Biceps Mechanical Properties Are Not Altered in the Presence of Asymptomatic Rotator Cuff Tendon Tears

Reuther, KE
Thomas, SJ
Satchell, LN
Soslowsky, LJ

University of Pennsylvania, Philadelphia, PA, USA,

Introduction

The long head of the biceps (LHB) tendon has different loading patterns in its intra- and extra-articular regions. The intra-articular region is exposed to complex loads including tension, compression, shear, and frictional forces, while the extra-articular portion is subjected primarily to tensional loads.[1] Previous studies have also shown that the intra-articular region has a more disorganized collagen organization and higher proteoglycan content than the extra-articular region,[1,2] and may be more prone to increased pathology with decreased healing potential. However, the mechanical properties in each of these regions have not been evaluated. In addition, degenerative changes in the LHB often occur secondary to rotator cuff tendon pathology[3,4] and the incidence of LHB pathology is correlated with the size and severity of rotator cuff tendon tears.[5,6] However, the effect of rotator cuff tear size on the mechanical properties of the human biceps tendon is not known. Therefore, the objectives of this study were to: 1) characterize the mechanical properties along the length of the human LHB tendon and 2) investigate the changes on the LHB tendon in the presence of an isolated supraspinatus (supra only) and combined supraspinatus-infraspinatus (supra-infra) rotator cuff tears. We hypothesized that: H1) in normal shoulders, the properties of the LHB tendon will vary along the length due to different environments and H2) in the presence of rotator cuff tears, the LHB tendon will have inferior mechanical properties, with greater damage seen with increasing rotator cuff tear severity.

Methods

Experimental Design and Sample Preparation: Fifty-one fresh-frozen human cadaver shoulders without documented history of shoulder pathology were dissected and 24 (48%) of these were found to have a rotator cuff tear. Of all shoulders dissected, 30 were sub-divided to create three age and gender-matched groups for the present study: control (N=11 (6M (male), 5F (female)), age 70.0±5.8), isolated supraspinatus tear (N=11 (6M, 5F), age 67.0±3.9), and combined supraspinatus-infraspinatus tears (N=8 (4M, 4F), age 69.5±5.9). Shoulders were dissected and the scapula and glenoid were resected, leaving the biceps tendon and its glenoid origin intact. At the time of testing, specimens were thawed and stain lines, for local optical strain, were placed along the bursal side, dividing the origin, intra-articular, and extra-articular regions of the tendon (Fig 1). Cross-sectional area was measured using a custom laser device. The remaining glenoid bone was then potted in PMMA and anchored with a screw. Tendon Mechanical Testing: To determine LHB tendon biomechanical properties, tensile testing was performed as follows: ten preconditioning cycles, stress relaxation to 5% strain at a rate of 4.5 mm/sec (5 %/sec) for 600 sec, and ramp to failure at 0.3%/sec.

Statistics: For normal controls (H1), mechanical properties were compared along the tendon length using a one-way ANOVA with Bonferroni post-hoc tests. To determine the effect of rotator cuff tears on tendon mechanics (H2), properties were assessed using a one-way ANOVA with Bonferroni post-hoc tests (significance at $p<0.05$).

Results

For normal controls, the cross-sectional area was significantly larger at the insertion site compared to both the intra- and extra-articular space regions. Additionally, biceps area was significantly larger in the intra-articular space compared to the extra-articular space (Fig 2). Linear modulus (Fig 3) and structural stiffness (data not shown) were significantly larger in the extra-articular space compared to both the intra-articular space and origin.

In the presence of an isolated supraspinatus tear, increased biceps cross-sectional area (hypertrophy) was measured in the intra-articular region of the tendon compared to control (Fig 2). Regardless of experimental group (control, supraspinatus only tear, supraspinatus-infraspinatus tear), no differences were observed for linear modulus (Fig 3) or stiffness (data not shown) in any region.

Paper No: 0103
2013 Annual Meeting
Orthopaedic Research Society
kreuther@seas.upenn.edu

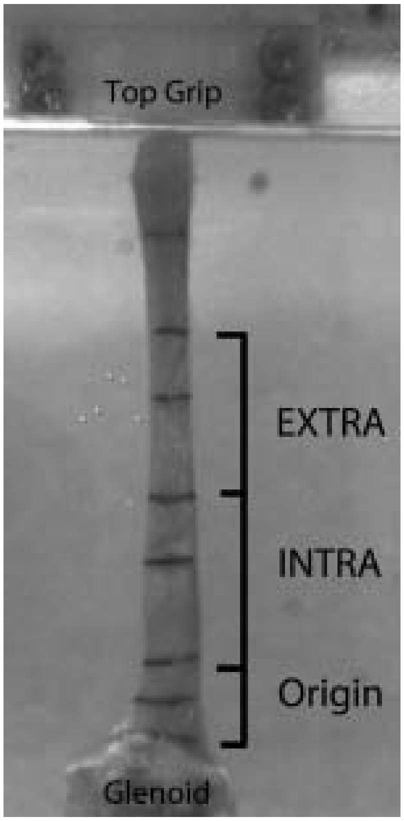

Figure 1. Stain lines were placed along the length of the tendon to measure local mechanical properties within each region (Origin, Intra-articular= INTRA, Extra-articular=EXTRA).

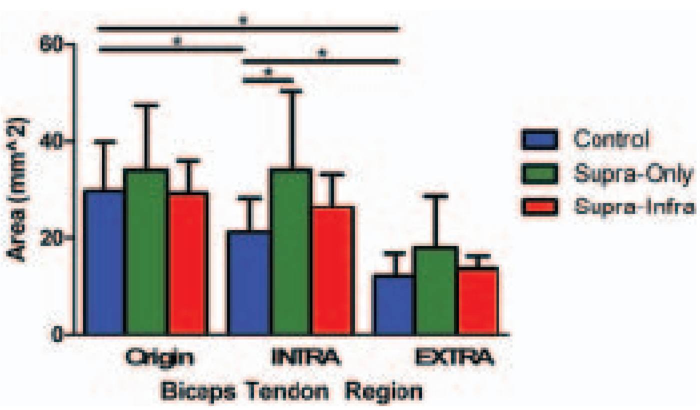

Figure 2. In control shoulders, biceps area was significantly decreased along the length of the tendon. In the presence of an isolated supraspinatus (Supra Only) tear, biceps area was significantly increased in the intra-articular space (mean±SD) (*$p<0.05$).

Discussion

This is the first study to measure the mechanical properties along the length of the human LHB tendon. Consistent with our first hypothesis, mechanical properties vary along the length of the tendon, with the extra-articular portion having a higher modulus than the rest of the tendon. These mechanical properties are consistent with the structural finding of more organized collagen fibers in the extra-articular region of the tendon as compared to the intra-articular region.[1] Additionally,

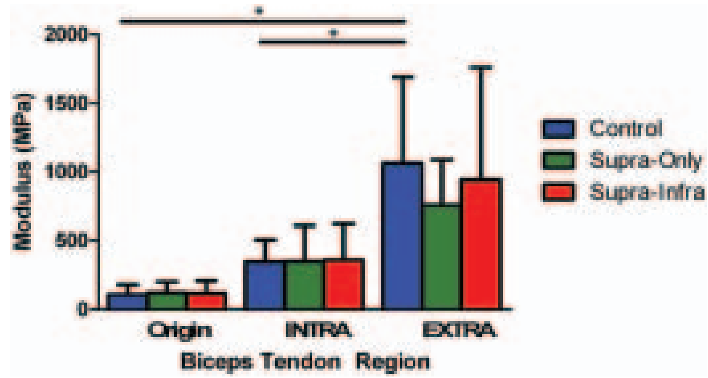

Figure 3. In control shoulders, biceps modulus was significantly larger in the extra-articular space. In the presence of rotator cuff tears, no regional differences were identified (mean±SD) (*$p<0.05$).

the lower modulus values at the origin and intra-articular region may place these regions at a higher risk for injury and are consistent with regions commonly associated with biceps pathology.[7]

Results also demonstrated that the mechanical properties of the LHB tendon were not altered in the presence of rotator cuff tears, consistent with previous studies.[8] However, hypertrophy of the tendon did occur in the intra-articular space (also consistent with previous findings in cadavers[9]) in the isolated supraspinatus tear group. At the shoulder joint, the LHB tendon is believed, by some, to function as a humeral head depressor and has been shown to play an important role as a joint stabilizer, particularly in rotator cuff deficient shoulders.[10] Our results suggest that the mechanical strength of the LHB is maintained and therefore may still function effectively in the presence of a rotator cuff tear.

Management of LHB pain in the presence of cuff tears is controversial and physicians often augment cuff repairs with tenotomy or tenodesis to reduce pain. The cadaver shoulders used in this study were classified as having no history of shoulder pathology and despite this classification, cuff tears were present in 48% of cadavers. Therefore, we speculate that these individuals either did not have sufficient pain to report to their physician or were asymptomatic, as a large percentage of rotator cuff tears are, indeed, asymptomatic. Previous studies have shown that greater humeral head migration occurs in shoulders with symptomatic tears than those with asymptomatic tears.[11] Successful compensation by adjacent muscles including the deltoid and subscapularis (which functions as a humeral head depressor and has shown increased activity in asymptomatic compared to symptomatic cuff tear patients[12]) may be achieved, preserving the loading environment of the LHB tendon and preventing tendon damage.

Significance

Results of this study suggest that a relationship may exist between asymptomatic cuff tears and the preservation and maintenance of LHB mechanical properties which warrants further investigation.

Acknowledgements

We acknowledge Jennica Tucker for dissection assistance. This study was funded by NIH/NIAMS.

References

1. **Berenson MC, Blevins FT, Plaas AH, et al.** Proteoglycans of human rotator cuff tendons. *J Orthop Res* 1996;14:518-25.

2. **Joseph M, Maresh CM, McCarthy MB, et al.** Histological and molecular analysis of the biceps tendon long head post-tenotomy. *J Orthop Res* 2009;27:1379-85.

3. **Ahrens PM, Boileau P.** The long head of biceps and associated tendinopathy. *J Bone Joint Surg Br* 2007;89:1001-9.

4. **Murthi AM, Vosburgh CL, Neviaser TJ.** The incidence of pathologic changes of the long head of the biceps tendon. *J Shoulder Elbow Surg* 2000;9:382-5.

5. **Chen CH, Hsu KY, Chen WJ, et al.** Incidence and severity of biceps long head tendon lesion in patients with complete rotator cuff tears. *J Trauma* 2005;58:1189-93.

6. **Peltz CD, Perry SM, Getz CL, et al.** Mechanical properties of the long-head of the biceps tendon are altered in the presence of rotator cuff tears in a rat model. *J Orthop Res* 2009;27:416-20.

7. **Refior HJ, Sowa D.** Long tendon of the biceps brachii: sites of predilection for degenerative lesions. *J Shoulder Elbow Surg* 1995;4:436-40.

8. **Carpenter JE, Wening JD, Mell AG, et al.** Changes in the long head of the biceps tendon in rotator cuff tear shoulders. *Clin Biomech* 2005;20:162-5.

9. **Toshiaki A, Itoi E, Minagawa H, et al.** Cross-sectional area of the tendon and the muscle of the biceps brachii in shoulders with rotator cuff tears: a study of 14 cadaveric shoulders. *Acta Orthop* 2005;76:509-12.

10. **Kido T, Itoi E, Konno N, et al.** The depressor function of biceps on the head of the humerus in shoulders with tears of the rotator cuff. *J Bone Joint Surg Br* 2000;82:416-9.

11. **Keener JD, Wei AS, Kim HM, et al.** Proximal humeral migration in shoulders with symptomatic and asymptomatic rotator cuff tears. *J Bone Joint Surg Am* 2009;91(6):1405-13.

12. **Kelly BT, Williams RJ, Cordasco FA, et al.** Differential patterns of muscle activation in patients with symptomatic and asymptomatic rotator cuff tears. *J Shoulder Elbow Surg* 2005;14:165-71.