

USE OF ULTRASOUND TO DYNAMICALLY EVALUATE ACHILLES TENDON MECHANICAL PROPERTIES IN STROKE

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INTRODUCTION

Recent findings show that the metabolic activity in human tendon is remarkably high which affords the tendon the ability to adapt to changing demands (Magnusson et al. 2008). Studying the tendon mechanical properties of the stroke survivors may help to understand the physiological mechanism of spasticity/contracture and provide guidance for rehabilitation.

B-mode ultrasound imaging has been widely used to investigate human tendon displacement, *in vivo*, during muscle maximum voluntary isometric contraction (MVC). However, due to muscle weakness, stroke survivors can only generate about 20%~40% of an average healthy subject MVC. Therefore smaller muscle-tendon junction (MTJ) displacement becomes more susceptible to error, indicating the need for more objective and accurate measurement. Moreover, decorrelation is inevitable between ultrasound frames due to out-of-plane motion and noise. Frame-by-frame analysis is a way to avoid severe decorrelation and allow the MTJ displacement to be studied dynamically with changes in load, but it is too labour intensive. Some automatic tracking methods have been developed (Magnusson et al. 2003; Loram et al. 2006). However the methods are limited to tracking the regions with high intensity gradient or consistently clear features. In this paper, a block-matching method based on minimum sum of absolute differences (MSAD) algorithm is introduced to measure the displacement of Achilles-

soleus MTJ under voluntary contraction. The viscoelasticity, as well as the Young's modulus of a stroke survivor's Achilles tendon was evaluated and compared to a healthy subject.

METHODS AND PROCEDURES



Figure 1. The experiment setup.

MSAD Block-Matching Algorithm:

A method was proposed recently to quantify regional myocardial dysfunction in mice (Li et al. 2007). Compared to previous methods, MSAD does not require clear features and is more robust to the false noisy speckles which are common in ultrasound images. Moreover, the MSAD implementation is highly computationally-efficient and compatible with different types of CPUs (Li et al. 2007).

Experiment Setup:

The setup consists of a custom knee-ankle device (Figure 1) and a LOGIQ-9 (GE, Waukesha, WI) ultrasound machine.

Experiment Protocol:

The subject was seated upright with the knee and ankle attached to the knee-ankle device (Figure 1). The Achilles tendon length at rest was measured using an extended field-of-view technique with a 14 MHz probe. The moment arm and the cross-sectional area of the Achilles tendon was measured using the method in (Maganaris and Paul 2002). A camcorder was used to monitor the calcaneus motion and the EMG of dorsiflexors was recorded. The subject performed a voluntary isometric contraction and relaxed following a ramping up and down pattern displayed on the screen. The ultrasound images, the synchronization signal, and the joint moment were recorded.

Data Processing:

The soleus MTJ displacement was calculated as an average of multiple tracked blocks. Sub-pixel displacement was estimated using parabolic interpolation. The recorded joint moment data were filtered and aligned with displacement data using the synchronization signal. The stress and the strain of the Achilles tendon were calculated.

RESULTS

The stress-strain relation curves of a representative stroke survivor and a healthy subject during dynamical loading are shown in Figure 2.

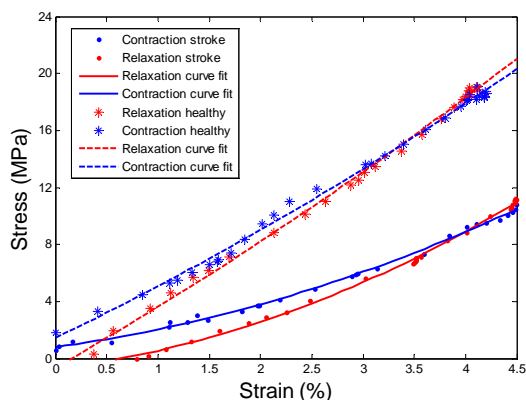


Figure 2. Stress-strain relation curves of a stroke survivor and a healthy subject. The dots and the stars represent the stress-strain relation of the stroke survivor and the

healthy subject, respectively. The blue and red colors represent the contraction and relaxation process, respectively. The stress-strain loops were fitted using quadratic polynomial curves. The maximum Young's moduli of the stroke survivor and the healthy subject were 469.5 MPa and 269.6 MPa, respectively. The hysteresis area (between the loading and unloading curves) of the stroke survivor and the healthy subject are 19% and 6.5% of the area between each loading curve and the abscissa, respectively.

DISCUSSION

Although the task was relatively easy, the stroke survivor still needed to go through considerable training, and the compensations for antagonist co-contraction and calcaneus motion need to be dealt with properly. Since the test was carried out within the toe region of the tendon elasticity curve, the Young's moduli of both subjects are lower than some previous results (Magnusson et al. 2003).

SUMMARY

A robust, computationally-efficient block matching method is introduced to study the Achilles tendon mechanical properties using ultrasound. Results show that the Achilles tendon of the stroke survivor is more compliant than the healthy subject. The larger hysteresis area of the stroke survivor indicates larger energy loss during locomotion.

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