Abstracts / Gait & Posture 33S (2011) S1–S66

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Kinematic orbital stability during step climbing in young subjects
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Introduction
Falls in the elderly represent a well known problem, having large clinical and economic consequences [1]. Many human tasks, like stairs climbing, are structurally cyclic, and result in several biomechanical time-varying variables (i.e. kinematic) which are all manifestation of the same motion pattern. Hence, kinematic data coming from different joints should not be analyzed independently when studying the kinematic pattern during the temporal evolution of the task. A better comprehension of the stability of kinematic patterns during motor tasks could give a significant contribution in assessing the risk of fall. Orbital stability allows us to study the stability of motor tasks by considering all these variables together. This approach has been applied to human walking [2] showing encouraging results; it seems to be a powerful tool for studying periodic-like systems that involve many variables like human motion. The aim of the present study was to investigate kinematic orbital stability of joint angles patterns during climbing of a single step in young subjects.

Materials and methods
A wooden step (height: 20 cm) was positioned on a force platform. Three healthy participants [25 ± 0 y, 1.74 ± 0.02 m, 70 ± 4 kg], with normal BMI and no prior history of falling, performed 3 repetitions of a step climbing test. Subjects were in the average of young healthy people in Italy [3]. The test consisted in climbing a single step and stopping over it. During the tests force plate (FP4060-07-1000, Bertec, USA) and kinematic (SmartE, BTS, Milan, Italy) data were acquired. An 8 segment model of the subject was obtained from kinematic data using CAST protocol [4].

Data coming from joint angles of lower limbs and trunk (flexion/extension, abduction/adduction, intra/extra rotation) defined a 21-dimensional state space:

\[ S(t) = \{\phi_1 \ldots \phi_{21}\} \in \mathbb{R}^{21} \] (1)

The sensitivity of kinematic patterns to small perturbations that naturally occur during step climbing was quantified using orbital stability analysis by calculating maximum Floquet multipliers (FM) using an established technique [5]. Floquet multipliers quantify how periodic systems respond to small perturbations discretely from one cycle to the next. If FM have magnitude <1, perturbations tend to shrink by the next repetition, and the system remains stable. The magnitudes of maximum FM was computed at the most significant time events of the task (leading heel off, leading toe off, leading heel strike, trailing toe off, trailing heel strike). The first limb to climb over the step is defined as leading limb, while the other limb is defined as trailing limb. All the subjects used the right leg as leading limb. The different phases of the task were identified from force plate data.

Results
All Floquet multipliers showed values <1 (Fig. 1). The values of maximum Floquet multipliers in proximity of the trailing toe off phase was slightly higher than in the other phases.

Discussion
Preliminary results obtained in investigating orbital stability of kinematic patterns during step climbing give interesting cues, and seem to confirm that the technique is adequate for studying human motor tasks.

Maximum Floquet multipliers showed values <1 in all the task phases; hence, orbital stability is maintained. The slightly higher value of mean max FM in proximity of the trailing toe off phase may entail a small physiological loss of stability in correspondence of that phase, probably due to the lower confidence of the subject in performing a phase of the task that actively involves the trailing limb.

Orbital stability analysis of step climbing in the elderly will be the object of further studies.

References

doi:10.1016/j.gaitpost.2010.10.056

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Investigating the relationship between walking energy cost and physical activity levels in young and older adults living in a city district: Application of a hierarchical clustering technique
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Introduction
The energy cost of walking (WEC) is a valid indicator of walking performance [1]. To date, it is unknown whether WEC is associated to the levels of habitual physical activity (HPA). The aim of
this study was to look at the relationship between WEC and HPA on a sample of young and older adults living in a city district, by using a hierarchical clustering approach (HC). This technique was adopted to identify natural groupings that may exist in the population of interest, with the advantage of taking into account several parameters rather than a single one for each individual [2].

### Materials and methods

Seventeen young (29 ± 2 years; mean ± S.D.) and 22 older (70 ± 3 years) healthy individuals living in a city district volunteered to participate in the study. HPA was monitored during a whole day using an inertial sensor device (IDEA MiniSun Inc.). In a separate laboratory session, participants walked on a 40-m circuit at three different self-selected speeds, each lasting 5 min: most comfortable (c), slow (s) and fast (f). Oxygen consumption was measured by a telemetric portable calorimeter (K4, Cosmed) and the energy cost of walking per unit of time (WECt) and per unit of distance (WECd) were estimated. HC analysis was performed (linkage: complete, distance: euclidean, [3]) considering both HPA and WEC. Statistical differences between clusters were then investigated using One-way ANOVA (p < 0.05). Correlation between HPA and WEC was also examined within each cluster data (SPSS v.13).

### Results

HC analysis led to definition of two distinct clusters as reported in Table 1.

No significant differences were observed between the two clusters in terms of WEC, while significant differences (*p < 0.05) were observed for the following parameters of HPA: time and counts during walking and sit to stand; mean and total speed and power; time in inclined position. In Cluster 1, WECt(c) was significantly correlated to: mean speed during walking; time, counts and speed during stepping (R ≥ 0.4, p < 0.04). WECt(f) was significantly correlated to: walking time; step speed; mean and total speed (R ≥ 0.4, p < 0.04). WECd(c) was correlated to step speed, mean and total speed (R ≥ 0.4, p < 0.04), and to walking speed, step time, count and speed, and run speed (R = 0.05, p < 0.04). Negative correlations were observed between both WECt and WECd and the habitual time spent reclining or lying. In Cluster 2, WECt was not significantly correlated to HPA, whereas only WECd(s) was significantly correlated to sit-to-stand count (R = 0.45, p < 0.05). HPA standard deviations within this Cluster were noticeably higher than those reported in Cluster 1.

### Discussion

Hierarchical clustering indicated the presence of two groups with different levels of HPA, irrespective of age: a lower and a higher HPA group (Clusters 1 and 2, respectively). In the lower group, there was an association between the level of HPA and WEC. On the contrary, in the higher group, HPA was not correlated to either WECt and WECd, which might be attributed to the high variability of HPA level within participants of Cluster 2. These results highlight the need to increase the number of clusters and verify the presence of further subgroups related to different HPA levels, such increasing the chance to find novel emerging associations between HAP and WEC.

### References


doi:10.1016/j.gaitpost.2010.10.057

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Evaluation of the upper limb motor performance of healthy and pathological children by means of a robotic device and an optoelectronic system

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### Introduction

In neuro-rehabilitation, robotic technologies introduced the ability to measure the motor performance of pathological children by means of the sensors mounted on the robotic devices. In fact, in addition to the clinical scales, some indexes can be calculated to evaluate the motor improvements of pathological subjects during robotic rehabilitation therapy. The indexes reported in literature are evaluated only at the robot end-effector and the measurement of upper limb kinematics and kinetics, such as shoulder and elbow angles and torques, can be evaluated only by means of a biomechanical model [1]. The present work is focused on the integration of robotic device sensors and an optoelectronic system in order to measure indexes of upper limb motor performance.

### Materials and methods

Seven healthy subjects (8 ± 2 years old), one pathological subject (8 years old) with stroke (manifested 8 months before the first evaluation) and one patient with cerebral palsy (6 years old) were involved in the present study. They performed circle drawing tasks (16 cm diameter) in the presence of visual feedback with the planar robot InMotion 2 (Interactive Motion Technologies, Inc.), a commercial version of the MIT Manus. The protocol consisted of clockwise and counterclockwise trials with two different starting points at three and nine o’clock. Each trial was repeated three times. The upper limb kinematics were measured by a 6-camera optoelectronic system (Vicon 512) with 9 markers applied on the upper limb and another one on the robot end-effector. The Joint Correlation (JC) index was evaluated as reported by Dipietro et al. [1]. It is an indicator of the synergy between the shoulder and elbow joints during a specific task such as circle drawing. Unlike the cited paper, the upper limb joint angles were directly measured with the optoelectronic system (Fig. 1a and b).

### Results

Fig. 1c shows the average value of Joint Correlation index for healthy subjects (A), stroke patient (B) and CP patient (C). The...