# Strain Distribution in the Biceps Femoris Long Head Muscle as Determined by Real-time MRI Tagging

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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 active, large knee flexion-extension motions have not been characterized in real-time. In this study, we developed a technique to determine strains in the hamstrings muscles during loaded dynamic knee flexion-extension motion with real-time tagging MRI, using a large-bore MRI scanner which allows for large ranges of knee motion. We applied the technique to determining the strain distributions in the biceps femoris long head muscle (the most commonly injured hamstring muscle) during active knee flexion.

## Methods

The biceps femoris long head of six normal volunteers (n=6) was scanned in a 70cm diameter bore Seimens Espree MRI scanner. To allow for a maximum range of knee joint angles, each volunteer was placed on his/her side inside the bore of the MRI scanner (Fig. 1A,B). A platform was placed under the volunteer's leg to ensure the flexion-extension motion remained in the same horizontal plane throughout the experiment. The imaging plane for the biceps femoris was defined based on spin-echo imaging (Fig. 1C). A real-time pulse sequence was modified to apply tags and begin acquiring images in response to an external trigger at the onset of knee joint flexion (i.e. when the leg is straight and beginning to bend) during a repeated flexion-extension motion (Guttman et al., 2003; McVeigh et al., 2005).

To determine the beginning of knee joint flexion in real time, a boot strap was placed on the foot of the volunteer such that a rope could be attached to the foot and to a position encoder (Fig. 1B). As the volunteer moved his/her leg in flexion and extension the encoder was able to detect changes in angular position at a resolution of 0.72 degrees and sent position encoder measurements at a rate of 500 Hz to a laptop for processing. By calculating the change in position encoder value, the beginning of the flexion was found in real time by determining when the position encoder values reached a local maximum and began a downward trajectory. When the beginning of flexion was determined a square-wave trigger pulse was sent to the scanner via a DAQ.

MR images were analyzed by making line measurements at three anatomical locations within the biceps femoris muscle (Fig. 1D,E). Line measurements were made at the start of the flexion motion (undeformed tags) and at two time frames following tag application (deformed tags), which corresponded to ~200 ms after the beginning of flexion. Engineering strain was calculated as the difference in line length on the undeformed tag image and the corresponding line length on the deformed tag image divided by the undeformed length ($\varepsilon = 100\%*(l_u - l_d)/ l_u$).

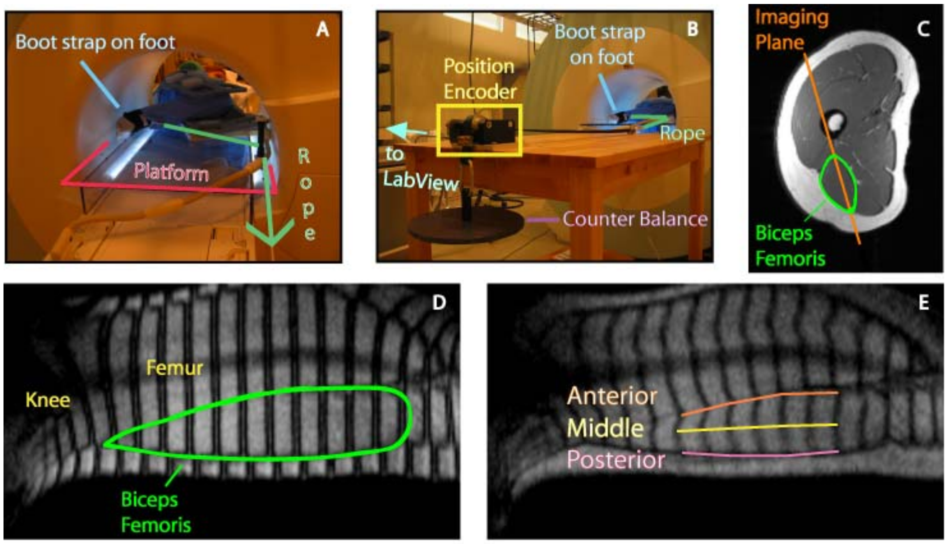

Figure 1. Volunteer lying in MRI scanner at full flexion (A,B). Axial view of thigh and imaging plane (C). Undeformed tag image (D). Deformed tag image with anatomical regions labeled (E).

## Results & Discussion

Strain results averaged across all six subjects for the biceps femoris long head muscle were 4.8% shortening (3.8% SD) for the anterior region, 0.9% (2.5% SD) for the middle region, and 4.7% (3.6% SD) for the posterior region (Fig. 2). For all six volunteers the anterior region shortened more relative to the middle region and in five of six volunteers the posterior region shortened more relative to the middle. These data suggest a non-uniform strain distribution across the anterior-posterior direction of the biceps femoris long head muscle. This result provides insight into the behavior of skeletal muscle *in vivo* and will reveal new insights into the underlying mechanisms for hamstrings muscle injuries.

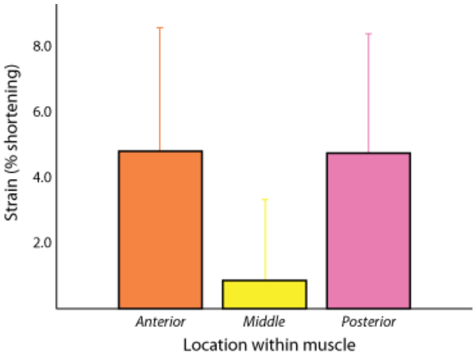

Figure 2. Strain at three anatomical locations within the biceps femoris long head muscle.

## References

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