TOWARDS AN ACCURATE BIOMECHANICAL MODEL OF THE ANKLE

Arakilo M. [1], Paul G.[1], Rasmussen J.[2]

[1] University of South Australia, Australia, Mike.Arakilo@postgrads.unisa.edu.au
[2] University of Aalborg, AnyBody Technology, Denmark

Introduction

When compared with similar joint arthroplasties, the prognosis of Total Ankle Replacement (TAR) is not satisfactory although it shows promising results post surgery. To date, most models do not provide the full anatomical functionality and biomechanical range of motion of the healthy ankle joint. This has sparked additional research and evaluation of clinical outcomes in order to enhance ankle prosthesis design. However, the limited biomechanical data that exist in literature are based upon two-dimensional, discrete and outdated techniques[1] and may be inaccurate.

Since accurate force estimations are crucial to prosthesis design, a paper based on a new biomechanical modeling approach, providing three dimensional forces acting on the ankle joint and the surrounding tissues was published recently[2], but the identified forces were suspected of being under-estimated, while muscles were . The present paper reports an attempt to improve the accuracy of the analysis by means of novel methods for kinematic processing of gait data, provided in release 4.1 of the AnyBody Modeling System (AnyBody Technology, Aalborg, Denmark) Results from the new method are shown and remaining issues are discussed.

Materials and methods

Kinematic and Kinetic data were collected during a steady state walking trial. Three-dimensional kinematic data were collected using an 8-camera MXF40 motion capture system (Vicon, OMG plc) at 120Hz. Force data were sampled using two KISTLER force plates at 2000Hz. All raw kinematic data were exported to BodyModel (Vicon Inc.) where the biomechanical model was defined and joint kinematics and moments estimated. A custom protocol including 22 markers was defined in order to register kinematics in the ankle complex accurately. Each foot had 6 markers defined on the 1st, 3rd, 5th metatarsals, medial and lateral ankle as well as a heel marker. Subject weight was 75kg.

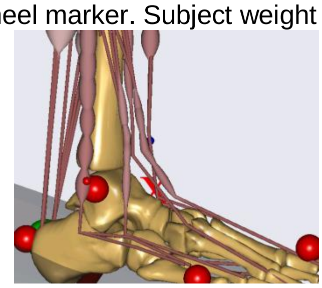

Figure 1: Ankle section of the lower extremity model[3].

Kinematic and kinetic data were filtered with a 4th order low pass Butterworth filter. The resulting C3D file was then input to the AnyBody model with custom modification and lower extremity muscle configuration according to Klein Horsman et al[3] (Fig. 1). The m. gastrocnemius was modified in order to correct for the muscular overload found by Arakilo et al[2]. Subsequently, the kinematic processing tool by Andersen et al.[4] was used to automatically scale the model and convert marker data to skeletal movement. The Min-Max optimization algorithm was chosen to calculate muscle activity.

Results and discussion

Overall average muscular activation was found to be higher for the new model over the previous one (40% MVC vs. 36% MVC). However, the toe off muscle activity was lower in the new model (43% MVC vs. 61% MVC). Also the Achilles tendon forces on both the right and left foot were found to be higher using the new model and more realistic compared to published data (Left: 4100N vs. 3000N; Right: 4800N vs. 3500N). The m. tibialis posterior of the right leg showed a maximum force of 850N compared to 90N in the previous model. Some high frequency fluctuations were found in the calculated m. tibialis anterior forces as shown below and may be due to filtering issues.

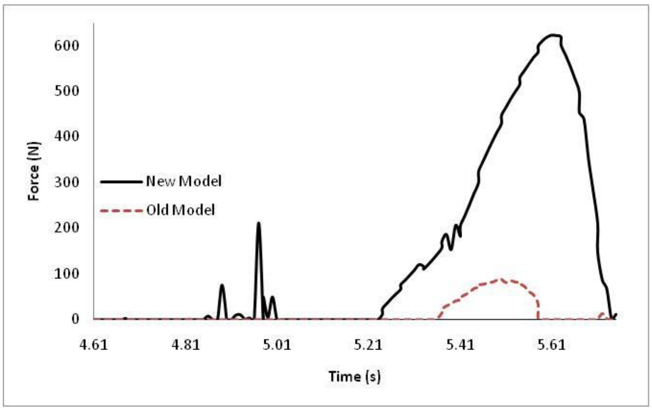

Figure 2: Comparison of left leg m. tibialis posterior forces for both models

Conclusion

Although the new model provides a significant improvement in the calculated muscle and tendon forces, further model optimization is required to achieve more physiologic results in the m. tibialis anterior.

References

[1] Stauffer R. *et al*., Clin. Orthop. 127, 189-196, 1977
[2] Arakilo M. *et al*., Proceedings of the 7th Australasian Biomechanics Conference, 19, 2009.
[3] Horsman MK et al., Clin. Biom. 22, 239–247, 2007
[4] Andersen MS et al. Comp.Meth.Biomech.Biomed. Eng., In Press.