THE USE OF ULTRASOUND ELASTOGRAPHY TO ASSESS LONG-TERM TENDON REMODELING AND MECHANICS FOLLOWING MUSCULOTENDON INJURY

Laura Chernak, Amy Silder, Kenneth Lee and Darryl Thelen

University of Wisconsin-Madison, Madison, WI, USA
email: lchernak@wisc.edu, web: http://www.engr.wisc.edu/groups/nmbl/

INTRODUCTION

Acute musculotendon strain injuries are challenging to treat clinically, with athletes being at a high risk of reinjury when returning to sport [1]. Long-term changes in musculotendon morphology may contribute to reinjury risk. In particular, previously injured muscles often exhibit evidence of residual scar tissue at the musculotendon junction [2], which has inferior structural organization of collagen fibers [3]. We recently showed using dynamic MR imaging study that such morphological changes are linked to alterations in muscle tissue deformation patterns near the site of prior injury [4]. However, the fast relaxation time of collagenous tissue limits the use of MRI to conduct similar analysis on tendon. An alternative approach is to use ultrasound (US) elastography [5], which is a speckle tracking approach to measuring *in vivo* tissue deformation patterns [6]. Our objective was to assess the potential for using US elastography to quantify tendon mechanics in normal and previously injured hamstrings undergoing passive stretch.

METHODS

Pilot data were obtained from a single adult male (28y) with a history of left biceps femoris injuries, including the most recent injury 5y prior to testing. A series of six passive knee extension trials were conducted for each limb with the subject supine on an examination table and the hip fixed to 90deg. The ultrasound transducer (10MHz, 38mm wide) was positioned over the biceps femoris proximal tendon/aponeurosis and aligned with the underlying fiber direction of the tendon. Radio frequency (RF) and B-Mode images were then simultraneously collected using a SonixTOUCH Research scanner (Ultrasonix Medical Corporation, Richmond, BC, Canada) as a therapist slowly extended the knee from 90deg to maximum extension. The force required to extend the knee was measured using a hand-held load cell, and an electronic goniometer was used to monitor the knee flexion angle (Fig. 1). Internal knee flexion moments throughout the trials were then computed from the collected data.

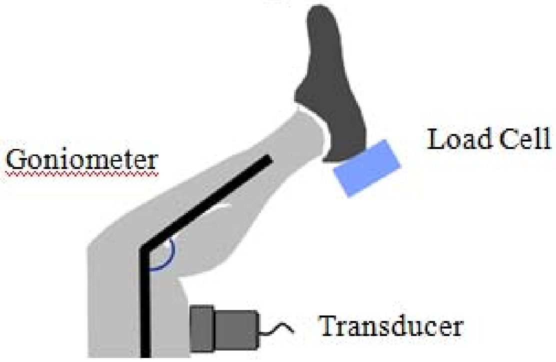

Figure 1. Experimental setup.

A statistical correlation approach was used to compute the cumulative two-dimensional motion of a region of interest containing the tendon. We did this by first defining a rectangular kernel around each pixel, and then cross-correlating the (0.4x0.2mm) RF signals within the kernel with candidate positions of the kernel in a subsequent frame [5,6]. The kernel translations that maximized the cross-correlation were then determined. Sub-pixel displacements were estimated using a 2D quadratic fit of the correlation function. After computing pixel displacements, a region of interest over the tendon was then identified and meshed via triangular elements with ~2mm edge lengths [4]. Linear least squares were used to compute the nodal displacements that best agreed with the computed pixel displacements at each frame. Frame-to-frame nodal displacements were accumulated over time to estimate the cumulative motion of the tendon. In this study, we report the tendon motion along the transducer beam direction, which is known to track approximately one order of magnitude better than transverse to the beam, due to the phase information inherent in the RF data [6].

RESULTS AND DISCUSSION

Passive moment-angle data demonstrated a high repeatability between trials for each limb (Fig. 2). The similarity between the slopes of the moment angle curves between limbs suggests that injury-related changes to muscle-tendon mechanics may did not seem to be detectable at the joint level for this subject.

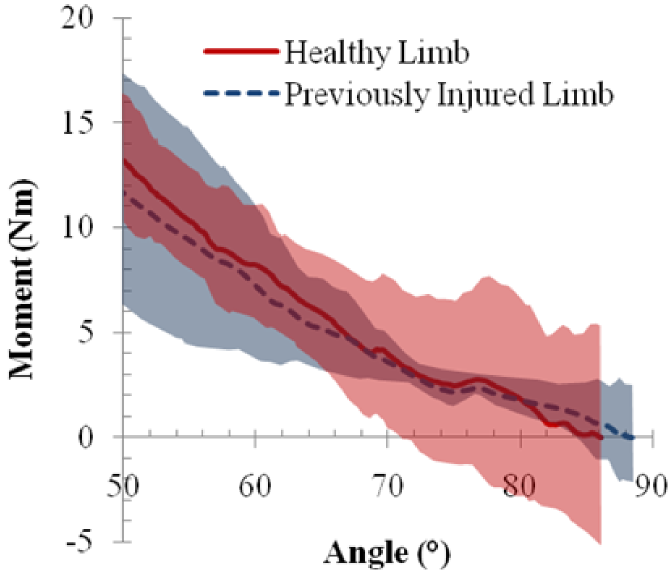

Figure 2. Passive knee flexion moment-angle relationships (mean±1sd) for the healthy and previously injury limb across four passive stretch trials.

The injured conjoint tendon was diffusely enlarged and heterogenously hypoechoic with loss of the normal parallel fibrillar pattern (Fig. 3). Computed displacement patterns were consistent between repeated trials for each respective limb, with ~1-4 mm of motion along the beam direction and ~5 mm of motion in the direction transverse to the beam. The previously injured tendon exhibited larger net motion and greater variability in motion across the tendon width, when compared with the tendon on the uninjured limb (Fig. 3). These dissimilarities suggest that mechanical differences between healthy and previously injured tendinous tissue are likely present, and may be detectable using ultrasound elastography.

CONCLUSIONS

Ultrasound elastography shows promise as a quantitative tool to characterize injury-induced changes in tendon morphology and mechanics.

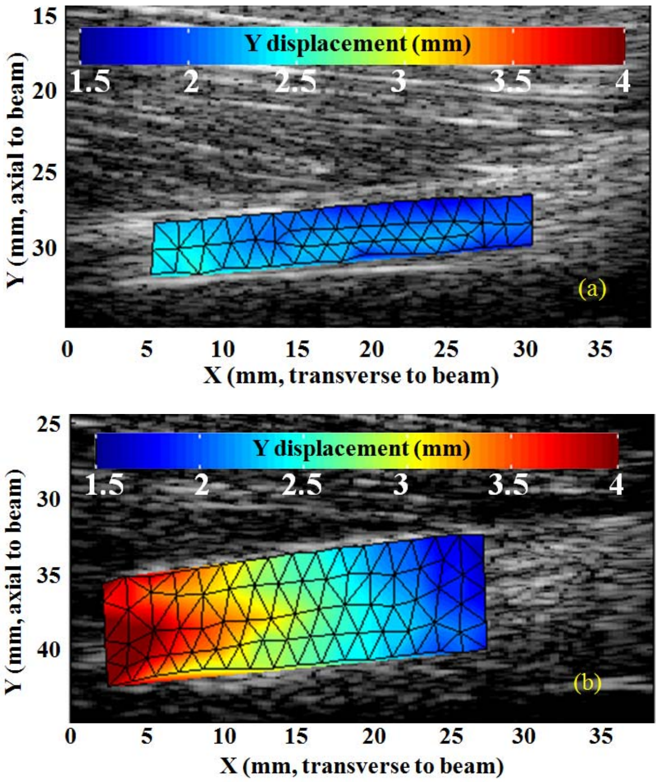

Figure 3. Along-beam displacement patterns in the proximal conjoint tendon for the (a) healthy and (b) previously injured limb

REFERENCES

1. Orchard J, et al. *Br J Sports Med* **36** 39–44, 2002.
2. Silder A, et al. *Skeletal Radiol* **37**, 1101-09, 2008.
3. Lin TW, et al., *J Biomech* **37**, 865-77, 2004.
4. Silder A, et al. *J Biomech*, in press.
5. Farron J, et al. *IEEE Trans Ultrason Ferroelectr Freq Control*, **56**, 27-35, 2009.
6. Ophir J, et al., *Proc. Inst. Mech. Eng.* **213**, 203-233, 1999.

ACKNOWLEDGEMENTS

NIH AR056201, Tomy Varghese, Amy Hauri, Bryan Heiderscheit, Ryan DeWall, Kate Ludwig.