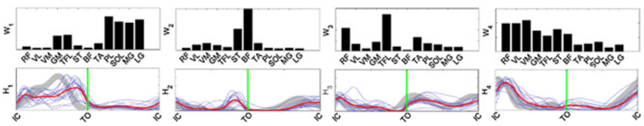

Fig. 1. Average synergy vectors W and H profiles, in arbitrary units. Grey: range of control subjects. Blue: single TF subjects. Red: average TF activation profiles. Vertical line: Toe Off.

itation process, trans-femoral amputees (TF) adapt their walking pattern to their new physical conditions. Previous studies have shown that the most significant differences in muscle activity of both legs are present during the swing phase of the prosthetic limb [2]. In the present study, modular motor control strategies in TF gait are investigated.

Methods: Data were collected in a Movement Analysis Laboratory at the Rome branch of INAIL Prosthesis Centre. 8 healthy subjects (58.5 ± 12 years old) and 16 trans-femoral amputees (52.5 ± 15 years old, wearing different kinds of prostheses) participated in the study. sEMG data were recorded from 12 muscles of the sound limb. Kinematic data were recorded with a BTS SMART DX 6000 stereophotogrammetric system. The experiment consisted of 12 repetitions of walking along a 9 m walkway at a comfortable self-selected walking speed. Muscle synergies were extracted by means of Non-Negative Matrix Factorization (NNMF), as to obtain synergy vectors W and synergy activation coefficients H (Fig. 1).

Results: Four modules were able to account for more than 90% of the variability in muscle activation for each subject. All four synergy vectors W have been found to be highly similar between the two populations (average normalized scalar product = 0.8), and modules extracted from TF amputees could well reconstruct muscle coordination of control subjects (through Non-Negative Reconstruction [3], applying NNMF with fixed synergy vectors). H1 and H2 were found significantly different in shape between populations, while all H coefficients showed a significantly delayed activation in TF.

Discussion: Results suggest that both populations share the same set of synergies. The difference in the activation of W2 might indicate a compensation, by means of an increased hip extension moment, of the reduced propulsion force during the swing of the prosthetic leg. The prolonged activation of W1 might reflect an ankle stabilization mechanism during the swing phase of the prosthetic leg. Further investigations are needed to differentiate the effect of different types of prostheses and different elapsed time from the first prosthesis implant, in order to provide a quantitative indication for a proper choice of the prosthetic device and for the most adequate treatment.

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O37

Towards performance indices for neuromuscular synergy in patients with intellectual disability

T. Caporaso [1,*], A. Palomba [2], S. Grazioso [1], D. Perez [2], G. Di Gironimo [1], A. Lanzotti [1], A. De Vito [2]

[1] *Fraunhofer JL IDEAS, DII – Università Federico II, Napoli, Italy*
[2] *Centro di Riabilitazione Don Orione, Ercolano NA, Italy*

Introduction: The diagnostic and statistical manual (DSM V) of mental disorders [1] emphasizes the need of using standard clinical methodologies to classify the impairment of patients with intellectual disability (ID) on their functional ability rather than on their intellectual quotient (IQ). Indeed, the ID often influences the motor component, resulting in poor muscular synergy and smoothness of movements. Despite the literature proposes the use of inertial sensors to evaluate kinematic parameters and smoothness of movements [2], there is no information available on adults with ID. This study aims at evaluating kinematics performance indices for smoothness movement in ID subjects by comparing their motor performances with respect to typically developed subjects (CO) of equal age.

Methods: Twelve ID adults (age 36.92 ± 8.27; 3F, 9M) and twelve CO adults (age 36.17 ± 8.44; 3F, 9M) have been involved and classified based on their level of motor activity. To make the two groups homogeneous, three subgroups of four elements (1F, 3M) have been defined: agonists (membership of their respective federations), trained (regular training sessions, at least 3 days/week), unskilled (do not performing any activity). Subjects with other concomitant pathologies, with high level of disability and/or taking psychopharmacological drug, were excluded from this study. The participants were asked to perform as fast as possible a 30-m linear run test. During the experiments, photocells (Polifemo Light Radio, MicroGate) were used to accurately measure the duration of the test. A triaxial inertia sensor (G-Sensor, BTS) was used to record data. The sensor was placed in correspondence to the L5 vertebra, which approaches to the center of mass of the body. Spatial-temporal parameters as step frequency (f), velocity, step length over height ratio (ρ) [3] have been extracted. The following smoothness performances indices have been obtained: normal total jerk for the anterior/posterior linear movements (μ), total spectral arch length (σ) and log normal total jerk for the rotations around the vertical axis (κ) [4]. The differences between the groups and subgroups have been evaluated by one-way ANOVA and Tukey test ($p < 0.05$), after verifying the homogeneity of the variance with the Levene's test.

Results: The differences between the two groups have been evaluated through the p-value. Significant differences have emerged on the duration of the tests, on ρ, and on the parameters regarding the fluidity of the movements around the vertical axis (σ and κ). These differences are even more evident for the two trained subgroups. No significant difference emerged for the f and μ values (Table 1).

Discussion: In this study, the ID subjects show a worse performance if compared to CO subjects, in terms of a lower step amplitude and a lower rotational smoothness around their vertical axis. The reason might be attributed to the reduced internal interrelations (afferent and efferent channel) of the praxia and of the neuromuscular postural synergies. Further developments will investigate the influence of performing experiments on paths with growing difficulty on these indices, eventually with the integration of electromyographic data.

Table 1
Kinematics parameters for the two groups, ID and CO (statistical differences * $p < 0.05$).

Performance indices	ID	CO	p-Value
Duration [s]	6.27 ± 1.08	5.39 ± 0.73	0.020*
f [step/s]	3.85 ± 0.24	3.92 ± 0.35	0.399
ρ [−]	0.75 ± 0.07	0.85 ± 0.08	0.004*
μ [−]	69.26 ± 39.25	55.55 ± 9.16	0.229
σ [−]	−44.20 ± 9.96	−35.20 ± 3.72	0.008*
κ [−]	146.04 ± 18.17	128.12 ± 12.72	0.009*

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O38

FES-augmented treadmill training based on muscle synergies to improve locomotion in chronic stroke patients. A pilot randomized control trial

M. Giardini [1,*], N. Chia Bejarano [2], F. Lunardini [2], M. Malavolti [2], A. Pedrocchi [2], A. Nardone [3,4], S. Ferrante [2]

[1] *Università del Piemonte Orientale, Novara, Italy*
[2] *Politecnico di Milano, Milan, Italy*
[3] *Istituti Clinici Scientifici Maugeri, Pavia, Italy*
[4] *Università di Pavia, Pavia, Italy*

Introduction: Functional Electrical Stimulation (FES) is a useful tool for the rehabilitation of post-stroke chronic patients [1]. In this study, during treadmill training, patients underwent a multi-channel FES treatment that leverages inertial sensors and muscle synergies to optimize the treatment by stimulating the impaired synergies exactly when they should have been recruited [2]. The aim of the current pilot work was to evaluate the efficacy of this treatment in improving gait in patients with chronic stroke.

Methods: Ten adult subjects with hemiparesis occurring more than 6 months after stroke underwent a three-week (12 sessions of 30 min each) gait training on treadmill. Patients were randomized into two groups: experimental (sex: 3 M and 2 F; age: 58.2 ± 6.6 years; Functional Independence Measure (FIM): 105.0 ± 10.4; Motricity Index paretic lower limb (MI): 52.6 ± 10.5) and control (sex: 4 M and 1 F; age: 53.8 ± 8.3; FIM: 120.6 ± 1.9; MI: 67.8 ± 12.5). For the experimental group, treadmill training was combined with a multi-channel synergy-based FES treatment [3]. At the beginning (T1) and at the end (T2) of the treatment, each participant was asked to perform 10 repetitions of the 10-meter Walking Test (10-m WT) while recording lower-limb kinematics (2 inertial sensors) and electromyography (9 muscles per side: Gluteus Maximum, Rectus Femoris, Vastus Medialis, Medial and Lateral Hamstrings, Medial Gastrocnemius, Soleus, Tibialis Anterior, Erector Spinae) [2]. The 4 synergies of rectilinear walking (weight acceptance, push off, trunk balance, leg deceleration) [3] were extracted and compared to those of healthy adults in terms of similarity.

Results: For all patients, treadmill speed was gradually increased during training and the final value was greater than the subject's overground self-selected speed. The main results are reported in Table 1 (mean ± strandard deviation values).

Table 1
Treatment results for the two groups.

	Experimental group	Control group
Training Gait Speed on treadmill (m/s) (T1)	0.48 ± 0.11	0.68 ± 0.05
Training Gait Speed on treadmill (m/s) (T2)	0.75 ± 0.12	0.94 ± 0.10
Gait Speed for 10-meter Walking Test (m/s) T1	0.61 ± 0.17	0.80 ± 0.15
Gait Speed for 10-meter Walking Test (m/s) T2	0.71 ± 0.17	0.83 ± 0.18
Weight Acceptance Similarity (T1)	0.58 ± 0.30	0.91 ± 0.04
Weight Acceptance Similarity (T2)	0.74 ± 0.11	0.91 ± 0.03

Discussion: Our results confirm the effectiveness of the intensive treadmill training in improving walking speed in chronic post-stroke patients. Such an improvement is larger when training is combined with FES treatment. Indeed, the average gait speed increase for patients in the experimental group was 0.1 m/s, compared to an increase of 0.03 m/s for the control group. The reported minimal clinically meaningful change for post-acute stroke patients in literature is 0.06 m/s [4], a value reasonably greater than the one for chronic patients. At the moment, we cannot exclude that the larger increase of gait speed in the experimental group may be partially due to the overall small sample size and the lower gait speed shown by the experimental group at T1, compared to the control one.

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O39

Muscle synergies and activation in Nordic walking compared with conventional walking

G. Boccia [1,2,*], C. Zoppirolli [2,3], L. Bortolan [2,3], F. Schena [2,3], B. Pellegrini [2,3], A. Rainoldi [1]

[1] *NeuroMuscularFunction research group, School of Exercise and Sport Sciences, Department of Medical Sciences, University of Turin, Turin, Italy*
[2] *CeRiSM Research Centre "Sport, Mountain, and Health", Rovereto, TN, Italy*
[3] *Department of Neuroscience, Biomedicine and Movement Science, University of Verona, Verona, Italy*

Introduction: Nordic Walking (NW) has increased in popularity in the last decades as a form of exercise for health [1]. Additional benefits of Nordic Walking compared with traditional brisk walking (W) is due to the use of the poles that requires the engagement of upper body. While metabolic responses have been widely studied, upper body muscular involvement and complexity of the gesture compared with W should be investigated. The first aim of this study was to evaluate force exerted through the pole and level of muscle activation responses to NW. Moreover, we aimed to assess whether NW, nevertheless it included a poling action, and therefore an additional task with respect conventional walking, relies on the same muscle coordination of the latter.

Methods: Eleven NW instructors volunteered to execute NW and W at 5.5 km h^{-1} on a treadmill. Body segments kinematics, poling force, and electromyographic (EMG) signals from 15 muscles of upper and lower body were measured during locomotion. EMG signals were also acquired during maximal voluntary contractions (MVC) to normalize muscle activation during locomotion.