

The Abduction Forces of In Vitro Cuff Tears Mimic Abduction Forces in Natural Tears

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INTRODUCTION: Research has successfully used shoulder simulators to study and improve rotator cuff (RC) surgery, but questions remain concerning the validity of using in vitro introduced tears to model in vivo pathologies. To address this issue, this study compares the abduction forces resulting from in vitro RC muscle insertion releases with the abduction forces resulting from tests of shoulder specimens with natural, full thickness medium tears. If similarities or differences in abduction force exist between the two groups, the result will suggest whether laboratory shoulder simulator tears properly simulate torn shoulders for cadaveric research. The hypotheses are as follows: torn and intact specimens have the same abduction force, cut and intact specimens have the same abduction force, cut and torn specimens have the same abduction force.

MATERIALS AND METHODS: Thirty-one cadaveric shoulders were obtained for this study: 24 intact specimens and 7 naturally torn full thickness medium tear specimens. Krackow whip stitched sutures were placed into the myotendinous junction of the supraspinatus (SS) cord, SS strap, upper and lower subscapularis (SSc), infraspinatus (IS) and teres minor (TM). After embedding the scapula in epoxy resin, the specimens were mounted in a shoulder simulator designed to hold the scapula in place, load the RC muscles along physiological lines of action, and record the force resisting abduction (abduction force) at the unconstrained distal humerus (Figure 1). A preload of ten Newtons was applied to account for hysteresis. Cyclic loading was applied at a frequency of 0.25Hz with loads ranging from 10N to the following physiological loads: SS cord 56N, SS strap 24N, IS 90N, TM 97N, upper SSc 108N, lower SSc 127N. The loads were determined using the cross-sectional area of each muscle and electromyographic activity (Kedgley 2007, Omi 2010, Roh 2000). Abduction force was recorded as the humerus pushed against a six degree of freedom load cell, and the abduction force used for comparison was taken at the peak of the fourth cycle. The same test was completed for each specimen at abduction angles of 0° and 30°. Intact specimens were tested to obtain the native abduction force of a healthy specimen. Following the initial tests, the intact specimens received releases of the SS humeral insertions of both the SS Strap and the SS Cord to simulate complete SS tears (Figure 2a). The cut specimens were tested using the same method to obtain their abduction forces. Naturally torn specimens were tested using the same method to obtain the abduction forces of shoulders with SS tears (Figure 2b). All specimens were tested using the same apparatus and the forces were run through t-distribution tests with three comparisons to consider: Torn Specimens vs Intact Specimens, Torn Specimens vs Cut Specimens, Intact Specimens vs Cut Specimens.

RESULTS SECTION: At both 0° and 30°, the abduction forces of naturally torn RC and intact RC are statistically different ($p < 0.001$ at 0°, $p < 0.002$ at 30°), as are the abduction forces of cut RC and intact RC statistically different ($p < 0.001$ for both). At both 0° and 30°, the abduction forces of torn RC and cut RC are not statistically different ($p \geq 0.461$ at 0°, $p \geq 0.100$ at 30°). At 0°, the abduction forces were: Torn $7.4 \pm 1.5N$, Cut $6.8 \pm 2.5N$, Intact $12.1 \pm 3.0N$; at 30°, the abduction forces were: Torn $8.14 \pm 1.99N$, Cut $6.58 \pm 2.04N$, Intact $11.92 \pm 2.55N$. (Figure 3)

DISCUSSION: This study supports the use of cuff SS insertional releases to model naturally occurring full-thickness medium RC tears in a shoulder simulator. The significant differences of the untorn native specimens with both the SS insertional release and the naturally torn cases demonstrate that the releases behave similarly to naturally torn cases. Furthermore, the lack of significance in the comparison of the cut specimens with the naturally torn specimens demonstrates that the two cases have some similarity. While this lack of significance does not prove the true similarity of the cut and naturally torn specimens, the lack of a difference shows that complete SS release can model full-thickness SS medial tears. Overall, the results show that artificially cut shoulders can accurately represent naturally torn shoulders in RC research.

SIGNIFICANCE/CLINICAL RELEVANCE:

Full-thickness medium tears lead to surgical intervention and a satisfactory laboratory model is essential for the translation of in vitro results to the clinical setting. The force generated in resisting abduction is one of many variables that measure RC function, but the similarities and differences in the abduction force among intact, insertional releases and natural tears found in this study give additional credence to the use of a shoulder simulator in RC research.

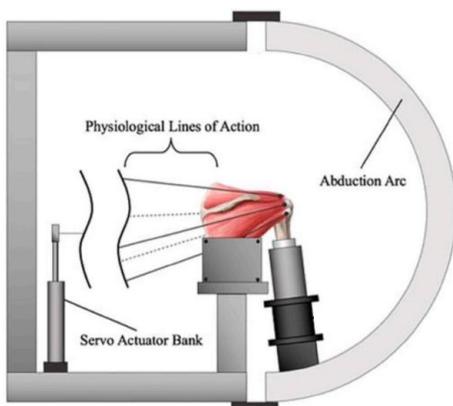


Fig. 1: Testing Apparatus

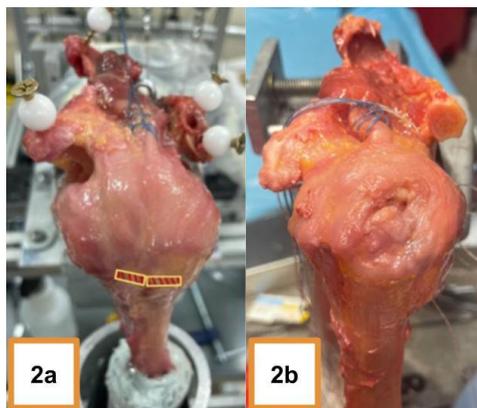


Fig. 2a: Intact Specimen with Cut Locations in Yellow
Fig 2b: Naturally Torn Specimen

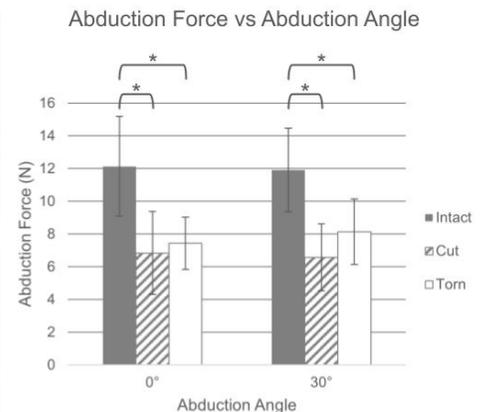


Fig. 3: Abduction Force vs Abduction Angle
*Statistical Significance