Physical examination of overhead-throwing athletes consistently demonstrates adaptive glenohumeral internal and external rotation range of motion of the dominant shoulder when compared with the nondominant limb. It can be concluded based on the results of several studies that throwers demonstrate significantly increased glenohumeral external rotation (external rotation gain) and significantly decreased glenohumeral internal rotation (glenohumeral internal rotation deficit [GIRD]) in the throwing arm.1,2,5,9,32,34 The reason for this altered range of motion is not clear, but it is believed to be a natural adaptation that develops in all throwers. Theories related to external rotation gain and GIRD include the presence of subtle microtrauma to the static and dynamic restraints of the glenohumeral joint from repetitive overhead throwing,1,10,33 contracture of the posteroinferior joint capsule,3,37 and osseous adaptation of...
the humerus.\textsuperscript{5,29,32} Despite the apparent alterations in the amount of rotation, the amount of total humeral rotation range of motion available in the throwing limb typically does not differ from that of the uninvolved limb.\textsuperscript{5,30,32} The total arc of motion has been described by Wilk et al\textsuperscript{29} as the full range of motion from maximum external rotation to maximum internal rotation and is reported to be approximately 180°. Thus, for every degree of external rotation gained, a degree of internal rotation can be lost without affecting the function of the throwing shoulder.\textsuperscript{41}

Range of motion alterations can become problematic in the throwing shoulder when the amount of glenohumeral internal rotation loss exceeds any gain in external rotation.\textsuperscript{4} This condition is a true internal rotation deficit from the total humeral rotation range of motion. The loss of internal rotation is believed to result from contracture and thickening of the postero-inferior portion of the glenohumeral joint capsule, which occurs from the repetitive microtrauma imparted during the deceleration phase of the throwing motion.\textsuperscript{3,31,37} In their review of the disabled throwing shoulder, Burkhart et al\textsuperscript{37} reported that arthroscopic findings in throwers who exhibit GIRD show a severely contracted and thickened postero-inferior recess in the posterior band of the inferior glenohumeral ligament. Ticker et al\textsuperscript{36} reported similar results, demonstrating thickened posterior capsules in patients diagnosed with limited internal rotation in conjunction with subacromial impingement. Excessive posterior capsular tightness and GIRD have been implicated in injuries to the throwing shoulder.\textsuperscript{3,37,38,40} Tyler et al\textsuperscript{38} developed and validated clinical assessment of posterior capsular tightness, which involves measurement of side-lying horizontal adduction of the humerus. It has been acknowledged that the assessment might better represent posterior shoulder tightness rather than isolated capsular tightness, given that other anatomical structures such as the rotator cuff could play a role.\textsuperscript{28,29} Thus, in the current study, we refer to the Tyler et al\textsuperscript{38} assessment findings as posterior shoulder tightness rather than as posterior capsular tightness. Tyler et al\textsuperscript{38} demonstrated that throwers have more posterior shoulder tightness than do non-throwing athletes. In a subsequent study, Tyler et al\textsuperscript{37} demonstrated that subjects with subacromial impingement develop posterior shoulder tightness.

It has recently been recognized that throwers can feel posterior shoulder pain during the late cocking phase, specifically at end ranges of external rotation.\textsuperscript{15,16,39} Unlike subacromial impingement, classically described by Neer,\textsuperscript{26} it is believed that this pain results from impingement of the supraspinatus (and occasionally infraspinatus) tendon, between the greater tuberosity and the posterior aspect of the humeral head with the posterosuperior glenoid labrum. Although it is believed that contact between the humeral head and the posterior glenoid rim is a normal physiological occurrence, the biomechanics of the throwing motion is believed to intensify this contact and its effect on the underlying anatomical structures.\textsuperscript{6,8,12,15,19,20,30,39} Thus, pathologic internal impingement can result. Using arthroscopy, clinicians have identified undersurface lesions on the posterior aspect of the supraspinatus tendon and/or anterior portion of the infraspinatus tendon as well as posterosuperior glenoid labrum fraying (type I or II superior labral anterior posterior [SLAP] lesion) in overhead-throwing athletes.\textsuperscript{6,19,20,39}

In the current study, we believed that posterior shoulder tightness and GIRD may be associated with pathologic internal impingement in throwers. Specifically, we hypothesized that throwers with pathologic internal impingement would exhibit significantly increased posterior shoulder tightness and GIRD without significantly increased external rotation gain. The purpose of this study was to identify increased posterior shoulder tightness and GIRD without increased external rotation gain in throwers diagnosed with pathologic internal impingement.

**MATERIALS AND METHODS**

**Subjects**

Eleven male competitive baseball players with diagnosed pathologic internal impingement in the throwing shoulder were matched with 11 control baseball players based on arm dominance, age, height, mass, playing position, and throwing experience. All subjects were between the ages of 18 and 30 years. The group included 14 collegiate baseball players and 8 semiprofessional adult-league participants. Subject demographic characteristics appear in Table 1.

The diagnosis of pathologic internal impingement in the experimental group was made by an orthopaedic surgeon experienced in treating throwing injuries (J.P.B.). A complete history and physical examination were coupled with an MRI arthrogram with gadolinium for diagnosis. Typically, the subjects with pathologic internal impingement demonstrated primary posterior superior shoulder pain that was exacerbated by throwing. The pain specifically intensified in the late-cocking phase of the throwing motion. Additional complaints included decreased ball velocity, endurance, and ball control during throwing. The special tests performed by the orthopaedic surgeon included an apprehension/relocation test, the active compression test of O’Brien et al,\textsuperscript{28} anterior/posterior drawer test, and sulcus test for inferior instability, testing of range of motion, manual muscle testing of strength for the shoulder girdle, and visual appreciation of scapular kinesis. Two of the 11 patients had subtle anterior instability with no frank instability. The MRI arthrogram was read by a board-certified musculoskeletal radiologist, who identified posterior labral fraying (type I or II SLAP lesion) and/or partial undersurface rotator cuff tear at the supraspinatus/infraspinatus junction. All subjects with impingement underwent a course of nonoperative treatment after laboratory tests; those who failed to positively respond to rehabilitation opted for surgical intervention. In the current study, 8 of the 11 subjects who participated eventually underwent surgical intervention, during which the pathologic internal impingement diagnosis was subsequently confirmed.

Other concomitant conditions such as a history of neck pain, external impingement, frank glenohumeral instability, or previous shoulder/elbow injury requiring absence from sport participation (longer than 2 weeks) resulted in exclusion from this study. The control subjects had no significant
history of shoulder/elbow injury that required absence from participation within the past 2 years.

**Procedures**

All testing in the current study was performed in a human movement research laboratory at a university-based medical center. Before testing, each subject provided informed consent as required by the university’s institutional review board. After consent, bilateral internal and external humeral rotation as well as posterior shoulder tightness were measured by a single examiner. Before the examiner performed this study, test-retest intrasession and intersession reliability as well as precision for the single examiner performing all assessments for range of motion and posterior shoulder tightness were established, yielding intrasession and intraclass correlations7,35 ranging from 0.85 to 0.94 posterior shoulder tightness. Three measurements were taken bilaterally and averaged for each limb.

To measure posterior shoulder tightness, a technique described by Tyler et al38 was employed (Figure 2). This technique required the subject to lie on the nontested side, with both the hips and knees in 90° of flexion, the entire body in contact with the table, and the nontesting arm positioned under the subject’s head. A small mark was made with a felt-tip pen on the medial epicondyle of the arm to be tested. The subject’s acromions were aligned perpendicular to the treatment table with the spine in neutral position. With the tester facing the subject, scapular movement was restricted by stabilizing the lateral border of the scapula in the retracted position and the subject’s humerus at 90° of shoulder abduction and 0° of humeral rotation for the beginning of the test. With the subject relaxed, the tester then passively lowered the arm into horizontal adduction while maintaining neutral humeral rotation and scapular stabilization. Full posterior shoulder range of motion was defined as achievement of maximum humeral horizontal adduction or the initiation of scapular motion. At the end range of motion, a second tester recorded the distance (in centimeters) between the felt-tip mark on the medial epicondyle to the bottom of the treatment table surface using a standard tape measure. The amount of horizontal glenohumeral adduction indicated the amount of posterior shoulder tightness; a greater distance between the medial epicondyle and the table indicated increased posterior shoulder tightness. Three measurements were taken bilaterally and averaged for each limb. Posterior shoulder tightness was calculated as the difference in measured horizontal adduction between the involved (throwing) and uninvolved limb.

![Figure 1. Assessment of glenohumeral external rotation (A) and internal rotation (B).](image)

However, maximum passive internal shoulder rotation was measured (Figure 1B). Glenohumeral internal rotation deficit was calculated as the difference in measured internal rotation between the involved (throwing) and uninvolved limb.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Throwers With Impingement (n = 11)</th>
<th>Throwers Without Impingement (n = 11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (mean ± SD), y</td>
<td>22.1 ± 3.5</td>
<td>21.2 ± 1.7</td>
</tr>
<tr>
<td>Height (mean ± SD), m</td>
<td>1.8 ± 0.1</td>
<td>1.8 ± 0.1</td>
</tr>
<tr>
<td>Mass (mean ± SD), kg</td>
<td>91.0 ± 14.6</td>
<td>89.9 ± 13.0</td>
</tr>
<tr>
<td>Throwing experience (mean ± SD), y</td>
<td>16.2 ± 3.5</td>
<td>13.4 ± 2.7</td>
</tr>
<tr>
<td>Playing positions</td>
<td>6 pitchers, 3 infielders, 2 outfielders</td>
<td>6 pitchers, 3 infielders, 2 outfielders</td>
</tr>
<tr>
<td>Level of skill</td>
<td>7 collegiate, 4 semiprofessional</td>
<td>7 collegiate, 4 semiprofessional</td>
</tr>
</tbody>
</table>
DISCUSSION

Glenohumeral internal rotation deficits and posterior shoulder tightness are common traits found in the throwing arm of all throwers. Yet these results demonstrate that throwers with pathologic internal impingement are unique in that they have significantly increased posterior shoulder tightness and GIRD compared with normal throwers. In addition, the throwing athletes with pathologic internal impingement did not demonstrate the significant increase in external rotation gain that typically accompanies losses in internal rotation found in the normal, healthy throwing shoulder.

A review of the literature indicates that the amount of GIRD typically present in throwers without a history of shoulder injury is in the range of 10° to 15°; comparing favorably with the results from the throwers without impingement in the current study (11.1°). The throwers with pathologic internal impingement had significantly increased GIRD (19.7°). Comparing our results with other research findings is difficult, given that there are little published data on GIRD in throwers with shoulder injury and no research related to pathologic internal impingement. Tyler et al37 demonstrated a loss of almost 22° of internal rotation motion in patients (nonthrowers) with subacromial impingement. Warner et al40 reported similar decrements associated with impingement. Burkhart et al3 reported unpublished data in which GIRD in excess of 25° was present in throwers with diagnosed type II SLAP lesions. Similar amounts of GIRD were found in the subjects with pathologic internal impingement who participated in the current study.

The throwers with pathologic internal impingement in the current study exhibited posterior shoulder tightness as measured with cross-body horizontal adduction. Both Tyler et al37 and Warner et al40 reported similar levels of posterior shoulder tightness (approximately 4-6 cm) in nonthrowing patients with subacromial impingement and suggested that posterior capsular contracture was the cause of the shoulder tightness. Again, no research to date describes the amount of posterior shoulder tightness present in throwers with pathologic internal impingement. Tyler et al37 reported that posterior shoulder tightness (as measured with cross-body horizontal adduction) and internal rotation are interrelated. It was reported that for every 4° of GIRD, a 1-cm increase in distance between the medial epicondyle and treatment table will be present, indicating increased posterior shoulder tightness. The average loss of internal rotation in the subjects with pathologic internal impingement in this study was 19.7°, whereas the average change in posterior capsule tightness was 4.2 cm. This finding equates to approximately 4.7° of loss of internal rotation for every 1-cm change in posterior shoulder tightness, comparing favorably with the Tyler et al37 dataset. The GIRD and posterior shoulder tightness identified with the Tyler et al37 method in the current study might be indicative of adaptive changes to the posterior shoulder structures, including the

**Figure 2.** Assessment of posterior shoulder tightness.

**Data Reduction and Analysis**

The GIRD, external rotation gain, and posterior shoulder tightness variables used for statistical analysis were calculated as the difference in amount of internal rotation, external rotation, and horizontal adduction, respectively, between the involved (throwing) and uninvolved (nonthrowing) limb. A 2-tailed, dependent-sample t test (SPSS version 11.0, SPSS Inc, Chicago Ill) was used to compare group differences for GIRD, external rotation gain, and posterior shoulder tightness. This statistical procedure was chosen because the variables (GIRD, external rotation gain, and posterior shoulder tightness) used for analysis take into account side-to-side differences. This approach was employed rather than a 2-factor (group and limb) analysis of variance model to reduce the variability in the amount of range of motion and tightness that might exist between subjects. An α level of .05 was set prior to all analyses.

**RESULTS**

The descriptive statistics for the internal rotation, the external rotation, and the posterior shoulder tightness of both involved and uninvolved limbs as well as the GIRD, external rotation gain, and difference in posterior shoulder tightness for the 2 groups appear in Table 2. The throwing athletes with pathologic internal impingement demonstrated significantly greater GIRD (impingement group = −19.7°, controls = −11.1°; t20 = −2.14, P = .03) (Figure 3) and significantly greater posterior shoulder tightness (impingement group = −4.2 cm, controls = −0.9 cm; t20 = −2.72, P = .03) (Figure 4) compared with the control subjects. No significant differences were observed in external rotation gain between the 2 groups (impingement group = 8.3°, controls = 5.1°; t20 = 1.59, P = .16) (Figure 3).
Pathomechanically, posterior shoulder tightness likely contributes to pathologic internal impingement. Harryman et al.\(^{13}\) demonstrated that when asymmetric tension within the capsule is present, alterations in the arthrokinematics of the glenohumeral joint result. For example, tightness in the posteroinferior capsule results in anterosuperior migration of the humeral head on the glenoid.\(^{13}\) This migration can contribute to impingement of the posterior cuff tendons. In addition, some posterior translation is necessary when the shoulder is in a position of abduction with external humeral rotation (ie, the late cocking phase).\(^{21}\) This posterior translation is limited when posterior capsular tightness is present. Burkhart et al.\(^{3}\) and Morgan and associates\(^{24}\) suggest in their reviews that the primary “culprit” to shoulder injury in throwers is posterior capsule contracture. They proposed that posterior capsular contracture shifts the glenohumeral fulcrum posterosuperiorly. As the shoulder externally rotates around the new fulcrum point, there is increased contact of the rotator cuff and posterior labrum.\(^{14}\) Grossman et al.\(^{11}\) used a cadaveric model to demonstrate that posterior capsular contracture with decreased internal rotation does not allow the humerus to externally rotate into its normal posterosuperior position in the cocking phase of throwing. The result might be impingement of the rotator cuff in the posterior shoulder. This impingement might be compounded if the scapula is in a more protracted position. Recently, Myers et al.\(^{25}\) demonstrated that throwers with pathologic internal impingement exhibit a more protracted scapula, possibly compounding the impingement.

Given the presence of posterior shoulder tightness and loss of glenohumeral internal rotation in throwers with pathologic internal impingement, some authors advocate stretching for restoration of posterior shoulder flexibility.\(^{14,22,41}\) Kibler and Chandler\(^{17}\) have described and validated an injury risk modification program for overhead-throwing athletes resulting in improved range of motion in the upper extremity. In a separate study, Kibler\(^{16}\)

### TABLE 2

<table>
<thead>
<tr>
<th>Variable</th>
<th>Throwers With Impingement</th>
<th>Throwers Without Impingement</th>
<th>(P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal rotation, deg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Involved limb</td>
<td>42.5 ± 12.1</td>
<td>51.1 ± 14.4</td>
<td></td>
</tr>
<tr>
<td>Uninvolved limb</td>
<td>62.2 ± 16.9</td>
<td>62.2 ± 13.7</td>
<td>(.03)^a</td>
</tr>
<tr>
<td>GIRD, deg</td>
<td>-19.7 ± 12.8</td>
<td>-11.1 ± 9.4</td>
<td>(.03)^b</td>
</tr>
<tr>
<td>External rotation, deg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Involved limb</td>
<td>125.8 ± 13.1</td>
<td>121.1 ± 8.7</td>
<td></td>
</tr>
<tr>
<td>Uninvolved limb</td>
<td>117.5 ± 16.7</td>
<td>116.0 ± 10.3</td>
<td></td>
</tr>
<tr>
<td>ERG, deg</td>
<td>8.3 ± 9.2</td>
<td>5.1 ± 5.3</td>
<td>(.16)</td>
</tr>
<tr>
<td>Posterior shoulder tightness, cm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Involved limb</td>
<td>27.0 ± 5.9</td>
<td>21.1 ± 6.2</td>
<td></td>
</tr>
<tr>
<td>Uninvolved limb</td>
<td>22.8 ± 4.3</td>
<td>21.9 ± 5.9</td>
<td></td>
</tr>
<tr>
<td>(\Delta)PST, cm</td>
<td>-4.2 ± 4.4</td>
<td>-0.9 ± 2.0</td>
<td>(.03)^b</td>
</tr>
</tbody>
</table>

\(^{a}\) Values are given as means ± SDs. GIRD, glenohumeral internal rotation deficit; ERG, external rotation gain; \(\Delta\)PST, difference in posterior shoulder tightness.

\(^{b}\) Significant difference between groups (\(P < .05\)).

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**Figure 3.** Glenohumeral internal rotation deficit (GIRD) and external rotation gain (ERG) in throwers with and without pathologic internal impingement.

**Figure 4.** Posterior shoulder tightness (PST) in throwers with and without pathologic internal impingement. \(\Delta\)PST, difference in posterior shoulder tightness.
also demonstrated that daily postero-inferior capsular stretching in a group of tennis players resulted in decreased GIRD and decreased incidence of injury compared with a control group. Burkhardt et al reported that manual stretching to minimize GIRD in a group of major league pitchers resulted in decreased injury. They believed that 90% of all throwers with symptomatic GIRD and posterior shoulder tightness will respond positively to a postero-inferior capsular stretching program. On the basis of the published literature, the posterior shoulder tightness and GIRD identified in the throwers of the current study may respond favorably to a stretching program targeting the posterior structures.

There are several limitations that warrant acknowledgment. In this study, the group of throwers was composed of both pitchers and position players (ie, infielders and outfielders). There are data to suggest that differences in range of motion exist between these 2 groups, with pitchers exhibiting more external rotation and less internal rotation compared with position players. We employed a matched-control group design to control for these inherent differences. Thus, each subject with diagnosed impingement was matched with a control subject who played the same position. We also did not examine the amount of humeral retroversion present in the throwing participants. Thus, we cannot comment on if and how much of the range of motion differences found in this study might have resulted from possible humeral version differences. It was our hope that by matching our subjects by years of participation, we could control this confounding variable. Fully understanding the influence of humeral retroversion on pathologic internal impingement is an area of future research. An additional limitation that warrants discussion is the assessment used to measure posterior shoulder tightness. Although it was meant to be an indicator of posterior capsular tightness, we, as well as others, recognize that assessment of internal rotation range of motion and cross-body glenohumeral horizontal adduction does not isolate the posterior capsule and may be influenced by the posterior rotator cuff musculature. Currently, there are no in vivo means of assessing posterior capsular tightness and isolating the posterior capsule. Thus, we opted for the 2 assessments (cross-body horizontal adduction and glenohumeral internal rotation) that were found to be reliable and used most often by clinicians.

CONCLUSION

Throwing athletes with pathologic internal impingement demonstrated significantly greater glenohumeral internal rotation deficits and posterior shoulder tightness compared to control subjects in this study. In addition, no significant differences were observed in external rotation gain in throwers with pathologic internal impingement. These findings could indicate a tightening of the posterior shoulder elements (capsule, rotator cuff), which may contribute to impingement. The results suggest that injury management should include stretching to restore flexibility to the posterior shoulder.

ACKNOWLEDGMENT

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REFERENCES