ACHILLES TENDON MOMENT ARMS VIA A HYBRID METHOD USING MOTION ANALYSIS AND ULTRASOUND: *IN VIVO* ESTIMATIONS IN MALE SUBJECTS

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INTRODUCTION

Developing accurate estimates of muscle-tendon parameters are important for use in biomechanical studies. The muscle moment arm (MA) is one such parameter; transforming the linear force developed by a muscle into a moment about a joint. The plantar flexion (PF) moment during stance is generated primarily by the gastroc-soleus acting through the Achilles tendon MA. Recently, we developed a novel hybrid method for computing Achilles tendon MA using ultrasound (US) and motion analysis (Cowder *et al*., 2007). The method has been validated using an animal model and found to have good accuracy (3.3% error). In this paper, we use this new technique to determine the average Achilles tendon MAs of 10 subjects.

PROCEDURE AND METHODS

The hybrid method was used to determine the Achilles tendon MAs of ten healthy male subjects with average age: 24.1±2.3 years, height: 1.77±0.05m, and mass: 76.07±9.07 kg. All subjects submitted written informed consent prior to testing and the testing protocol was approved by the Human Subjects Review Board at the University of Delaware. Subjects were positioned in an isokinetic dynamometer (Biodex System 3, Shirley, NY) (Figure 1). The Biodex was used to monitor ankle joint angle and to provide resistance for isometric PF maximum voluntary contraction (MVC).

Figure 1. Subject placement in Biodex with markers and gel standoff pad attached. Ankle is in neutral angle with knee at 90º.

Reflective markers were placed on the subject's lateral and medial malleoli to define the ankle joint axis. The ankle joint center was assumed to lie at the midpoint between the markers. In addition, markers were placed on the US probe to establish a correspondence between the ankle joint center and the US image. A seven camera motion capture system (Qualisys ProReflex, Gothenburg, Sweden) was used to capture marker locations during testing. B-mode US images at 10 MHz of the Achilles tendon were recorded using a 60mm linear probe and gel pad (Aloka SSD-5000, Tokyo, Japan) (Figure 2).

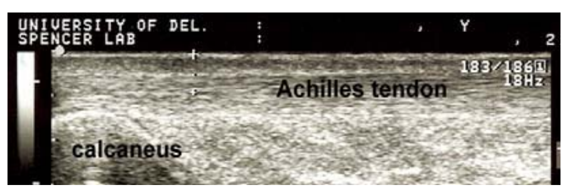

Figure 2. Sonogram with Achilles tendon.

A gel pad was used for acoustic coupling. US recording was synchronized with motion data using a contact switch attached to the freeze image button on the US console. Two trials at rest and two trials at MVC were collected at each of 5 ankle angles ranging from 20º dorsiflexion (DF) to 20º PF in increments of 10º.

RESULTS

Hybrid method estimates for Achilles tendon MAs with SD error bars are shown in Figure 3. MAs at rest increased in length from 34.5±1.9 mm at 20º DF to a peak 36.9±1.9 mm at 10º PF. During MVC, MAs increased from 35.5±1.8 mm at 20º DF to 38.1±2.6 mm at 20º PF. Small increases in MA length between rest and MVC were observed with an average increase of 3.4±0.9%.

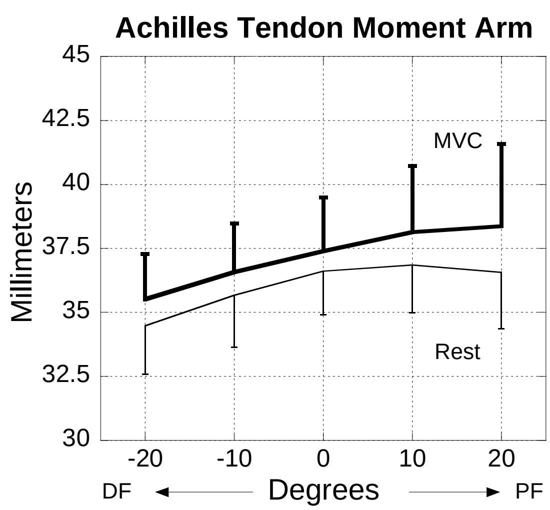

Figure 3. Achilles tendon MAs at rest (thin curves) and at MVC (bold curves).

DISCUSSION

We observed an increase in the MA as the ankle angle progressed from DF into PF. We also noted that MAs were slightly greater (3.4%±0.9%) during MVC than at rest. These observations are similar to findings reported by Maganaris *et al*. (2000). They too observed a similar trend of increasing MA from DF to PF and also increased MAs during MVC compared to rest. In contrast, the magnitude of the MAs between studies were significantly different. The hybrid MAs were 15% to 35% smaller than those reported by Maganaris. Subjects in both studies were similar in size and therefore not likely the reason for such large differences. MAs computed by Maganaris were based on the concept of virtual work (An *et al*., 1984) and requires a change in joint angular position to approximate the MA. They used a change of 15º (i.e., ± 7.5º) when computing the MA for a specific angle and therefore each MA may be thought of as an average value over the range. This may be a potential source of error contributing to differences between studies. Our hybrid method uses measurements made directly at the angle of interest and thus requires fewer potentially error prone measurements.

SUMMARY

MAs computed using the hybrid method showed the same trend as values reported in the literature, although, the magnitudes were less. Based on the results of our validation experiments we are confident the MAs for subjects in our study are physiologically representative of their true Achilles tendon MA.

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