EFFECT OF ROTATOR CUFF MUSCLE IMBALANCE ON GLENOHUMERAL CONTACT PRESSURE AND HUMERAL EXTERNAL ROTATION: A CADAVERIC STUDY

Teruhisa Mihrat1,2, Jeffrey Gates1, Michelle H. McGarry1, Jason Lee1, Mitsuo Kinoshita3, Thay Q. Lee1
1Orthopaedic Biomechanics Laboratory, Long Beach VA Healthcare System and University of California, Irvine, Long Beach, CA; 2Orthopaedic Surgery, Osaka Medical College, Osaka, Japan
tqlee@med.va.gov

Introduction: Shoulder internal impingement and peel-back mechanism during late cocking phase of throwing motion are thought to cause rotator cuff injury and type II SLAP lesion. While shoulder internal impingement is pathological, a forceful internal impingement is pathological. Previous cadaveric studies showed that excessive humeral external rotation caused a detachment of the superior labrum and the increased strain of the superior labrum, suggesting that increased external rotation results in peel-back of the superior labrum. According to previous EMG study throwing athletes who had shoulder pain had a decreased activity of subscapularis muscle at the late cocking phase of throwing. Therefore, we hypothesized that the imbalance of rotator cuff muscle strength leads to shoulder internal impingement and/or peel-back mechanism. The objective of this study was to assess the effect of rotator cuff muscle imbalance on glenohumeral contact pressure and humeral external rotation.

Materials and Methods: Eight cadaveric shoulders were tested using a custom shoulder testing system. To simulate a late cocking position of throwing motion, all measurements were performed at 60° of glenohumeral abduction and maximum humeral external rotation. Horizontal abduction positions of 20°, 30°, and 40° with respect to the scapular plane were tested. Glenohumeral contact pressure and area at maximum external rotation were measured using Tekscan sensors. Relationship between the location of the rotator cuff insertion on the greater tuberosity and the geometric center of the glenoid was recorded using a Microscribe 3DLX. Humeral external rotation angle was measured with 2.2 Nm of external rotation torque. Based on EMG data, a control rotator cuff muscle strength condition was defined by using 5N for the supraspinatus (SSP), 80N for the subscapularis (SubS), and 30N for the infraspinatus (ISP). Rotator cuff muscle imbalance was simulated by changing each rotator cuff muscle force (decreased SSP: 2N, increased SSP: 15N, decreased SubS: 30N, increased SubS: 100N, decreased ISP: 20N, increased ISP: 40N). Each measurement was compared between the control and the rotator cuff imbalance condition. Data were analyzed using Tukey’s post hoc test.

Results: A decrease in subscapularis muscle strength caused a significant (P<0.001) increase in maximum external rotation angle with the same external torque. The increase in external rotation due to a decrease in subscapularis muscle strength was 8.9±3.0° in 20° of horizontal abduction, 4.6±2.5° in 30° of horizontal abduction, and 4.6±2.7° in 40° of horizontal abduction with respect to the scapular plane. Other muscle loading conditions did not change the external rotation angle (Fig 1).

![Figure 1: Maximum external rotation, *p<0.05.](image)

With decreased subscapularis muscle strength, the posterior–superior glenohumeral contact pressure significantly (P<0.01) increased by 0.39±0.26 MPa in 20° of horizontal abduction, 0.17±0.15 MPa in 30° of horizontal abduction, and 0.05±0.09 MPa in 40° of horizontal abduction, with respect to the scapular plane. Decreased subscapularis muscle strength also led to a significant (P<0.001) decrease in glenohumeral contact area. Other muscle force conditions did not affect the glenohumeral contact pressure or area (Fig 2).

![Figure 2: Glenohumeral contact pressure in 30 degrees of horizontal abduction, *p<0.05.](image)

At maximum external rotation, the rotator cuff insertion shifted posteriorly with decreased subscapularis muscle force (P<0.05). At 20° of horizontal abduction, the cuff insertion was posterior to the posterior edge of the glenoid, representing no internal impingement. However, at 30° and 40° of horizontal abduction, the cuff insertion remained overlapped with the posterior–superior glenoid. Therefore, the rotator cuff tendon was impinged between the greater tuberosity and glenoid with all muscle strength conditions at 30° and 40° of horizontal abduction (Fig 3).

![Figure 3: Location of the rotator cuff insertion at maximum external rotation. IP, posterior edge of infraspinatus; SA, anterior edge of supraspinatus; MP, point midway between SA and IP; SubS dec, decreased subscapularis muscle force.](image)

Discussion: An increase in humeral external rotation is thought to result in peel-back of the superior labrum. Only decreased subscapularis muscle force significantly increased humeral external rotation under equal amounts of external rotation torque. This suggests that decreased subscapularis muscle force may lead to peel-back of the superior labrum due to increased external rotation. Glenohumeral contact pressure showed a significant increase with a decreased subscapularis muscle force suggesting that an impinged rotator cuff tendon between the greater tuberosity and glenoid may become problematic. Throwing with decreased subscapularis muscle strength may cause a forceful internal impingement and a peel-back of the posterior–superior labrum. Therefore, throwers whose subscapularis muscle strength is decreased, should stop pitching to avoid forceful internal impingement or peel-back, which may cause rotator cuff tear or type II SLAP lesion. Subscapularis muscle strengthening is necessary for throwers to prevent impingement.

Acknowledgements: VA Rehab R&D, John C. Griswold Foundation.