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Biceps Detachment Alters Rotator Cuff Tendon Properties and Joint Function in a Supraspinatus Tendon Tear Rat Model

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INTRODUCTION

The glenohumeral joint of the shoulder is stabilized by the rotator cuff musculotendinous units with the supraspinatus superiorly, the subscapularis anteriorly and the infraspinatus and teres minor posteriorly. Tears of the rotator cuff are often related to overuse and are commonly concurrent with damage to the long head of the biceps (LHB).[1,2,3] To alleviate pain which is frequently attributed to the LHB, surgeons regularly tenodese or tenotomize the LHB.[4] Recent data in a rat model indicates that the LHB may play a role in anterior stabilization of the glenohumeral joint in the presence of multi-tendon cuff tears (involving the supraspinatus and infraspinatus).[5] However, the mechanical effect of detachment of the LHB in the presence of an isolated supraspinatus tear is unknown. Therefore, the objective of this study was to use an established rat rotator cuff detachment model[6] to investigate shoulder function and mechanical properties of the infraspinatus and subscapularis tendons 8 weeks following supraspinatus and LHB tendon detachment. We hypothesized that detachment of the LHB in the presence of a supraspinatus tear would decrease shoulder function and intact cuff tendon mechanical properties.

METHODS

Experimental design

Twenty-eight adult male Sprague-Dawley rats (IACUC approved) underwent 4 weeks of overuse treadmill activity (17 m/min, 1 hr/day, 5 days/wk, 10° decline) to create a tendinopathic condition in the supraspinatus tendon prior to surgical detachment to induce an "acute-on-chronic" condition. Animals were then randomized into two surgical groups: unilateral detachment of the 1) supraspinatus tendon only (SO) or 2) supraspinatus and LHB tendons (SB).[8] Post-surgery, animals were allowed 1 week of cage activity before gradually returning to the overuse protocol over a 2 week period. All animals then completed 5 weeks of overuse activity prior to sacrifice (8 weeks post tendon detachment).

Ambulatory measurement

To assess shoulder joint function,[9] forelimb ground reaction forces were recorded using an instrumented walkway one day prior to detachment surgery (baseline) and at 3, 7, 14, 28, 42, and 56 days after surgery.

Tendon mechanical testing

Tensile testing was performed on the upper and lower bands of the subscapularis tendon[10] and the infraspinatus tendon. Tendons were dissected from the shoulder and cleaned of excess soft tissue. Stain lines were then placed along the length of the tendon for optical strain measurement. Cross sectional area was measured using a custom laser device. Tendons were then subjected to a mechanical testing protocol consisting of a preload to 0.08 N, ten cycles of preconditioning (0.1-0.5 N at 1% strain/s), a stress relaxation to 5% strain (5%/s) followed by a 600s hold, and a ramp to failure at 0.3%/s. Stress was calculated as force divided by cross sectional area and 2D Langrangian strain was determined optically using custom tracking software.

Statistical analysis

For the ambulatory assessment, significance was assessed using a 2-way ANOVA with repeated measures on time with follow-up t-tests between groups at each time point. Multiple imputations were conducted using the Markov chain Monte Carlo method for missing data points (~8%). Tissue mechanics were assessed using a one-tailed t-test. Significance was set at $p < 0.05$.

RESULTS

Ambulatory measurement

Significant alterations in ground reaction forces were noted in the SB group compared to SO (Figure 1). Specifically, the SB group had a significant change in medial/lateral force towards medial at 3, 7, and 14 days after surgery. Additionally, the SB group had significantly decreased propulsion force and braking force compared to the SO group at 3, 7, and 14 days after surgery. No differences existed between groups in vertical force.

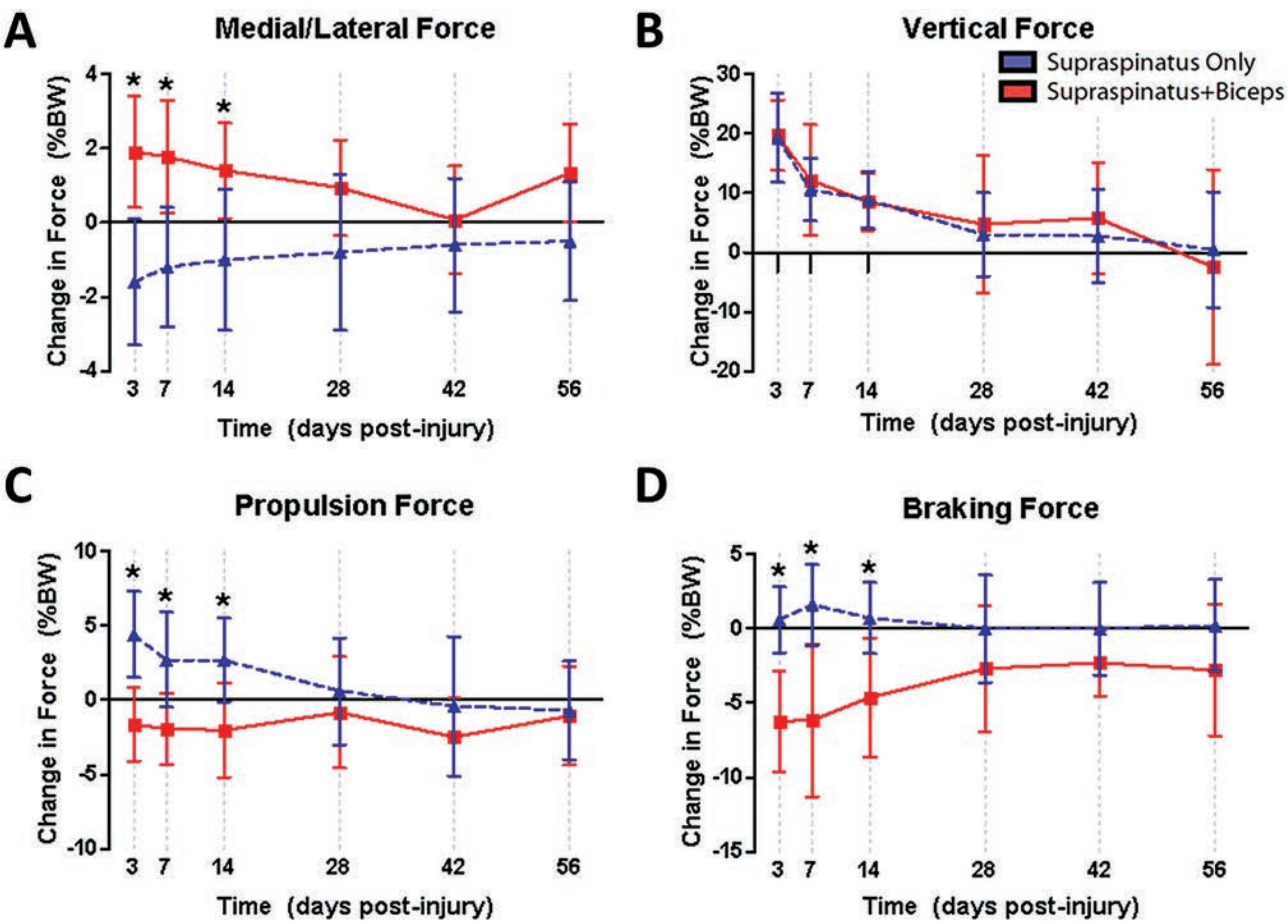

Figure 1. (A-D) (A) The SB group had a more medial force at 3, 7, and 14 days compared to the SO group. (B) No differences were found between groups in vertical force. (C) The SB group had a decreased propulsion force at 3, and 14 days compared to the SO group. (D) The SB group has a decreased braking force at 3, 7, and 14 days compared to the SO group.

Tendon mechanics

In the infraspinatus tendon, stiffness and elastic modulus at the insertion were significantly decreased in the SB group compared to the SO group (Figure 2). The midsubstance of the infraspinatus tendon had a significant increase in cross-sectional area in the SB group (Figure 2). No significant changes were noted at the insertion site of the upper-subscapularis tendon. Cross-sectional area and elastic modulus were significantly increased in the midsubstance of the upper-subscapularis tendon (Figure 2). No significant changes were found in the lower-subscapularis tendon at either the insertion or the midsubstance.

DISCUSSION

Detachment of the LHB in the presence of a supraspinatus tear alters shoulder function, is detrimental to the infraspinatus tendon, and improves mechanical properties of the upper-subscapularis tendon midsubstance. Alterations in ground reaction forces indicate a change in glenohumeral joint function between the SO and SB groups. Decreased braking and propulsion forces in the SB group compared to the SO group indicate inferior joint function, in contrast to the previous multi-tendon (supraspinatus and infraspinatus) study in which LHB tendon detachment restored propulsion force close to baseline.[5] A change towards increased medial force suggests that the SB group compensated for a lack of medial stability due to LHB tendon detachment, which is similar to the previous multi-tendon study, suggesting that the LHB plays a role in medial stability both in the presence and absence of the infraspinatus. The absence of the LHB tendon may result in posterior translation of the humeral head and impingement of the infraspinatus under the posterior-lateral acromion. Previous findings of a multi-tendon tear showed decreased joint damage and improved mechanical properties of the subscapularis tendon upon the detachment of the LHB tendon by balancing the anterior forces of the glenohumeral joint.[5] In the current study, detachment of the supraspinatus tendon alone did not disrupt the anterior-posterior force balance; however, the additional detachment of the LHB tendon did result in altered anterior-posterior forces and damage to the infraspinatus tendon. Slight, but significant improvement in the midsubstance mechanical properties of the upper-subscapularis tendon suggests that detachment of the LHB tendon may allow the subscapularis tendon to adapt to a supraspinatus tear in a positive manner, although the mechanism of action is unknown. Possible reasons include a reduction in bony adjacency with the coracoid process and functional differences in the glenohumeral joint after a

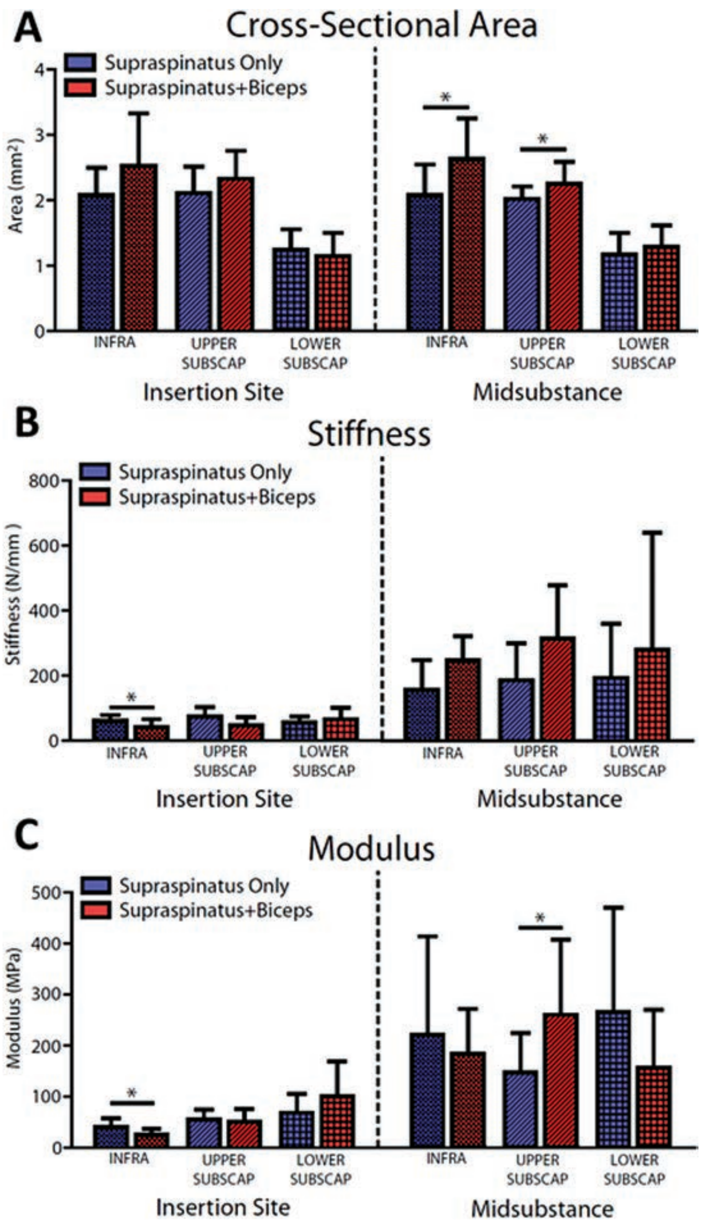

Figure 2. (A-C) (A) No changes in cross section area at the insertion of any tendon. The SB group had increased cross sectional area at the midsubstance of the infraspinatus and the uppersubscapularis. (B) The SB group had decreased stiffness at the insertion of the infraspinatus. There were no changes in stiffness at the midsubstance of any tendon. (C) The SB group had decreased modulus at the insertion of the infraspinatus. The upper-subscapularis had increased modulus at the midsubstance.

LHB tendon tear. In conclusion, detachment of the LHB in the presence of an isolated supraspinatus tear to alleviate pain might increase the probability of tear progression towards the infraspinatus. This data will help guide clinicians in treatment options for patients with supraspinatus tendon tears.

SIGNIFICANCE

This study provides evidence to dissuade LHB tendon tenotomy in the presence of a supraspinatus tendon tear based on mechanical force balance concepts.

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