Motion Analysis

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A COMPARISON BETWEEN FOUR FOOT MODEL PROTOCOLS: THE EFFECT OF WALKING ON A TREADMILL

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Introduction and Objectives: The interest on the foot ankle complex modelling is increasing in the last years. In gait analysis, the most widespread models are those proposed by Stebbins *et al.* [1], Leardini *et al.* [2], Sawacha *et al.* [3], and Saraswat *et al.* [4], which segment the foot-complex in three bodies, coherently with the anatomy. To the Authors' knowledge, a comparative exam of the performances inherent with the previously indicated models is not available. The main goal of the research project is the comparison of the foot models described in [1–4] by applying the four marker sets simultaneously on the subject.

Considering the significant number of markers to be applied (i.e. 27) and to facilitate marker tracking and labelling, the trials were conducted on a treadmill. However, kinematic and kinetic variables obtained in treadmill or overground walking might show different values [5]. Thus, as a prior study toward a comparison of the model outputs on a larger sample of individuals, this work investigated the comparability of treadmill and overground walking conditions in terms of main joint kinematics variables obtained for the four examined foot models.

Methods: The right lower limb and pelvis of four healthy adults with no ankle impairments were simultaneously equipped with the four marker sets [1-4] (4 mm hemispherical markers), Figure 1. The data collection was performed using a Vicon system (T 10-camera-workstation, Nexus 1.8.5 software, 100 Hz, Vicon Motion Systems, Oxford - UK).

A static trial was collected to define the local coordinate systems (CS), and five strides were then collected on a treadmill and overground. The treadmill speed was set at 3 m/s, whereas in the overground condition subjects were asked to walk at a self-selected speed.

Each model was analysed by properly selecting the relative marker set to obtain the kinematic angles. Joint kinematic angles were first expressed as a percentage of the gait cycle and then the sagittal range of motion (ROM) and the maximum plantar flexion and dorsiflexion for all the joints defined in the models were extracted using MATLAB (MathWorks, Natick - USA). The mean values were calculated along the five strides. The output of each model was tested with a repeated measure ANOVA ($p=0.05$) to investigate the differences between the two walking conditions (IBM SPSS Statistics v21, IBM Corporation, Armonk - USA).

Results: As a qualitative result, we can report the difficulty in tracking the marker trajectories when walking overground, while the tracking was simple enough in the case of using the treadmill. The statistical analysis shows that none of the joint kinematic variables significantly changed between the two conditions ($p>0.05$). We found the lowest *p*-values for the

plantar/dorsiflexion ROM of the forefoot relative to calcaneus in the Saraswat's model (p=0.16) and for the maximum dorsiflexion of the mid-foot relative to calcaneus in the Sawacha's model (p=0.23). The largest value (p=0.99) has been obtained for the plantar/dorsiflexion ROM of the forefoot relative to tibia in the Stebbins model, for the foot relative to tibia both in the Leardini and Sawacha models, and for the maximum plantar flexion of the forefoot relative to tibia in the Saraswat model.

Figure:

Caption: Figure 1 – The full marker set obtained by fusing the four foot protocols: 13 markers for the Stebbins' model [1], 14 markers for the Leardini's model [2], 13 markers for the Sawacha's model [3] and 16 markers plus the triad on the hallux for the Saraswat's model [4].

Conclusion: Since that to the Authors' knowledge there are no articles on the described comparison considering a segmented foot model as the ones proposed in [1–4], in the present study we achieved an evaluation of the kinematic variables defined on the sagittal plane from four subjects equipped with the four foot models. The same variables were extracted both from a walking trial collected asking the subjects to walk on a treadmill and to walk overground.

While Riley *et al.* [5] asserted the differences on the hip, knee and ankle angles on the sagittal plane considering the two walking conditions, the 21 variables here examined indicate that no significant differences were observed between the two walking conditions (p always ≥0.16).

This finding allows the Authors to develop a methodology in the on-going phase of the research project for quantifying the goodness of the models in terms of repeatability, reproducibility and reliability that include the use of the treadmill for the walking trials.

However, it has to be noticed that the number of subjects involved in the study might have affected the results.

References: [1] Stebbins et al., Gait Posture, 23: 401-410, 2006.

[2] Leardini et al., Gait Posture, 25: 453-462, 2007.

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