ROTATOR CUFF MUSCLE ARCHITECTURE: IMPLICATIONS FOR GLENOHUMERAL JOINT STABILITY

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INTRODUCTION

Muscle architecture provides insight into the excursion and force generating ability of muscles. Previous studies comparing the architecture of the shoulder rotator cuff muscles failed to normalize muscle fiber lengths to sarcomere length and, consequently, the position of shoulder fixation influenced previous fiber length and physiological cross-sectional area (PCSA) estimates. The purpose of this investigation was to determine the architecture of the four rotator cuff muscles using fiber lengths normalized to sarcomere length.

METHODS

Ten fresh-frozen shoulders were prepared by skinning, Formalin fixing, and rinsing in 1X PBS. The mass of each muscle was measured after sharp dissection from bony attachments. Fiber lengths and pennation angles were measured from three to five predetermined locations within each muscle using digital calipers and a goniometer. Sarcomere lengths for each muscle fiber bundle were determined by laser diffraction using the zeroth to first order diffraction angles as previously described [1]. To account for variations in muscle fiber length that may occur during fixation, fiber bundle lengths were normalized by scaling measured sarcomere length to a standard sarcomere length for human muscle of 2.7 μm [2]. Using these normalized muscle fiber lengths, PCSA was calculated using the following equation [3]:

$$PCSA \ (cm^2) = \frac{Mass \ (g) \bullet \cos\theta}{\rho \ (g/cm^3) \bullet L_f \ (cm)}$$

where ρ represents muscle density (1.112 g/cm^3) [4] and θ represents surface pennation angle.

One-way repeated measures ANOVAs and *post-hoc* T-tests with Bonferroni corrections were used for between muscle comparisons. Values are reported as mean ± SE unless otherwise noted.

RESULTS AND DISCUSSION

Masses were significantly different among all muscles. Subscapularis was the heaviest (101.8 g ± 11.5 g), followed by infraspinatus (78.0 g ± 7.5 g), supraspinatus (34.0 g ± 4.3 g) and teres minor (21.2 g ± 2.0 g) muscles.

Fiber lengths were significantly shorter in the supraspinatus muscle (4.50 cm ± 0.32 cm) compared to the infraspinatus (6.57 cm ± 0.33 cm), teres minor (6.10 cm ± 0.35 cm) and subscapularis (6.00 cm ± 0.47 cm) muscles (Figure 1). This is interesting in light of the fact that the supraspinatus and infraspinatus sarcomere lengths (3.23 μm ± 0.05 μm and 3.18 μm ± 0.06 μm) were significantly longer than the teres minor

(2.80 μm ± 0.07 μm) or subscapularis (2.52 μm ± 0.09 μm) muscles. This implies that, at approximately neutral shoulder positions, the intrinsic length of the fibers is relatively long in these muscles. Secondly, it demonstrates that architectural studies that do not normalize muscle fiber lengths to sarcomere length significantly overestimate fiber lengths in supraspinatus and infraspinatus muscles.

The PCSA of supraspinatus (6.6 cm^2 ± 0.6 cm^2), infraspinatus (10.7 cm^2 ± 1.0 cm^2), teres minor (3.2 cm^2 ± 0.3 cm^2) and subscapularis (15.5 cm^2 ± 1.4 cm^2) muscles were all significantly different from each other (Figure 1).
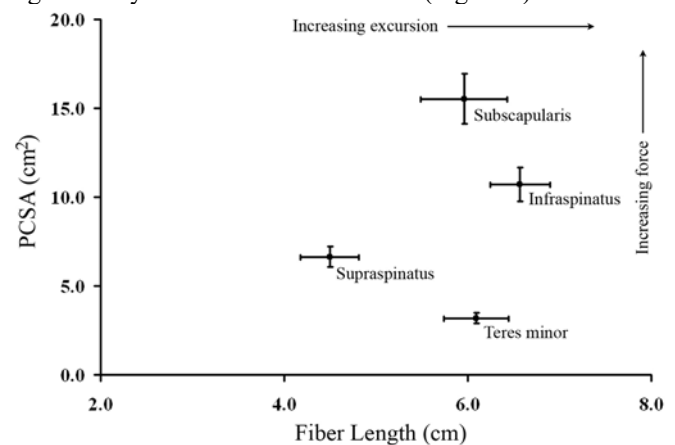
Figure 1. Scatter plot of normalized muscle fiber length versus PCSA. Supraspinatus muscle had significantly shorter muscle fiber lengths than the other three rotator cuff muscles and all muscles had significantly different PCSAs.

CONCLUSIONS

Based on architecture, subscapularis would produce the largest forces, while infraspinatus would operate over the widest range of shoulder positions. Surprisingly, supraspinatus has the shortest muscle fibers, indicating that its function as a glenohumeral stabilizer is limited to a relatively narrow range.

REFERENCES

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