[3] Pelosin E, et al. Neurorehabil Neural Repair 2010;24(8):746-52.

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