MEASURING FASCICLE LENGTHS IN EXTRINSIC AND INTRINSIC THUMB MUSCLES USING EXTENDED FIELD-OF-VIEW ULTRASOUND

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Introduction

Measuring muscle fascicle lengths is critical for understanding the force-length and force-velocity properties of muscles [1]. Muscle fascicles are defined as bundles of muscle fibers and can be measured *in vitro* by dissection or *in vivo* using ultrasound or magnetic resonance imaging [2]. Ultrasound is relatively cheap, easy to use [1], and has been accepted as a reliable measurement method for a variety of muscles [1, 3, 4, 5]. However, most prior ultrasound studies have focused on the lower limb, with few studies examining upper limb muscles [5] and no studies, to our knowledge, explicitly measuring thumb muscle fascicles.

Effectively measuring fascicle length of thumb muscles is an important step toward understanding force transmission in the multiarticular muscles of the wrist and hand. Additionally, validated methods for measuring both extrinsic and intrinsic hand muscles *in vivo* could be used to understand how these muscles change with age or pathology. Thus, the objective of this study was to test the reliability and validity of measuring muscle fascicle lengths of extrinsic and intrinsic thumb muscles using extended field of view ultrasound (EFOV-US) imaging.

Methods

Eight healthy adult subjects (4 female, avg. age 21.6 ± 1.3 years, avg. height 175.85 ± 8.26 cm) participated in this IRB-approved study. In each subject, one extrinsic thumb muscle, the flexor pollicis longus (FPL), and one intrinsic thumb muscle, the abductor pollicis brevis (APB), were imaged. Additionally, to enable comparison to prior work [5], the extensor carpi ulnaris (ECU) was imaged. All images were acquired with a SuperSonic Imagine Mach 30 (LH20-6 and L18-5 linear transducers).

Prior to imaging, the path of each muscle was determined and marked. During imaging, the probe was moved distally for the FPL and proximally for the ECU. Images for FPL and APB were acquired with the subject's shoulder at 90° and the forearm in a supine position. For the ECU, subjects sat with both the shoulder and elbow at 90° and hand lightly resting on a hand grip. Subjects were instructed to remain relaxed throughout imaging.

For each subject, 10 images of the ECU, 10 images of the FPL, and 15 images of the APB were recorded. For the ECU and FPL, the best 5 images for each combination of muscle and subject were identified and 2 fascicle length measurements were recorded from each image. For the APB, due to its small size, only one measurement was taken from the 10 best images for each subject. All fascicles were measured from aponeurosis to aponeurosis using the ultrasound machine's built-in measurement software. Averages were calculated for each muscle within each subject and across all subjects. Two-sided t-tests were performed to compare the subject averages with those reported in the literature [5, 6, 7].

Results and Discussion

The EFOV-US method used obtained reliable fascicle length measurements for the ECU (5.12 ± 0.3 cm), FPL (6.15 ± 0.53 cm), and APB (4.0 ± 0.4 cm). EFOV-US measurements for the ECU ($p = 0.12$) and APB ($p = 0.58$) were not significantly different than those reported in the literature (Fig.1).

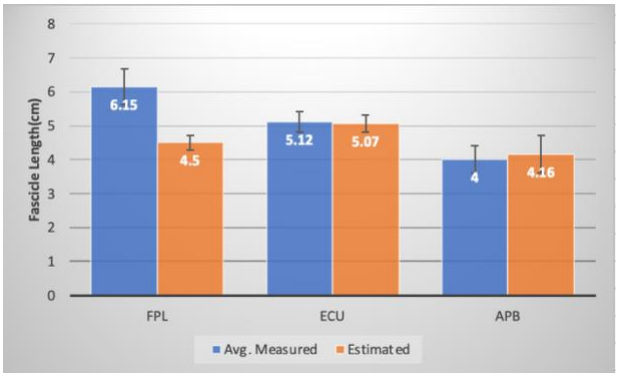

Figure 1: Comparison of average fascicle length for each muscle across all subjects to estimated values found in literature [5, 6, 7].

In contrast, FPL measurements were consistently greater ($p < 0.01$) than those reported in the literature (Fig. 1). Potential reasons for this discrepancy include differences in limb posture during measurement. Additionally, prior work measured FPL fascicle lengths in cadaveric specimens. Differences in the age of the specimens versus the subjects of this study as well as differences between living and preserved tissue could account for the reported differences in FPL fascicle lengths.

Interestingly, ECU measurements were strongly correlated with subject height ($r^2 = 0.792$) and forearm length ($r^2 = 0.792$). However, FPL ($r^2 < 0.4$) and APB ($r^2 < 0.1$) measurements were only weakly correlated. This highlights the need to directly measure thumb muscle fascicle lengths, instead of relying upon anthropometric scaling.

Use of EFOV-US to measure fascicle lengths requires images aligned with the fascicle plane. Despite all images being acquired by one trained sonographer, an average of 7.9% of the images were unmeasurable due to lack of visible fascicles. This highlights the need to record multiple images and for research-specific sonography training to ensure high repeatability.

Significance

To our knowledge, this is the first study to measure fascicle lengths of extrinsic and intrinsic thumb muscles using EFOV-US technology. Measuring thumb muscle fascicle lengths *in vivo* will inform our understanding of hand forces and hand pathologies.

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