CHARACTERIZING HAMSTRINGS MUSCLE DYNAMICS DURING KNEE FLEXION-EXTENSION USING REAL-TIME MRI

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INTRODUCTION

The hamstrings muscles are highly susceptible to strain injuries and are commonly injured during running and sports-related activities. In order to understand the mechanisms for muscle tissue injury, we must characterize the local tissue strains during knee motion. While dynamic magnetic resonance imaging (MRI) has been previously used to study musculoskeletal motion (Asakawa et al., 2003), local hamstring muscle tissue strains during large knee flexion-extension motions have not been characterized *in vivo* due to limitations in scanner bore size. The goal of the current work is to develop an experimental approach to characterize hamstring muscle tissue strains in real time during loaded dynamic knee flexion-extension motion.

METHODS

Four volunteers were placed in the left lateral position to allow for a large range of knee angles inside a wide bore (70 cm), 1.5T Siemens Espree scanner (Figure 1). The wide bore scanner permitted knee angles ranging from 40 degrees at full extension to 140 degrees at full flexion. A real-time pulse sequence developed for interventional MRI (Guttman et al., 2003; McVeigh et al., 2005) was modified to apply and image a parallel line-pattern of temporary magnetic fiducial markers (or tags) on thigh muscles during knee flexion-extension. Tag application and image acquisition were initiated by a trigger pulse sent to the MRI scanner by a LabView control program. The LabView control program monitored leg movement via a position encoder connected to the foot by a rope with a counter balance on the opposite end to provide a controlled amount of resistance during the flexion-extension motion. LabView sent a trigger pulse to the scanner when the knee reached full flexion or extension. Position encoder values were calibrated based on direct measurements of knee angle made from a set of real-time dynamic images at the knee joint (Fig. 2A)

Because tag movement reflects underlying tissue movement (McVeigh, 1996, Ozturk et al., 2003), we calculated muscle tissue strains based on the distance between adjacent tags at the start of and during knee flexion/extension. Percent strain (S) was calculated according to the formula $S = 100*(l_f – l_o)/l_o$, where l_f is the current distance between tags and l_o is the initial distance. Strain measurements were obtained at 6 locations in the biceps femoris long head (Fig 2B).

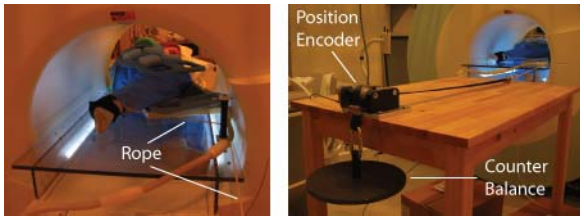

Figure 1: Volunteer in MRI scanner, and position encoder with counter balance attached to foot.

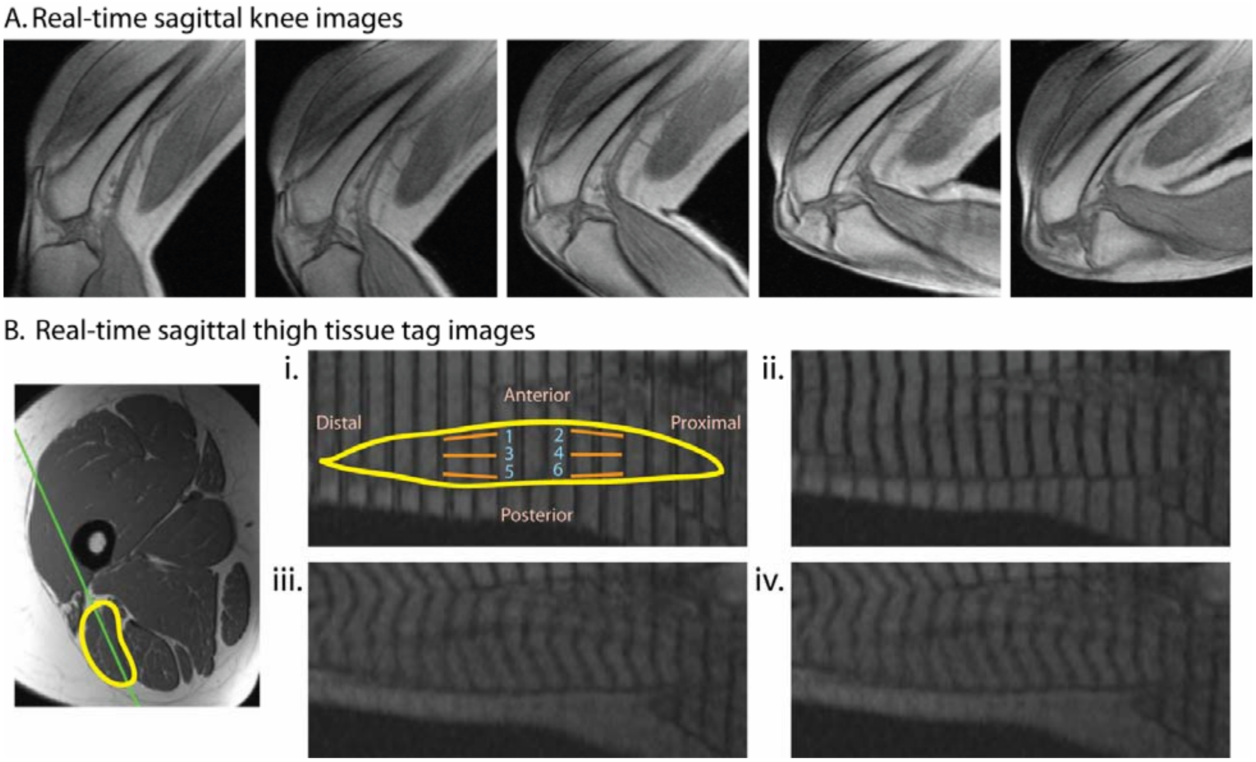

Figure 2: Real-time sagittal MR images demonstrating large knee flexion-extension angles (A), high-resolution axial image highlighting imaging plane in green for the biceps femoris muscle (B), circled in yellow, and four successive tagged images starting with undeformed tag lines (i-iv). Strain measurement regions are indicated by numbered line segments.

RESULTS AND DISCUSSION

Joint angles calculated from the calibrated position encoder compared favorably to a separate set of angles measured directly. For two sets of measurements made by the same user the angles calculated from the encoder differed from direct measurements by 4.78 ± 3.33 degrees and 5.92 ± 4.90 degrees (mean ± standard deviation).

Analysis of the tagging data (Fig. 2B) collected during active dynamic knee flexion revealed that some regions within the biceps femoris long head lengthen while others shorten. For example, for the 4 subjects imaged in this study, minimum strains (across 6 regions within the muscle) ranged from -11.48% to -3.90% and maximum strains ranged from 2.61% to 4.33% (these values correspond to approximately 30 degrees range of knee flexion; negative values indicate shortening, and positive values indicate lengthening). These results highlight the complex behavior of the hamstrings during dynamic knee motion. Further refinements in this technique will allow for a detailed exploration of tissue strains during large ranges of dynamic active knee motion and reveal new insights into the mechanisms for hamstrings strain injury.

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