O026

The use of a new weight-bearing measuring device for accurate assessment and biofeedback training following lower limb injury and surgery

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Summary: Auditory and visual biofeedback has been utilized in stroke rehabilitation, trans-tibial amputation and the implantation of artificial joints in order to provide performance-relevant cues to both patient and clinician about the occurrence, duration, and location of a force component of motor performance. Biofeedback systems give more reliable, accurate and objective data compared to clinical examination and scales. The Smartstep™ system allows for the first time, rehabilitation to be carried out and accurately measured in all activities of daily living.

Conclusions: Patients need to return to full weight-bearing rapidly following lower limb surgery. Use of the new patient-customized auditory feedback device provides a more accurate and rapid rehabilitation tool than previous methods. It was demonstrated that auditory biofeedback was useful in stimulating added weight-bearing in those cases where there was a significant load difference between the affected and unaffected lower limb.

Introduction: The achievement of normal and bilaterally symmetrical weight-bearing ability is an important pre-requisite in rehabilitation protocols following lower limb pathology or surgery. The restoration of unilateral weight-bearing asymmetries has up to the present time relied principally on visual assessment and instructive cues, patient self-observation, training in front of a full-length mirror and standing on a bathroom scale. These are frequently inaccurate and represent unscientific rehabilitation outcome measures.

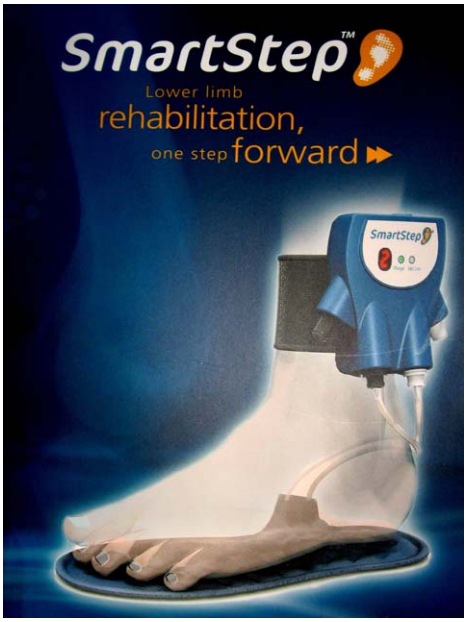

Figure 1. The Smartstep™ system.

Patients/Materials and Methods: Patients who had undergone various orthopedic traumas and surgeries were tested using the new, innovative insole device (Smartstep™, Figure 1). If a weight-bearing discrepancy was noted on evaluation, the patient-customized auditory feedback device was employed in order to attempt to restore equal weight-bearing in bilateral limbs.

Results: Whilst utilizing the new patient-customized auditory feedback device, accurate weight-bearing comparisons between bilateral lower limbs were recorded. In most cases, after a single session utilizing the feedback device, weight-bearing values were objectively and statistically improved and in some cases maintained, without the feedback device being further employed.

Discussion: It is now possible to precisely analyze and compare changes in weight-bearing parameters in subjects that exhibit changes from the norm as a result of lower-limb pathology due to injury or following surgery. These results may form the basis of rehabilitation protocols which aim to restore normal weight-bearing in some activities of daily living.

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Oral Session 5: Normal gait – Quality assurance

O027

Normalization scheme and walking speed affect signs of gait maturation

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Summary: Key gait parameters were examined for main effects of age, and interaction effects of age × speed. Differences between conventional and nondimensional normalization schemes were also tested.

Conclusions: Indicators of mature gait depend on normalization scheme and walking speed.

Introduction: Gait maturity affects treatment decisions for physical therapy, orthopaedic surgery, and neurosurgery. Studies of speed, cadence, and step length suggest that a mature gait pattern is attained by 90 months of age [1]. Examination of bodyweight-height (BWH) normalized ankle kinetics have shown changes occurring beyond 108 months [2,3]. We hypothesized that (i) nondimensional (ND) normalization would reduce apparent age-related changes, and (ii) faster gait would present a greater challenge to the control system, and therefore reveal ongoing neuromaturation effects not visible in self-selected comfortable walking (free) speed gait.

Patients/Materials and Methods: Gait data had previously been collected for 82 children walking at a variety of speeds from very slow to fast (46% to 130% free speed) [4]. Peak kinematic, kinetic, and EMG parameters were extracted from the gait cycle epoch that begins in late stance and ends just after foot off. This period was chosen due to the complex control required for transitions

between single and double support. Moments and power were normalized using both BWH and ND schemes [5]. A repeated measures general linear model examined the effects of speed and age.

Results: *EMG*: There was no age effect seen in Rectus Femoris or medial Gastrocnemius peaks. Tibialis anterior showed an age effect up to 8–10 years. *Kinematics*: Hip and ankle showed age effects up to 10–12 years. *Moments*: Moments at the hip, knee, and ankle all showed an age effect with BWH normalization. This effect disappeared in each measure with ND normalization [e.g. Figure 1]. *Power*: ND normalization removed the age effect for knee and hip power. Ankle power exhibited a main effect due to age, as well as an interaction effect (age × speed), regardless of the normalization scheme used (BWH vs. ND). When data was re-analyzed without the fast walking speed, the age effects in peak ankle power disappeared.

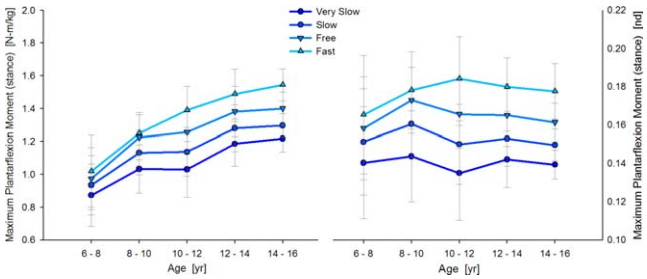

Figure 1.

Discussion: Evidence of gait maturation may include EMG, kinematic, or kinetic data. The choice of normalization scheme has a pronounced effect on age-dependence of joint moments; with the ND scheme eliminating apparent age effects at all speeds. Age effects in ankle joint power were seen for both BWH and ND scaled data, but were largely restricted to fast walking speeds. The findings of this study suggest that both normalization scheme and walking speed should be carefully considered in the assessment of gait maturation.

References

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O028

Simultaneous estimation of effect of factors that affect kinematic gait data in a reference population using functional data analysis

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Summary: Functional data analysis (FDA) was used to assess the impact of different factors on kinematic data in a healthy reference population. The results mainly showed a significant effect of walking speed on knee flexion/extension, knee rotation and ankle dorsi/plantar flexion.

Conclusions: Walking speed has significant effects on the kinematics, even when adjusting for confounders. This can be shown with the use of FDA which allows for comparing multiple explanatory variables for gait simultaneously.

Introduction: The aim of the study was to assess whether the five factors walking speed, gender, age, height and weight significantly affect kinematic data. Not one by one, as is partly already established in the literature, but simultaneously. This is in order to both adjust for possible confounders, as well as reduce the possibility of surrogate effects. In order to achieve this we turned to the statistical methodology called FDA. This approach views each gait curve not as a selection of points, but as a smooth function. As the entity under study is one, functional object, standard statistical methodologies, such as ANOVA, can be applied with proper modification.

Patients/Materials and Methods: Kinematic gait data from 36 healthy subjects above 18 years of age were collected using six infrared MX 13 cameras (Vicon Motion Systems, Oxford) and two force platforms (AMTI OR6–7). The population was dichotomised at the median value for the factors investigated. Speed: 1.41 m/s, age: 39.5 years, height: 173.1 cm, weight: 69.5 kg. One trial from each subject was included in the analysis and turned into a functional object using Fourier transformation. ANOVA for functional data was applied to statistically test for significant effects on kinematic curves due to one or more of the factors, while controlling for confounding effects of the others.

Results: Preliminary results for the first 24 subjects (male: 3, female: 21) show that FDA identified significant effects of walking speed on knee flexion/ extension, knee rotation and ankle dorsi/plantar flexion. Minor effects were found of gender on foot progression angle, and of age on pelvic tilt and ankle dorsi/plantar flexion. No significant effect of height and weight was identified. Final results will be presented.

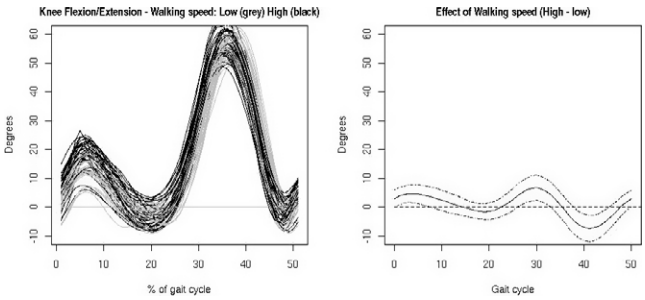

Figure 1. Left panel: Knee flexion/extension for 24 subjects with high (black) and low (grey) walking speed. Right panel: Estimated difference between the walking speeds. As the unit of observation is a function, the regression coefficient and 95% confidence interval (CI) are functions, too. The 95% CI for the regression coefficient curve lies above zero (implying statistical significance) mainly during loading response and preswing and midswing.

Discussion: The functional approach of FDA detects statistically significant effects of speed, gender and age on kinematic curves even in a normal population. These findings largely match with known effects in the literature, as there is more knee flexion during loading response in higher speeds. More women than men were included in the calculations for the preliminary results, making the gender effects uncertain. Whether the estimated differences might also be partly explained by other factors, such as a phase shift with