Effect of Posterior Capsule Tightness on Glenohumeral Translation in the Late-Cocking Phase of Pitching

Kim M. Clabbers, John D. Kelly, Dov Bader, Matthew Eager, Carl Imhauser, Sorin Siegler, and Ray A. Moyer

Context: Throwing injuries. Objective: To study the effects of posterior capsule tightness on humeral head position in late cocking simulation. Design: Eight fresh frozen shoulders were placed in position of “late cocking,” 90 degrees abduction, and 10 degrees adduction and maximal external rotation. 3D measurements of humeral head relationship to the glenoid were taken with an infrared motion sensor, both before and after suture plication of the posterior capsule. Plications of 20% posterior/inferior capsule and 20% entire posterior capsule were performed, followed by plications of 40% of the posterior/inferior capsule and 40% entire posterior capsule. Setting: Cadaver Lab. Intervention: Posterior capsular plication. Main Outcome Measures: Humeral head position. Results: 40%, but not 20%, posterior/inferior and posterior plications demonstrated a trend to increased posterior/superior humeral head translation relative to controls. Conclusion: Surgically created posterior capsular tightness of the glenohumeral joint demonstrated a nonsignificant trend to increased posterior/superior humeral head translation in the late cocking position of throwing. Key Words: Posterior capsule, labrum, rotator cuff, posterior/superior humeral head migration

Overhead athletes are known to suffer greater risk of shoulder injury.\textsuperscript{1,2} Several factors, both intrinsic and extrinsic, have been proposed to explain the greater propensity to injury. Overhead athletes are known to develop alterations in glenohumeral motion in time,\textsuperscript{3,4,5,6,7} namely, increases in external rotation and decreases in internal rotation are both observed in experienced throwers, swimmers, and tennis players.\textsuperscript{8,9} These motion alterations are thought to occur secondary to capsular changes or to alterations in humeral version.\textsuperscript{10,11,12} Recently, glenohumeral internal rotation deficit (GIRD) has been proposed as a major risk factor for the development of posterior cuff and labral injury in the overhead athlete.\textsuperscript{2} Specifically, some investigators posit that a tight posterior inferior capsule serves as a
“checkrein” to extreme external rotation in the abducted (thrower’s) position and forces the humeral head to migrate posteriorly/superiorly. This deviation in motion axis is theorized to potentiate posterior superior labral and cuff injury. There is a paucity of scientific data corroborating this notion and sought to answer the question of whether surgically created posterior capsule tightness would materially affect glenohumeral kinematics in the position of throwing.

**Method**

Eight shoulders from four fresh-frozen cadavers, thawed overnight, were prepared by a mid-humerus cut and disarticulation of the scapulothoracic and sternoclavicular joints. All tissues superficial to the rotator cuff musculature, including the deltoid were removed. The shoulders were mounted onto a board via three transfixion screws through the scapula and the board was clamped onto a shoulder positioning apparatus. Two Steinman pins were inserted into the humeral shaft and were connected to an external fixator for positioning of the humerus. A smaller Steinman pin was inserted into the bicipital groove as a marker for external rotation.

The posterior capsule was identified via a split in the infraspinatus and bluntly freed from cuff fibers. The humerus was positioned at 45 degrees abduction (relative to the vertical glenoid face as measured with a goniometer) with 0 degrees flexion, maximal internal rotation, and posteriorly subluxated to obtain the largest possible dimension of the posterior capsule. The total posterior capsule span (TPCS) was then measured as the distance from the lateral border of the mid-glenoid to the posterior border of the greater tuberosity at the superior-inferior center of the insertion of the rotator cuff tendon “sleeve” with a caliper. This line of measurement was marked with a marking pen and became the “equator” of the posterior capsule. The average distance of the TPCS was 88.25 mm (range 74 to 100 mm).

The entire posterior capsule was marked and divided into five equal segments, each comprising one-fifth (20%) of the capsular length (Figure 1). Capsular imbrications were performed using a horizontal mattress stitch of #2 Ticron to achieve various horizontal capsular plications. The posterior inferior capsule was defined as that exposed capsular portion below the equator. Four separate imbrications were performed: 20% of the posterior inferior capsule, 20% of the entire posterior capsule, 40% of the posterior inferior capsule, and 40% of the entire posterior capsule. Capsular imbrications of 20% TPCS and 40% TPCS each consisted of horizontal mattress stitches using #2 Ticron suture. The first stitch was placed along the equator of the posterior capsule, while the second and third stitches were placed in parallel one centimeter superior and one centimeter inferior to the equator to affect a total posterior capsular plication. Each stitch was started at a standard distance of 50% TPCS lateral from the posterior border of the greater tuberosity and captured either 20% or 40% lateral to medial posterior capsular volume. Each stitch location was measured and marked with a marking pen before suture placement. All the sutures to affect the various imbrications were placed before tightening. Care was taken to ensure all sutures maintained tissue “bite” (and therefore imbrication) during all testing. Imbrications were performed in succession, with 20% posterior inferior placation performed first followed by 20% total posterior plication. Subsequently, 40% posterior inferior imbrication was performed with the 40% total posterior
capsular imbrication affected last. Measurements of glenohumeral position with the kinematic system were performed in succession immediately following the various capsular imbrications. Internal rotation of the glenohumeral joint was not measured directly.

Three-dimensional kinematic measurements were determined in three positions both before and after respective plications—30 degrees abduction/0 horizontal adduction, 90 degrees abduction/0 horizontal adduction and finally, 90 degrees abduction maximal external rotation/10 degrees horizontal adduction position—(simulated arm position during the late cocking phase of throwing.) Abduction was measured with respect to the glenoid using a goniometer. External rotation torque was applied until elastic limit of the tissue was attained. Final external rotation was measured and ranged from 160 to 180 degrees.

**Instrumentation**

To measure and record the positions of the humerus and glenoid relative to each other, an Optotrak 3020 (Northern Digital Inc., Waterloo, Ontario, Canada) three-dimensional kinematics system was used. An infrared transmitter was rigidly mounted on each scapula and humerus in order to record the absolute position and orientation of each. This allowed the joint to be placed in any position, and the abduction/adduction, flexion/extension, rotation, and any translation of the humeral head relative to the glenoid would be measured. The shoulder positioning apparatus was positioned relative to the Optotrak’s sensors so the orientation of the x-axis was in a medial-lateral direction, the y-axis was in an anterior-posterior direction, and the z-axis was in a superior-inferior direction, all relative to the vertical glenoid face and vertical scapular body. The Optotrak 3020 has a known accuracy of 0.1 mm in the x and y coordinates and 0.15 in the z coordinate.
To construct frames of reference to show the relative positioning of the joint, digitization points were taken on the scapular and humerus of each specimen at the end of each trial. This established the relationship between the infrared transmitter and the bone to which it was fixed. There were three points taken from each bony structure. The three points taken on each scapula were located at the superior angle, the inferior angle, and the center of the glenoid fossa (after venting the capsule to visualize the glenoid). The three points taken on each humerus were located at the bicipital groove, the posterior border of the greater tuberosity (the lateral point of the posterior capsule “equator”), and the distal humeral shaft directly distal to the bicipital groove. Once a plane was established, the coordinate system could be formed for each scapula and humerus to compare their relative positions.

Testing

Three arm positions were tested with each shoulder joint with no capsular imbrication or with some degree of capsular imbrication. The humerus was manually positioned and measured with a goniometer, and the external fixator was locked to hold the exact position while the Optotrak 3020 recorded each static position for 10 seconds at a 40-Hertz sampling rate. Each set of data collected (per position) was converted to one value to show the relative position of the humerus to the scapula. The first position recorded was a neutral reference with the humerus positioned in 30 degrees abduction, 0 degrees rotation, and 0 degrees horizontal adduction. The second position was an abduction reference. The humerus was positioned in 90 degrees abduction, 0 degrees rotation, and 0 degrees external rotation. The third position tested was the late-cocking phase position with the humerus at 90 degrees abduction, 10 degrees horizontal adduction, and maximal external rotation. The average manual measurement of external rotation was 103 degrees (range 90 to 116 degrees).

Each shoulder specimen was placed in the three positions with no capsular imbrication and recorded. The middle (along the equator) and inferior sutures of 20% TPCS were then tightened and the late-cocking phase position was recorded. This simulated tightening of the posterior/inferior capsule. The superior 20% TPCS suture was then tightened and the late-cocking phase position was recorded. This simulated tightening of the entire posterior capsule. The 20% TPCS superior suture was cut to release the superior posterior capsule. Then the 40% TPCS sutures were tightened in a similar fashion and the late-cocking phase position was recorded for 40% TPCS imbrication for a tightened posterior/inferior capsule and entire posterior capsule. There was no significant change in the degrees of external rotation obtained with the varying tightness of the posterior capsule. This procedure was performed for each shoulder specimen followed by digitization of each specimen. The data were analyzed for change in translation compared to neutral in the x (anteroposterior), y (medial-lateral), and z (superior-inferior) axis using ANOVA with repeated measures.

Results

Measurements of humeral head position (+ denotes anterior, - posterior) in the simulated late cocking position demonstrated that in the anterior-posterior, or y, axis
there was an average translation of -2.96 mm in the unimbricated shoulder (Table 1). The 20\% inferior capsular imbrication, on average, translated 1.03 mm more anteriorly than unimbricated control specimens. Imbrication of 20\% of the entire posterior capsule had, on average, net -0.46 anterior translation compared to controls while the 40\% posterior inferior capsular imbrication had an average translation that was 1.33 mm posterior to controls. Imbrication of 40\% of the entire posterior capsule similarly resulted in an average translation of 0.89 mm posterior to control shoulders. These differences, however, failed to reach statistical significance (P value of 0.19).

In the superior-inferior, or z, axis there was an average translation (- denotes inferior, + superior) of -32.42 mm in the unimbricated shoulder (Table 2). The 20\% inferior capsular imbrication had an average translation of 2.90 mm superior to controls. Similarly, imbrication of 20\% of the entire posterior capsule had an average translation of 2.61 mm superior to controls. Forty percent posterior inferior capsular imbrication had an average translation of 3.85 mm superior to controls with imbrication of 40\% of the entire posterior capsule resulted in an avg. superior translation of 3.89 mm. These differences in results also failed to reach statistical significance (P value of 0.40).

Thus, in the normal, or unimbricated, shoulder, there was a trend toward relative posterior and inferior translation of the glenohumeral joint when the shoulder was placed in the abducted-externally rotated (late-cocking) position. When 20\% of the posterior capsule was imbricated, average values suggested a more relative anterior and superior position of the glenohumeral joint as compared with controls. When 40\% of both the posterior and posterior inferior capsule was imbricated, average values reflected a trend to a relative posterior and superior shift when

<table>
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<th>Specimen</th>
<th>AP 0</th>
<th>AP 20% Imbrication post–inferior capsule</th>
<th>AP 20% Imbrication entire posterior capsule</th>
<th>AP 40% Imbrication post–inferior capsule</th>
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Delta = difference from control
compared with controls. These changes can be seen graphically in Figures 2 and 3. There was little difference in translation between tightening of the posterior inferior capsule compared to the entire posterior capsule. Statistical significance between any subgroups was not achieved due to a low power and a large standard deviation in measurements.

**Discussion**

Overhead athletes are known to experience a greater incidence of shoulder afflictions than controls. Intrinsic factors proposed to explain the inordinate frequency of cuff and labral injury in this population include acquired capsular laxity\textsuperscript{14-16} humeral

<table>
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<tr>
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<th>SI 20% Imbrication entire posterior capsule</th>
<th>SI 40% Imbrication post–inferior capsule</th>
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</table>

**Figure 2**

*Translation of the Humeral Head in Relation to the Glenoid Fossa Anterior (+) / Posterior (−)*

head version,\textsuperscript{17} and acquired posterior capsular contracture.\textsuperscript{2} Internal rotation deficits have been shown to occur in overhead athletes\textsuperscript{18} and appear to progress with years and exposure to play.\textsuperscript{19} This internal rotational deficit is due presumably to both capsular contracture\textsuperscript{2} and bony adaptive changes.\textsuperscript{10-13} Posterior capsular contracture in throwers is thought to occur in response to the chronic distractive forces applied to the posterior/inferior capsule during the follow through phase of throwing. Burkhart et al\textsuperscript{2} posit that this acquired capsular contracture causes a “checkrein” to extreme external rotation in the abducted position and forces the humeral head to assume a new center of rotation posterior and superior to the native position. This posterior and superior shift purportedly increases posterior labral and cuff strain, increases “peel back” forces on the posterior/superior labrum, and creates a “pseudolaxity” of the anterior inferior glenohumeral ligament.\textsuperscript{2}

In the normal shoulder, the late-cocking position of throwing causes a postero-inferior translation of the humerus on the glenoid.\textsuperscript{20,21,22} Our results corroborate this finding, with the non-imbricated specimens demonstrating a posterior inferior shift in abduction/external rotation. In the presence of intact anterior capsular restraints, the ABER position would be expected to cause tightening of the inferior glenohumeral ligament (IGHL). Tightness anteriorly would cause obligate translation posteriorly due to the capsular constraint mechanism proposed by Harryman.\textsuperscript{21} Inferior translation can be explained by constraint of the rotator interval capsule. With only mild tightness of the posterior capsule, we found a trend to shift glenohumeral translation anterosuperiorly relative to controls. The absolute translation was still postero-inferior, however, but there may be enough constraint posteriorly to cause some relative obligate translation anteriorly with minor posterior imbrication. With more extreme posterior capsular tightness, our samples demonstrated a trend in translation posterosuperiorly relative to controls. This is in accordance with the prediction of Burkhart et al\textsuperscript{2} that significant posterior inferior capsular contracture creates a tether to humeral head rotation and drives the humeral head posterior/superiorly during the late cocking phase of throwing. The results are intriguing and are in accordance with the recent findings of Grossman et al,\textsuperscript{22} who demonstrated relative posterior/superior humeral head migration.
in the presence of both posterior capsule tightness and anterior capsular laxity in cadaveric shoulders placed in abduction/external rotation. Of note, in our study, a trend to relative posterior/superior translation in the abduced external rotation position was found only in the 40%, rather than 20% imbrication groups. This suggests that perhaps only more severe posterior capsular contracture induces the translational changes.

O’Brien23 introduced the concept of the inferior glenohumeral ligament (IGHL) as a “hammock-like” structure, which enveloped the inferior humeral head in abduction. In extreme external rotation, the posterior band of the IGHL was proposed to shift anteriorly with humeral rotation and rest at the inferior pole of the humerus. Burkhart et al2 propose that a contracted posterior IGHL would create a tether to increasing external rotation in the abduced humerus and literally drive the joint center of rotation posterior and superior. Increased excursion in the posterior superior direction could conceivably explain higher stresses placed across the posterior superior labrum via increased “Peelback” forces on the superior labrum24 and higher tensile forces on the posterior cuff. Indeed, throwers are found to have a higher incidence of posterior labral and cuff injury. In fact, Burkhart et al25 have suggested that overhead throwers who develop posterior capsular contracture incur more labral and cuff injury compared to throwers without posterior capsular tightness. Our data neither supports nor refutes this contention, since statistical significance was not attained; however, the trends of the data presented are consistent with Burkhart’s thesis in that greater amounts of posterior inferior imbrication placed the humeral head closer to the posterior superior labrum in the “late cocking” position.

The large variance in measurement of humeral position and the lack of power due to the small numbers of specimens likely explains the lack of significance. The acquisition of descriptive data, as presented here, includes many variables that are difficult to control. A power analysis was not performed prior to initiation of the study and this is certainly a weakness of the investigation. Furthermore, the amount of torque applied to the cadaveric specimens to effect the “late cocking” position of extreme external rotation was not quantified, with the tissue elastic limit serving as the endpoint to rotational torque. Finally, cadaveric specimens, lacking muscular effects on joint capsular kinematics, certainly do not mimic entirely the true clinical state.

Future research considerations include repeating the study with larger number of specimens or devising more direct means of measuring posterior labral strain in the presence of a surgically created posterior capsular contracture.

Conclusions

The surgical imbrication of the posterior capsule of the cadaveric glenohumeral joint produced a trend to posterior/superior migration of the humeral head in the simulated late cocking position. Significance was not attained, presumably due to large measurement variance and lack of power.

References