ANTERIOR AND CENTERLINE STRAINS DIFFER IN THE BICEPS BRACHII DURING ACTIVE ELBOW FLEXION

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INTRODUCTION

Assumptions about the architecture and contractile properties of muscle are made in models of the musculoskeletal system. For example, the assumption that skeletal muscle shortens uniformly along its length is commonly made to facilitate modeling of muscle contraction mechanics.

In vivo data are required to test assumptions about muscle contraction, improve the accuracy of representations of muscle-tendon mechanics, and further our understanding of muscle function. Magnetic resonance imaging (MRI) and ultrasound imaging have been used to study muscle architecture and contraction mechanics *in vivo* (Drace & Pelc, 1994; Fukunaga et al., 1997). Strains estimated with cine phase contrast MRI have suggested that shortening of the biceps brachii along its centerline is not uniform (Pappas et al., in review). We hypothesized that the large central aponeurosis of the biceps brachii, which was included in the centerline strain measurements, was the principal source of non-uniform shortening.

The purpose of this study was to compare shortening along the anterior fascicles of the biceps brachii, which do not include tendon, with shortening along the centerline of the biceps brachii muscle-tendon complex. *In vivo* muscle-tendon strains were estimated at two different load levels to study the dependence of the strain measurements on load.

METHODS

Cine phase contrast MRI was used to measure *in vivo* biceps brachii tissue velocity over a mid-sagittal imaging plane during elbow flexion in 12 healthy subjects. Estimates of muscle-tendon displacement and strain were derived through integration of the quantitative three-dimensional velocity images (Zhu et al., 1996). Each subject performed cyclical elbow flexion and extension tasks over an 80° range of motion, from near full extension to approximately 90° flexion, within a 1.5T GE MR imager. Subjects performed elbow flexion against 5% and 15% of their measured maximum voluntary contraction (MVC) strength.

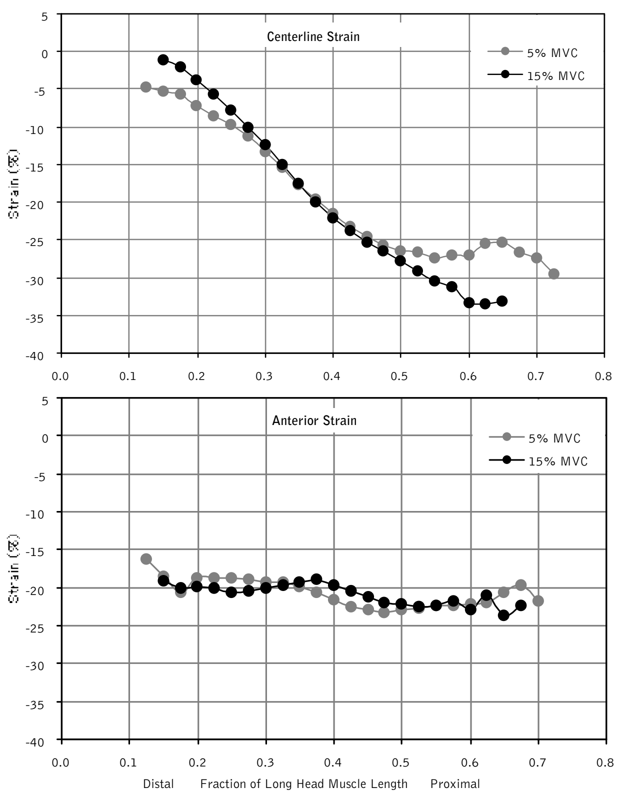
Displacement and strain in the biceps brachii during elbow flexion were determined by tracking the position of square (1cm x 1cm) tissue regions of interest (ROIs) over the entire motion cycle. Centerline strain was determined from the position trajectories of ROIs distributed along the longitudinal axis of the biceps brachii. Anterior strain was computed from ROIs located subcutaneously along the superficial boundary of the biceps (in the mid-sagittal plane). The strain distributions along the centerline axis and anterior boundary of the muscle were computed for the muscle in its most flexed state, relative to its state at extension. A negative strain indicated the distance between two tracked regions decreased and implied local muscle shortening as compared to the state of the muscle in an extended elbow position.

RESULTS

At maximum elbow flexion, the strain along the centerline of the biceps brachii was highly non-uniform (Fig. 1, top panel). Shortening along the centerline of the muscle-tendon complex was non-uniform for both loading conditions and was significantly lower in magnitude at the distal end of the muscle as compared to shortening at the midportion and proximal end of the muscle. Mean strain levels at the distal end of the muscle, within the aponeurosis region, were between zero and -5%. Shortening in the midportion and proximal end of the muscle was between 20-35%. The trends in the centerline strain distribution at maximum elbow flexion were similar across the two load levels and consistent with a previous study of centerline strain during elbow flexion with a 2-lb loading condition (Pappas et al., in review).

The strain along the anterior fascicles at maximum flexion was approximately constant over the entire length of the biceps (Fig. 1, bottom panel). The mean strains for the 5% and 15% MVC cases were both 21% and were not significantly different from each other.

Figure 1. Centerline (top panel) and anterior (bottom panel) strain distributions in the biceps brachii for



5%, and 15% MVC loading conditions. Negative strains indicate local muscle shortening in elbow flexion as compared to extension.

DISCUSSION

Our results demonstrate a dramatic difference in the shortening between the centerline and anterior portions of the biceps brachii. Centerline strain at the distal end of the muscle was significantly lower in magnitude than strain at the midportion and proximal end of the muscle-tendon complex. Lower strain levels observed at the distal end of the muscle are likely due to the existence of a prominent internal aponeurosis, which spans the distal third of the muscle. In contrast, shortening along anterior fascicles was approximately constant under the two loading conditions, suggesting uniform muscle fiber shortening during active contraction. The fascicles in the anterior region of the muscle were specifically chosen to exclude the central tendon of the biceps brachii.

Our results support the hypothesis that non-uniform shortening along the centerline of the biceps brachii arises from the presence of the central aponeurosis in the distal third of the muscle. The architectural properties of the biceps brachii may lead to a distribution of fiber lengths and sarcomere lengths during contraction. Such length heterogeneity has important functional consequences, such as alteration of the muscle's force-length properties (Huijing,1995).

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