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Title
3D Gait Kinematic of Transtibial Amputees Walking in Every-day-life Environments: Reliability Study of a Protocol based on Inertial & Magnetic Sensors

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Summary
A protocol named Outwalk has been recently proposed for the 3D gait analysis in real-life environments of transtibial amputees. This study addresses Outwalk’s inter-rater reliability by involving 10 amputees and 2 rater. Results support the applicability of Outwalk in the clinical routine.

Introduction
The instrumental 3D gait analysis of amputees is currently limited to few prosthetic centres in which expensive movement analysis laboratories are available. Moreover, in the lab the gait of a patient can be conditioned by the stress imposed by the operators and by the artificial surrounding environment. Inertial and Magnetic Measurement Systems (IMMSs) might allow to overcome these limitations, being low-cost and portable. In addition, since the 3D orientation of their Sensing Units (SU) is known in a global earth-based coordinate system, which is ubiquitous, long measurements can be possible “out-of-the-lab”, in real-life environment, e.g. where the gait-training is carried out. For this purpose, we proposed a protocol named ‘Outwalk’ to measure the 3D kinematics of gait based on the IMMS by Xsens Technologies (NL) [1].

The aim of the present work was to test the inter-rater reliability of the protocol on Transtibial Amputees (TA).

Methods
To measure the pelvis-trunk, hips, knees, and ankles 3D kinematics, Outwalk requires to 1) position 8 SUs on trunk and lower-limb segments; 2) flex-extend each knee to estimate its mean flexion-extension rotation axis; 3) measure the SUs’ orientation with the subject in the upright anatomical posture [1].
Ten TA (45±10 year-old, K2-K3 level) participated in the experiment after signing an informed consent, together with 2 operators (O1, O2). O1 and O2 independently applied Outwalk on each subject and acquired the amputee’s gait kinematics while walking at self-selected speed in the park of our Centre along a 30m straight path. Acquisitions by O1 and O2 were 10 min apart. Gait cycles were segmented using the algorithm described in [2]. To quantify the inter-operator reliability we computed, among others, the Standard Error of Measurement (SEM) of the 36 parameters described in [3], based on an ANOVA with repeated measures, as recommended in [4,5].

Results
For the interest of brevity, Table 1 reports SEM values for the 14 most significant parameters of the 36 examined, both for the sound and prosthetic side. The SEMs reported both consider random and systematic effects. The names used for the parameters are those reported in [3], to which the reader is referred for a detailed description. Here suffices to say that: 1) H, K, A refer to hip, knee and ankle; 2) parameters ending with 6 and 7 refer to the sagittal and frontal plane range of motion (ROM); 3) ending with 2 refer to the maximum flexion/plantaflexion at loading response; ending with 3 refer to the maximum extension/dorsiflexion in stance phase; ending with 5 refer to the maximum flexion/dorsiflexion in swing.

Conclusion
Results appear consistent with reports on other populations [5,6]. In particular, the sagittal ROMs (H-K-A6) have a SEM<1.9°. Regarding the hip, H7 (useful for the analysis of hip circumduction deviations) appear particularly reliable with a worst-case SEM of 1.3°. Regarding the knee, K2 and K3 (SEM< 2°) appear reliable to draw conclusions on a flexed-knee gait, and K5 about the lack of foot clearance related to insufficient knee flexion in swing. Regarding the ankle, results for A2 and A3 (SEM< 1.8°) suggest the possibility of precise conclusions over vaulting problems, and A5 for push-off problems. SEMs for the prosthetic ankle (<1°) suggest the possibility of a detailed analysis of performance between different types of foot.

Even though partial, results suggest the applicability of Outwalk for the “out-of-the-lab” gait analysis of TA amputees, with important implications for the diffusion of this powerful instrument to every-day-life clinical routine even in small prosthetic centres.
References


Image: Table Outwalk_None.jpg

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Table 1 SEM values for important features of the kinematic patterns of hip, knee and ankle, as defined in Benedetti et al (1998) Clin Biomech.