ACHILLES AND PATELLAR TENDON LOADING DURING GAIT MEASURED USING A NON-INVASIVE ULTRASONIC TECHNIQUE

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INTRODUCTION

In vivo measurement of tendon and ligament loads remains a challenge. Forces acting on these structures during exercise have either estimated indirectly using EMG and inverse dynamics or measured by means of invasive techniques [2]. Recently, a non-invasive technique has been proposed, based on the measurement of the velocity of ultrasound (US) propagation in the tendon [1]. It has been demonstrated that this velocity is dependent on the force applied to the tendon (Fig. 1A). In this paper we report preliminary results of measurements performed on the Achilles tendon and patellar tendon in humans during walking.

METHODS

Ultrasonic (US) measurements were performed using a dedicated device composed of an electronic battery-powered module connected to an ultrasonic probe. The probe consists of 4 transducer elements, one acting as an emitter and the others as receivers. Knowing the distance separating these receivers, the speed of sound (SOS) is easily obtained by dividing this distance by the time required by the US waves to travel from one receiver to another.

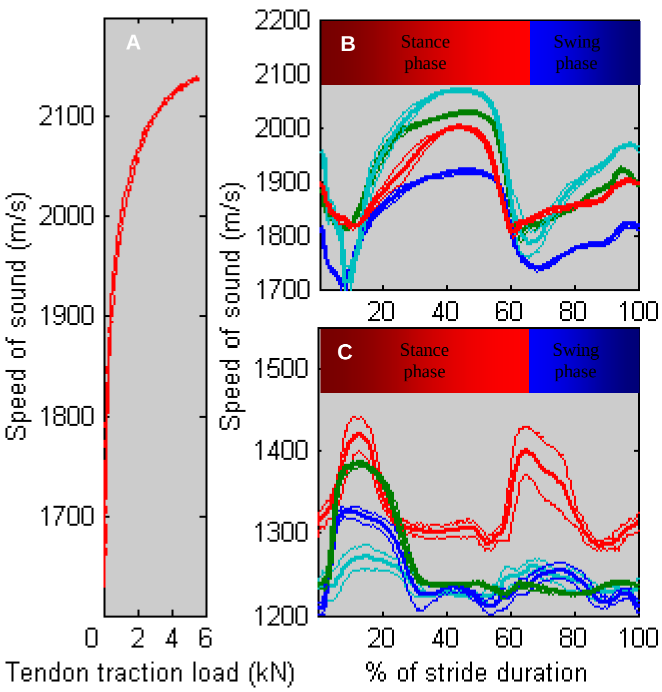

Figure 1: A - Relationship between ultrasound velocity and load in an equine superficial digital flexor tendon.
B and C - Ultrasound velocity (mean ± SD) recorded at the walk in the Achilles tendon and in the patellar tendon, respectively.

Data were collected in four subjects (1 female, 52 kg, and 3 males, 68, 80 and 88 kg). Each subject performed 10 barefoot walking trials with the US probe on the right Achilles tendon and 10 other trials with the probe on the right patellar tendon.

An extra analog input on the US device was used to record the vertical ground reaction force (Fz) from an AMTI force plate. After time normalization to percentage of stride duration, SOS and Fz data were averaged over the 10 gait cycles.

RESULTS AND DISCUSSION

Results obtained in the Achilles tendon (Fig. 1B) are consistent with those from implanted sensors. As described by Finni *et al*. [2], the tendon force decreases suddenly at heel contact on the ground followed by a steep rise in tendon load during the first part of the stance phase. The patellar tendon (Fig. 1C) shows a peak in the first half of stance, as seen in knee extensor moments during gait (Winter, 1983).

In all subjects, SOS was higher in the Achilles tendon, which may be due to higher tensile stress during gait. Between-subject differences in SOS were not related to body weight. These variations could be due to differences in muscle activation, or differences in elastic properties of the tendons. Further studies, using simultaneous EMG and inverse dynamic analyses, are needed to resolve this issue.

When compared to inverse dynamic analysis, the ultrasound method has several advantages. First, no assumptions on antagonistic co-contraction are needed. This enables direct inferences about individual muscle forces. Second, no low-pass filtering is needed and this results in better temporal resolution.

When compared to EMG, the ultrasound method has the advantage that calibration to force appears possible (Fig. 1A). Until we can non-invasively obtain a force-SOS relationship for a specific tendon in a specific subject, applications are limited to those that only require within-subject comparisons.

CONCLUSIONS

This new non-invasive technique opens up a range of investigative opportunities in various fields of research. It should also be a useful clinical tool for diagnosis, evaluation and follow-up of muscle, tendon and ligament injuries or dysfunctions.

REFERENCES

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