A GENERAL METHOD TO APPLY SOFT TISSUE WRAPPING CONSTRAINTS TO MUSCLE PATHS: APPLICATION TO THE ANKLE

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Introduction

One of the purposes of musculoskeletal models is to predict muscle forces according to an overall minimisation function. This is commonly based on an individual muscle's moment arm about a joint, its maximum force generating capacity and the moment it is trying to balance. Therefore, accurate knowledge of musculo-tendon paths is required to calculate appropriate muscle forces. However, as most muscle geometry datasets are in the form of digitised points, this simplification of musculo-tendon paths often results in non-physiological muscle moment arms. The aim of this work was to implement a simple, yet novel approach for defining soft tissue wrapping constraints in a musculoskeletal model of the ankle.

Methods

A data set from the literature [Klein Horsman, 2007] was implemented in an ankle model, with muscle points scaled for the shank and foot. Cylindrical wrapping objects of different diameters were defined along the malleolar axis for each of the 7 muscle bundles, while muscle moment arms were calculated relative to the functional axis and joint centre.

The wrapping algorithm used 'via' points nearest the joint centre (if available, otherwise the origin and insertion) to define the initial line of action. The minimum distance between a point on this line of action and the wrapping object's axis was then found. If this point was on the correct side of the wrapping surface, it was considered to be physiological and used to calculate the muscle moment arm. If not, it was "pushed" to the surface of the cylinder in the sagittal plane. This point was checked to ensure it was on the correct side of the cylinder, otherwise it was pushed to the opposite side.

This point defined a new line of action for the muscle, with which the muscle moment arms about all three rotational axes of the segment could be calculated.

The method was then tested using data from an active heel drop exercise. This particular task was chosen because it provided a large range of motion about the ankle joint.

Results

The results presented are flexion/extension moment arms during the heel-drop phase of the task. The "Achilles" moment arm was taken as the average of the Gastrocnemius, Soleus and Plantaris moment arms. Moment arms were found to range between 20 to 25mm, 20 to 26mm and 38 to 48mm for Tibialis Anterior, Peroneus Brevis and the Achilles tendon respectively (Fig. 1).

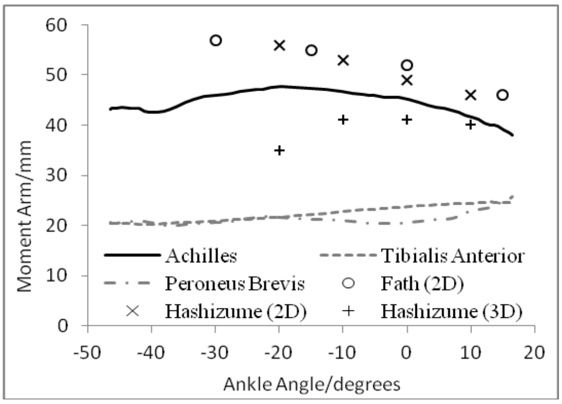

Figure 1: Relation between ankle flexion angle and muscle moment arms. Points from previous studies are for Achilles moment arms. A negative angle corresponds to plantarflexion.

Discussion

This work presented a generic, vector-based method to calculate muscle moment arms with specific examples at the ankle. Despite the differences to measured absolute values, the relative change was found to be similar to those reported previously for the Achilles tendon (26% here compared to 22% and 24% increases) [Fath, 2010 & Hashizume, 2012].

The generic nature of the method presented here could be applied to other joints where a cylindrical wrapping surface is an acceptable approximation.

References

Fath *et al* J. Appl. Physiol, 109: p1644, 2010.
Hashizume *et al*, J. Biomech, 45: p409, 2012.
Klein Horsman *et al* J Clin. Biomech, 22: p239, 2007