Change in Glenohumeral Rotation and Scapular Position After a Division I Collegiate Baseball Season

Stephen John Thomas, Charles B. Swanik, Kathleen Swanik, and John D. Kelly

Context: Pathologies such as anterior instability and impingement are common in baseball and have been linked to decreases in internal-rotation (IR) motion and concurrent increases in external-rotation (ER) motion. In addition, alterations to scapular upward rotation have been identified in this population. Objective: To measure glenohumeral (GH) IR and ER rotation, total range of motion (ROM), and scapular upward rotation throughout the course of a Division I collegiate baseball season. Design: Pretest to posttest study. Setting: Controlled laboratory setting. Participants: Thirty-one collegiate baseball players with no current shoulder or elbow injury completed this study. Intervention: Participants were measured for all dependent variables at preseason and postseason. Main Outcome Measures: GH IR and ER were measured supine with the scapula stabilized. Total GH ROM was calculated as the sum of IR and ER measures. Scapular upward rotation was tested at rest, 60°, 90°, and 120° of GH abduction in the scapular plane. Results: Overall, the dominant arm had significantly less GH IR and significantly more ER than the nondominant arm. The total motion on the dominant arm was significantly less than on the nondominant arm. No significant differences were observed from preseason to postseason for IR, ER, or total motion. Dominant-arm scapular upward rotation significantly decreased at 60°, 90°, and 120° of abduction from preseason to postseason. Conclusion: Collegiate baseball players presented with significant GH-motion differences (decreases in IR and increases in ER) in their dominant arm compared with their nondominant arm. There was also significantly less total motion on the dominant arm. After 12 wk of competitive Division I collegiate baseball, there were significant decreases in upward rotation over the season.

Keywords: shoulder, prevention, prospective study

Unilateral alterations to glenohumeral and scapulothoracic range of motion in overhead athletes are well documented in the literature. Previous studies have shown that the deceleration forces placed on the glenohumeral and scapulothoracic joints during overhead throwing can be 1.5 times body weight. These large repetitive forces have been thought to cause bony and soft-tissue adaptations to the shoulder complex. Several theories exist regarding glenohumeral internal-rotation deficits (GIRD) and gain of external rotation on the dominant arm. It has been commonly held that immature throwers incur proximal humeral physeal remodeling that leads to humeral retroversion. This results in a decrease in internal rotation and an increase in external rotation. Several others also suggest that there are soft-tissue adaptations that occur in throwers in addition to changes in humeral retroversion. Many posit that the GIRD experienced by overhead athletes is due to either rotator-cuff tightness or posterior-capsule thickness, which may be a result of the chronic eccentric loading of the posterior shoulder during the deceleration phase. The gain of external rotation is commonly thought to be due, in part, to an attenuation of the anterior capsule caused by the repetitive anterior glenohumeral-joint force during the late cocking phase.

Positional changes of the scapula have commonly been reported in injured overhead-throwing athletes. Clinically it has been observed as inferior angle or medial border winging with an excessively protracted scapula. Biomechanically it has been described as decreased upward rotation, posterior tilting, and increased internal rotation on the dominant or injured arm. Chronic eccentric stress is also placed on both the static and the dynamic scapular stabilizers and may cause a fatigue- or pain-related inhibition of the lower trapezius and serratus anterior muscles. Muscular imbalance creates instability of the neuromuscular control of the scapular stabilizers. These alterations have also been observed in healthy overhead athletes and may be linked...
to the development of common shoulder injuries such as subacromial impingement, rotator-cuff pathology, and SLAP lesions.6,22,23

The temporal course and development of these adaptations has yet to be determined in collegiate baseball players. Due to the increased skill level and year-round play at the collegiate level, these adaptations may manifest at an accelerated rate, thereby placing the collegiate athletes at a heightened risk of shoulder injury. Therefore, the purpose of our study was to measure glenohumeral internal and external rotation in conjunction with scapular upward rotation in collegiate baseball players after a single baseball season.

Methods

Design

A pretest–posttest design was used to assess 1 independent variable and 14 dependent variables. The 1 independent variable was the point in time at which the evaluation was performed (preseason and postseason). The dependent variables were dominant and nondonominate glenohumeral internal rotation, glenohumeral external rotation, total glenohumeral rotation, and scapular upward rotation. Total motion was calculated as glenohumeral internal plus external rotation. Scapular upward rotation was measured at rest, 60°, 90°, and 120° of glenohumeral abduction. The measurements were recorded 2 times throughout the course of the 12-week season (preseason and postseason). In addition, glenohumeral internal rotation, external rotation, and total motion were analyzed bilaterally.

Participants

Thirty-one collegiate baseball players initially volunteered to participate in this study. Due to participant dropout throughout the season, 24 players (11 pitchers, 13 position players; age 20.3 ± 1.1 y, mass 92.2 ± 8.0 kg, height 186.4 ± 6.1 cm) composed the final study group. Exclusion criteria consisted of previous surgery, shoulder pathology, or current shoulder pain within the last 6 months. Participants did not perform any team stretching programs during the season. The study was approved by a university institutional review board. Informed-consent, health-history questionnaire, and Health Insurance Portability and Accountability Act forms were all completed before testing.

Instrumentation

Glenohumeral internal and external rotation were measured using a Saunders digital inclinometer (The Saunders Group Inc, Chaska, MN). Test–retest reliability of glenohumeral range of motion was assessed by the primary investigator and reported in a previous study.22 Intraclass correlation coefficient (ICC), standard error of measurement (SEM), and minimal detectable change (MDC) values for glenohumeral range of motion were .989, 1.0°, and 1.4° for internal rotation and .943, 2.6°, 3.7° for external rotation, respectively.22

Scapular upward rotation was measured using a Saunders digital inclinometer (The Saunders Group Inc, Chaska, MN) modified to rest evenly on the scapular spine.22 The digital inclinometer was modified using methods described by Johnson et al.22 Test–retest reliability of the scapular upward-rotation measurements was assessed by the primary investigator in a previous study.22 ICC, SEM, and MDC values for scapular upward rotation were .967, 0.7°, and 1.0°; .946, 1.6°, and 2.3°; .974, 0.9°, and 1.3°; and .965, 0.9°, and 1.3° at rest, 60°, 90°, and 120° of glenohumeral abduction, respectively.22

Procedures

Passive internal- and external-rotation measurements were performed following standard procedures from our laboratory and have been previously reported.22 For the measurement, the subject was lying in the supine position with the glenohumeral joint in 90° of abduction. The scapula was stabilized by the tester’s hand and the arm was rotated until scapular motion was detected. The inclinometer was then placed on the dorsal surface of the forearm, and the hold button was pressed to record the measurement. This was repeated 3 times, and the average of the 3 measurements was taken. Preseason measures were taken a week before the start of the season. Postseason measures were taken within a week after the completion of the season. Participants did not perform any warm-up or stretching before data collection. All measurements were taken bilaterally by the primary investigator. The primary investigator was blinded to the arm dominance of the athlete, and the order of testing was alternated.

Scapular upward-rotation measurements were performed following standard procedures from our laboratory and have been previously reported.22 First the subject was asked to stand with normal relaxed posture. A guide pole was used to help position the subject’s arm at 60°, 90°, and 120° of abduction. When the appropriate amount of abduction was determined, a pin was inserted into the guide pole. The pin location was then marked and recorded for consistency in the postseason measurement. The subject was asked to abduct his arm until it was positioned against the pin. The lateral arm of the inclinometer was then placed over the posterolateral acromion, and the medial arm was placed over the root of the scapular spine. The hold button was pressed to record the measurement. This was repeated twice and the average of the 2 measurements was taken. All measurements were taken bilaterally by the primary investigator. The primary investigator was blinded to the arm dominance of the athlete, and the order of testing was alternated.

Statistical Analyses

Data analysis consisted of descriptive statistics. Statistical tests included separate 1-way multivariate analyses of
Results

When combining the preseason and postseason measurements, there was significantly less internal rotation ($P \leq .001, 17.2^\circ$), significantly more external rotation ($P = .014, 2.1^\circ$), and significantly less total motion on the dominant arm than on the nondominant arm ($P \leq .001, 15.1^\circ$; Figures 1 and 2). No significant main effects for time were observed in glenohumeral internal rotation, external rotation, or total motion.

Significant main effects for time were found for dominant-arm scapular upward rotation ($P = .001$; Figure 3). Follow-up ANOVAs revealed that scapular upward rotation significantly decreased from preseason to postseason at 60° ($P = .039, 1.6^\circ$), 90° ($P = .001, 3.6^\circ$), and 120° ($P = .001, 3.9^\circ$) of abduction (Figure 3).

No significant main effects for time were found for nondominant-arm scapular upward rotation ($P = .118$; Figure 3).

Discussion

We were surprised that we did not observe any temporal changes in shoulder range of motion throughout the collegiate baseball season. Previously, research has demonstrated mixed results. Dwelly et al\textsuperscript{28} demonstrated an increase in external rotation and total motion but no change in internal rotation over the course of the season in collegiate baseball and softball players. Among a mixed population of high school female overhead athletes, we previously found a decrease in internal rotation with no significant differences in external rotation or total motion.\textsuperscript{22} Similar to the current results, Laudner et al\textsuperscript{29} did not find any significant changes in range of motion over the course of a season in professional baseball players. Due to the variety of populations throughout these studies, it is difficult to speculate about the lack of range-of-motion changes over the season. However, due to the similarities with Laudner et al,\textsuperscript{29} it may be possible that a large portion of the adaptations in range of motion are developed at a younger age, therefore making it difficult to identify changes over just 1 competitive season in these age groups. Further research should focus on identifying the progression of range-of-motion adaptations throughout a player’s career.

The results of this study did demonstrate alterations in glenohumeral range of motion when comparing the dominant and nondominant arms. Similar to previous research, the dominant arm had significantly less internal rotation (17.2°) and significantly more external rotation (2.1°). Total motion was also significantly less (15.1°) on the dominant arm. These results are in agreement with

![Figure 1](image-url) — Combined preseason and postseason dominant- and nondominant-arm glenohumeral internal and external rotation (mean ± SD). *Significant difference between dominant and nondominant arms ($P < .05$).
Figure 2 — Combined preseason and postseason dominant- and nondominant-arm glenohumeral total motion (mean ± SD). *Significant difference between dominant and nondominant arms (P < .05).

Figure 3 — Dominant-arm scapular upward rotation after the 12-week collegiate baseball season (mean ± SD). *Significant difference between preseason and postseason (P < .05).
previous observational studies of high school, collegiate, and professional baseball players. The alterations in glenohumeral range of motion are most likely multifactorial, consisting of bony, musculotendinous, and capsular adaptations. The specific tissue adaptations that lead to GIRD are still not completely understood; however, correlations have been demonstrated with humeral retroversion and posterior-capsule thickness. Posterior-capsule thickness is thought to cause a shift in the humeral head into a more posterosuperior direction during the late cocking position of throwing. This alteration in the arthrokineamtics of the humeral head has been suggested to potentiate internal impingement, rotator-cuff tears, and SLAP lesions. Of note in the current study, GIRD did not change over the 12-week collegiate baseball season, although there was an existing GIRD of 17.2°. Recently, Wilk et al found that professional pitchers with 20° or more of GIRD are twice as likely to develop shoulder injuries as pitchers without GIRD. Similarly, Shanley et al found that high school baseball players with a decrease of ≥25° of dominant-arm internal rotation were at 4 times greater risk of an upper extremity injury. Although our population of collegiate baseball players had slightly less than 20° of GIRD, they may still be at a risk for shoulder injuries similar to that described by Wilk et al and Shanley et al. External-rotation gains have been suggested to be caused by both humeral retroversion and an attenuated anterior capsule. Previous studies have found strong correlations between external-rotation gain and humeral retroversion. However, recently Borsa et al examined anterior-capsule laxity using diagnostic ultrasound bilaterally in professional baseball pitchers and found the laxity to be equal bilaterally. This suggests that the dominant-arm anterior capsule may not become attenuated due to repetitive overhead throwing and the increased amount of external rotation may be primarily due to humeral retroversion or an inherent laxity. This is in agreement with the results of the current study, which did not demonstrate changes in external rotation over the course of the collegiate baseball season.

The total-motion concept has been used clinically for several years to determine if the shift in the arc of glenohumeral range of motion on the dominant arm is due to bony or soft-tissue adaptations. The thought is that if the total motion is equal bilaterally, the shift in the arc of motion is primarily due to humeral retroversion. If total motion is not equal bilaterally, then there are secondary soft-tissue adaptations contributing to the motion alterations of the dominant arm. We found a significant decrease (15.1°) in total motion on the dominant arm compared with the nondominant arm. These results suggest that there are secondary soft-tissue adaptations in this group of uninjured collegiate baseball players. Wilk et al examined professional baseball pitchers during spring training and found that those with more than a 5° bilateral difference in total motion were more likely to be injured than pitchers without a bilateral difference in total motion. In our study, there was 15.1° bilateral difference in total motion, which, based on the results of Wilk et al, would significantly increase the likelihood of these players developing shoulder or elbow injuries.

Scapular alteration or dyskinesis is common in overhead athletes and has been well documented in the literature. Scapular dyskinesis has been defined as an observable alteration in the position or motion of the scapula. This motion consists of upward/downward rotation, internal/external rotation (winging), and anterior/posterior tilting. An alteration in any or all of the described motions has been shown to be present in shoulder pathology including subacromial impingement, internal impingement, rotator-cuff tears, and SLAP lesions.

The results of our study revealed that dominant-arm scapular upward rotation at 60°, 90°, and 120° of abduction decreased over the course of the 12-week collegiate baseball season. The observed decreases in scapular upward rotation are in the functional range of shoulder motion for baseball players. Clinically these positions are described as the painful arc and used to evaluate patients with impingement symptoms. At these positions of shoulder motion, decreases in scapular upward rotation may be problematic and theoretically lead to subacromial impingement and loss of rotator-cuff strength. These results are similar to those of previous research in high school baseball players that also demonstrated decreased scapular upward rotation at 90° and 120° of abduction over the course of a season. Combined, these results demonstrate the cumulative effects of overhead throwing on scapular upward rotation. The lower trapezius, serratus anterior, and upper trapezius function together as a force couple to upwardly rotate the scapula. It is thought that due to the repetitive nature of overhead throwing the lower trapezius and serratus anterior develop a fatigue-related inhibition. In fact, previous research in an impingement population has demonstrated decreased EMG activity of the lower trapezius and the serratus anterior during arm elevation. In addition to fatigue inhibition of the scapular stabilizers, it has been thought that alterations at the glenohumeral joint may also contribute to decreased scapular upward rotation. Burkhart et al wrote that the development of posterior-capsule thickness or GIRD can mechanically force the scapula into more scapular protraction during the deceleration and follow-through phase of the overhead throw. This may increase the mechanical stress on the scapular musculature and static restraints, leading to chronic tissue damage. In previous research we have found that baseball players with 15° or more of GIRD had significantly less scapular upward rotation than players with 14° or less of GIRD. Although these results cannot explain causation, they do demonstrate an association between glenohumeral motion alterations and scapular-motion alterations.

There are several limitations to the current study that should be acknowledged. First, our assessment of scapular motion was limited to scapular upward rotation and assessed in isometric positions. There are several other scapular motions that can be assessed...
and have been shown to be altered in baseball players and patients with impingement syndrome. However, these assessments required equipment that is mounted on the participant’s skin and thus may not completely capture accurate scapular motion due to skin-motion artifact during dynamic shoulder elevation.42 Next, we only assessed glenohumeral and scapular motion before and after a 12-week season. Longer longitudinal studies that assess players over multiple seasons may provide additional understanding of the progression of these adaptations. In addition, we did not calculate the amount of throwing exposure for these baseball players over the season. Previous research has suggested that increased exposure leads to shoulder injuries43 and theoretically would increase the possibility of developing motion adaptations. Next, the players were not followed for the development of shoulder injuries throughout the season. Therefore, the decreases in scapular upward rotation can only be suggested to place collegiate baseball players at higher risk of developing shoulder or elbow injuries. Finally, although the participants did not perform any team stretching programs, we do not know whether they performed any individual stretching.

In conclusion, collegiate baseball players were found to demonstrate a significant loss of scapular upward rotation after only a 12-week competitive baseball season. This change in scapular motion has been associated with subacromial impingement syndrome, as well as supraspinatus weakness, and may be a result of glenohumeral internal-rotation deficits already present. Future research should focus on examining shoulder adaptations over multiple seasons and identifying the association with shoulder and elbow injuries.

References