A COMPARISON OF TWO FOOT MODELS USED IN CLINICAL GAIT ANALYSIS

[1,3]Krista J Evans and [1,2,3]Michael H. Schwartz
[1]Graduate Program in Biomedical Engineering, University of Minnesota, Minneapolis, Minnesota USA,
[2]Department of Orthopaedic Surgery, University of Minnesota, Minneapolis, Minnesota, USA,
[3]Gillette Children's Specialty Healthcare, St. Paul, Minnesota, USA; email: KJEvans@gillettechildrens.com

INTRODUCTION

The location and orientation of talo-crural (TC) and sub-talar (ST) joint axes play an important role in determining foot kinematics and kinetics. The single rigid segment foot model (conventional model) commonly used in clinical gait laboratories contains several significant shortcomings including i) reliance on physical exam based measurements, which are susceptible to significant random and systematic errors [1], and ii) approximating the foot as a single rigid vector [2]. As a result, foot motion data has been widely viewed as a weak link in clinical gait analysis. Other foot models have been proposed, and this study aims to evaluate the clinical usefulness in two proposed foot models: the three-segment foot model, proposed by Kaufman, et al., (Mayo model) and the functional model. The Mayo model defines three rigid segments (tibia, hindfoot, and forefoot), aligns the segments using anatomical landmarks, and computes Euler angles between the segments [3]. The second model considered here, the functional model, uses optimization to estimate functional TC and ST axes [4]. The TC and ST axes are used to create a four-segment foot model (tibia, talus, calcaneous, and forefoot). This study consists of an *in-vivo* assessment of the two proposed models in both typical and pathological feet.

METHODS

Three-dimensional marker trajectories were collected for multiple subjects using a 12 camera Vicon 612 system (Oxford Metrics, Oxford, England). Both physical and virtual markers, as well as functional calibrations were used to define required parameters for all three foot models. Functional calibrations consisted of range-of-motion trials performed to locate the centers and orientations of the subject's TC and ST axes. Each subject then performed five walking trials, which were used to calculate foot kinematics. For both multi-segment foot models (Mayo and functional), marker trajectory data was low-pass filtered using a Savitzky-Golay smoothing filter, and was rigidly-transformed with respect to each model-defined rigid body segment using Procrustes analysis. The location of the TC and ST joint axes can be described by a position vector in a marker-based coordinate system. The orientation of these axes can be described by 2 rotations in the same coordinate system.

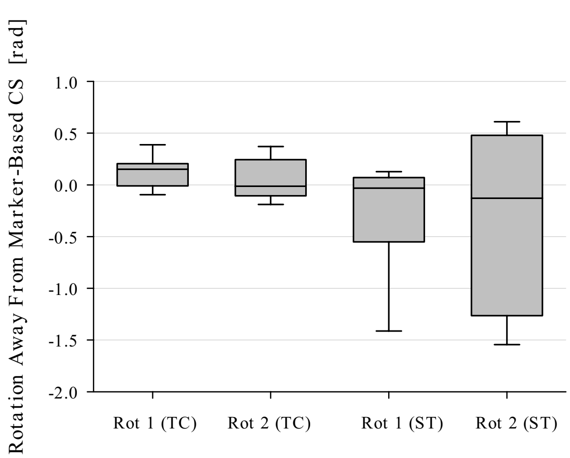

Figure 1: Rotations of the talo-crural and sub-talar joint axes, as calculated by the functional method [4]. The talo-crural axis is expressed relative to the bi-malleolar axis.

RESULTS AND DISCUSSION

Initial comparisons between the marker-based bimalleolar axis (Mayo model) and the estimated TC axis (functional model) show good agreement (Figure 1). The transverse plane orientation of the estimated TC axis (Rot 2 TC) relative to the marker-based bi-malleolar axis was the most accurate estimation of the calculated four rotations when compared to the marker-based bi-malleolar axis. The measure of coronal plane orientation of the estimated TC axis (Rot 1 TC) had the most precise results. The functional method allows objective location of the TC axis without the need for subjectively placed skin-mounted markers to identify the bimalleolar axis. Furthermore, the bimalleolar axis is based on anatomical landmarks, and is different than the TC orientation described by Inman [5]. This difference may be especially important in clinical gait analysis of pathological feet.

Initial results also show that the ST axis is not as precisely located as the TC axis. Since there is no gold-standard to compare the ST axis, the accuracy was not quantified. Current efforts are focused on using anatomical landmarks to assist in consistently describing the ST axes [5]. Using anatomical landmarks as initial estimations of both the ST and TC joint axes is meant to decrease computation time, provide indirect assessment of accuracy, and increase the precision.

CONCLUSIONS

The functional model provides precise and objective location of the TC axis. However, current studies suggest that the location of the ST axis is not as consistent or reliable as has been reported [4]. Current efforts are focused on improving the estimation of the ST and TC axes using the functional method in combination with the Mayo foot model.

REFERENCES

1. Schwartz MH, et al. *Proc. of the ESMAC Meeting*, Warsaw, Poland, 2004.
2. Davis RB, et al. *Human Movement Science* **10**, 575-587, 1991.
3. Kaufman KR, et al. *Proc. of the 8 th Annual GCMAS*, Wilmington, DE, 2003.
4. van den Bogert AJ, et al. *J Biomech* **27**, 1477-1488, 1994.
5. Stiehl, JB (ed.). *Inman's Joints of the Ankle*. Baltimore, Williams & Wilkins, 1991.