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original research

Glenohumeral Rotation and Scapular Position Adaptations After a Single High School Female Sports Season

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Context: Anterior instability and impingement are common in overhead athletes and have been associated with decreases in internal rotation (IR) and increases in external rotation (ER) motion. However, the chronology and the effect of different female sports on these conditions have yet to be determined.

Objective: To measure glenohumeral IR and ER rotation, total range of motion, and scapular position in female overhead athletes over a single competitive season.

Design: Multiple group pretest-posttest study.

Setting: High school.

Patients or Other Participants: Thirty-six female overhead athletes (age = 15.29 ± 1.18 years, height = 164.16 ± 7.14 cm, mass = 58.24 ± 9.54 kg) with no history of shoulder or elbow surgery participating in high school swimming, volleyball, or tennis.

Intervention(s): Participants were measured for all dependent variables at preseason and postseason.

Main Outcome Measure(s): Participants were measured for glenohumeral IR and ER with the scapula stabilized. Total glenohumeral range of motion was calculated as the sum of IR and ER. Scapular upward rotation was measured at 0°, 60°, 90°, and 120° of glenohumeral abduction in the scapular plane, and scapular protraction was measured at 0°, 45° (hands on hips), and 90° of glenohumeral abduction.

Results: Internal rotation decreased from preseason to postseason ($P = .012$). Swimmers had less IR than both volleyball and tennis players ($P = .001$). External rotation also decreased in the swimmers ($P = .001$). Overall, preseason to postseason total motion decreased for athletes participating in swimming ($P = .001$) and tennis ($P = .019$). For all participants, preseason to postseason scapular protraction at 45° glenohumeral abduction decreased ($P = .007$).

Conclusions: Female overhead athletes demonstrated decreases in IR after only one competitive season. Clinically, our results indicate that overhead athletes should be monitored for motion changes throughout their competitive seasons.

Key Words: scapular dyskinesis, posterior shoulder capsule

Key Points

- Internal rotation decreased in female high school overhead athletes after competing in one 12-week season of swimming, volleyball, or tennis.
- External rotation decreased in swimmers but was unchanged in volleyball and tennis players.
- Scapular upward rotation at 90° increased in swimmers and decreased in volleyball players.
- Scapular protraction at 45° decreased in all athletes.
- Close monitoring of passive internal rotation is warranted in female high school overhead athletes.

Disorders such as anterior instability and impingement are common in overhead athletes and are thought to result from years of repetitive demands placed on the shoulder complex.[1–3] Clinically, authors of several studies[1,4–12] have identified decreases in internal rotation (IR) with concurrent increases in external rotation (ER) motion, as well as scapular alterations. Some investigators[2,6,8,9] believe that increases in glenohumeral ER are associated with the repetitive stretching of the anterior capsule. Others[1,13–16] have suggested that the IR deficits result from an acquired tight posterior capsule. Concomitant changes, including increased protraction or decreased upward rotation, have also been identified[17,18] in the scapular motion of athletes and may be defined as *scapular dyskinesis*, which is an observable alteration in the position of the scapula and the patterns of scapular motion in relation to the thoracic cage. Together, these adaptations in motion are thought to adversely affect the normal functioning of the shoulder complex.[1,3,10,18–20] Although these alterations seem consistent in the overhead athlete population, differences among athletes in different sports are unclear, and the development of these changes remains somewhat controversial. Therefore, the purpose of our study was to conduct prospective measurements of glenohumeral IR and ER in conjunction with scapular positioning in female overhead athletes throughout a traditional high school sports season.

METHODS

Research Design

We used a pretest-posttest design to assess 3 independent variables and 5 dependent variables. The independent variables were sport (swimming, volleyball, and tennis), time (preseason and postseason), and arm (dominant and nondominant). Both the dominant and nondominant arms of participants were measured and compared bilaterally; however, they were not analyzed over the course of the 12-week season of each sport because swimming involves the use of both arms overhead and volleyball at times involves the use of both arms overhead. The dependent variables were glenohumeral IR, glenohumeral ER, total glenohumeral rotation, scapular upward rotation (0° [rest], 60°, 90°, and 120° of glenohumeral abduction), and scapular protraction (0° [rest], 45° [hands on hips], and 90° glenohumeral abduction). Total glenohumeral rotation was calculated as internal rotation plus external rotation with the dominant and nondominant arms grouped together. The measurements were taken 2 times (preseason and postseason) during the 12-week season of each sport.

Participants

Thirty-six female high school overhead athletes volunteered to participate in this study: 10 swimmers (age = 15.33 ± 1.33 years, height = 162.30 ± 7.98 cm, mass = 57.27 ± 9.04 kg), 16 volleyball players (age = 15.13 ± 1.09 years, height = 165.10 ± 8.18 cm, mass = 59.32 ± 12.36 kg), and 10 tennis players (age = 15.50 ± 1.08 years, height = 164.30 ± 5.23 cm, mass = 57.32 ± 5.41 kg). Exclusion criteria included a history of surgery on either shoulder or current shoulder disorder. Before testing, participants completed a health history questionnaire and a form to acknowledge that they understood that the privacy of their health information would be protected according to the Health Insurance Portability and Accountability Act of 1996. Participants or their parents (for those who were less than 18 years of age) provided informed consent. The study was approved by the Temple University Institutional Review Board.

Instrumentation

Glenohumeral IR and ER Assessment. Glenohumeral IR and ER were measured using a Saunders digital inclinometer (Saunders Group Inc, Chaska, MN). A priori test-retest reliability of glenohumeral range of motion was assessed by the primary investigator (S.J.T.). Both shoulders of 10 healthy volunteers were measured and then measured again 3 to 5 days later. The intraclass correlation coefficient (ICC [2,1]) and standard error of measurement (SEM) values for glenohumeral IR were 0.989 and 1.03°, respectively, and for glenohumeral ER, these values were 0.943 and 2.55°, respectively.

Scapular Upward Rotation Assessment. Scapular upward rotation was measured using the digital inclinometer that was modified to rest evenly on the scapular spine (Figure 1). To modify it, we used methods described by Johnson et al.[21] A priori test-retest reliability of the scapular upward rotation measurements was assessed by the primary investigator. Both shoulders of 18 healthy volunteers were measured and then measured again 3 to 5 days later. The ICC (2,1) and SEM values for scapular upward rotation at 0° (rest) were 0.967 and 0.70°, respectively; at 60° of glenohumeral abduction, these values were 0.946 and 1.55°, respectively; at 90° of glenohumeral abduction, these values were 0.974 and 0.86°, respectively; and at 120° of glenohumeral abduction, these values were 0.965 and 0.89°, respectively.

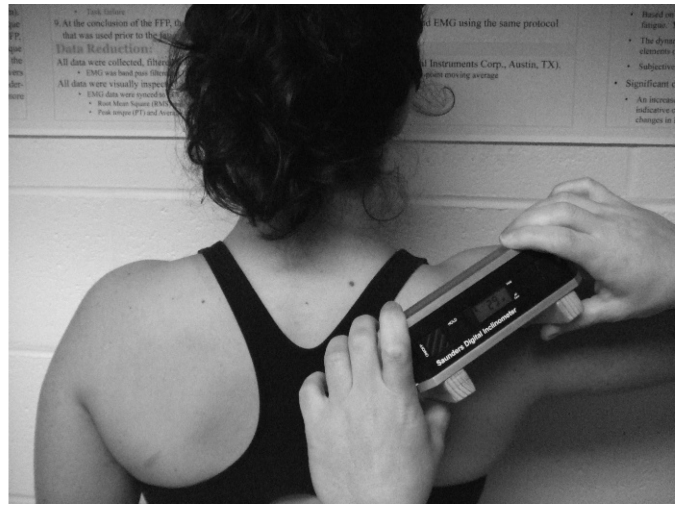

Figure 1. Measurement of scapular upward rotation using a modified digital inclinometer.

Scapular Protraction Assessment. We used the lateral scapular slide test as described by Kibler[17] to measure scapular protraction with a vernier caliper (model 505-633-50; Mitutoyo, Andover, United Kingdom) that recorded in centimeters. A priori test-retest reliability of the scapular protraction measurements was assessed by the primary investigator. Both shoulders of 18 healthy volunteers were measured and then measured again 3 to 5 days later. The ICC (2,1) and SEM values for scapular protraction at 0° (rest) were 0.935 and 0.328 cm, respectively; at 45° (hands on hips) of glenohumeral abduction, these values were 0.970 and 0.186 cm, respectively; and at 90° of glenohumeral abduction, these values were 0.975 and 0.231 cm, respectively.

Procedures

Glenohumeral IR and ER Assessment. Passive internal rotation and external rotation measurements were taken with the participant in the supine position and the glenohumeral joint in 90° of abduction. Next, the scapula was stabilized by the tester's hand, and the arm was rotated until scapular motion was detected.[22] The inclinometer was placed on the dorsal surface of the forearm, and the hold button was pressed to record the measurement. This process was repeated 3 times, and the average of the 3 measurements was used. All measurements were taken bilaterally by the primary investigator, and the participants did not perform warm-ups before the measurements. The primary investigator was blinded to the arm dominance of each athlete, and the right arm was tested first.

Scapular Upward Rotation Assessment. Scapular upward rotation measurements were taken with the participant standing with normal relaxed posture. A guide pole was used to help position the participant'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, and that location was recorded for consistency in the postseason measurement. The participant was asked to abduct her arm until it was positioned against the pin.

Figure 2. Measurement of scapular protraction using a vernier caliper.

This position was maintained until the measurement was recorded. Next, the lateral arm of the inclinometer was placed over the posterior lateral 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 used. All measurements were taken bilaterally by the primary investigator, and the participants did not perform warm-ups before the measurements. The primary investigator was blinded to the arm dominance of each athlete, and the order of testing was alternated.

Scapular Protraction Assessment. Scapular protraction measurements were taken with the participant standing with normal relaxed posture. The measurements were performed at 3 positions (0° [rest], 45° [hands on hips], and 90° of glenohumeral abduction with maximum IR) (Figure 2). First, the inferior angle of the scapula was palpated, and the lateral arm of the caliper was placed at the tip of the inferior angle. The medial arm of the caliper was positioned at the corresponding spinous process, and the measurement was recorded. This was repeated 3 times, and the average of the measurements was used. All measurements were taken bilaterally by the primary investigator, and the participants did not perform warm-ups before the measurements. The primary investigator was blinded to the arm dominance of each athlete, and the order of testing was alternated.

Data Analysis

Data analysis consisted of descriptive statistics. Statistical tests included a 3 (sport) × 2 (time) analysis of variance (ANOVA) with repeated measures for IR and ER. A 3 (sport) × 2 (time) multivariate ANOVA (MANOVA) with repeated measures was performed for scapular upward rotation and scapular protraction. The α was set a priori at .05. Post hoc Tukey tests were performed to compare between-sports differences. Post hoc paired-samples *t* tests were performed when a time × sport interaction was discovered. One-way ANOVAs were performed to compare IR and ER between the dominant and nondominant arms. One-way MANOVAs were performed to compare scapular upward rotation and protraction between the dominant and nondominant arms. We used SPSS (version 13.0 for Windows; SPSS Inc, Chicago, IL) for data analysis.

Table 1. Preseason to Postseason Glenohumeral Internal Rotation (Mean ± SD)

Sport	Preseason, °	Postseason, °[a]
Swimming	50.58 ± 6.81	50.65 ± 6.48
Volleyball	57.16 ± 6.17	55.82 ± 4.92
Tennis	60.85 ± 4.79	56.7 ± 6.92

[a] Difference between preseason and postseason ($P < .05$).

RESULTS

Glenohumeral IR

Means and SDs for glenohumeral IR are presented in Table 1. Main effects were found for time and sport. For time, preseason to postseason IR decreased ($F_1 = 6.721$, $P = .012$) (Figure 3). Post hoc Tukey testing revealed a difference in IR among sports ($F_{1,2} = 11.867$, $P = .001$). Swimmers had less IR compared with both volleyball ($P = .001$) and tennis ($P = .001$) players (Figure 4). Internal rotation was less in the dominant arm than in the nondominant arm ($F_1 = 16.92$, $P < .001$) (Figure 5).

Glenohumeral ER

Means and SDs for glenohumeral ER are presented in Table 2. A time × sport interaction was identified ($F_{1,2} = 11.042$, $P = .001$). Post hoc paired-samples *t* tests revealed that, from preseason to postseason, ER decreased in the swimmers ($t_9 = 4.438$, $P = .001$). We found no other differences among sports or over time. External rotation was greater in the dominant arm than in the nondominant arm ($F_1 = 18.280$, $P < .001$) (Figure 5).

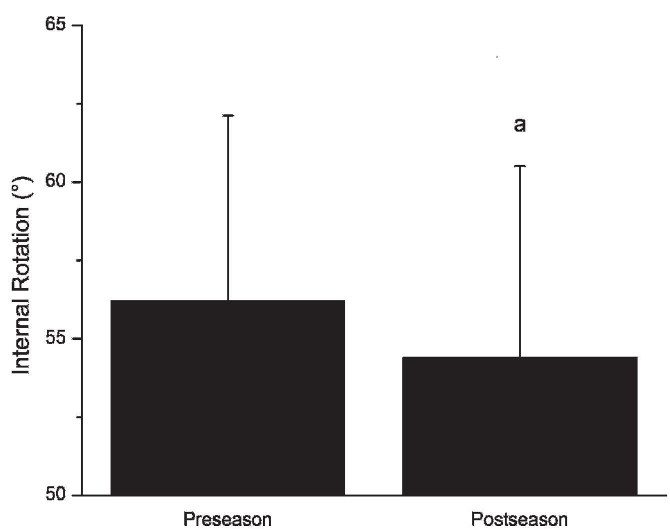

Figure 3. Overall preseason to postseason glenohumeral internal rotation means (degrees). [a] Indicates difference between preseason and postseason ($P < .05$).

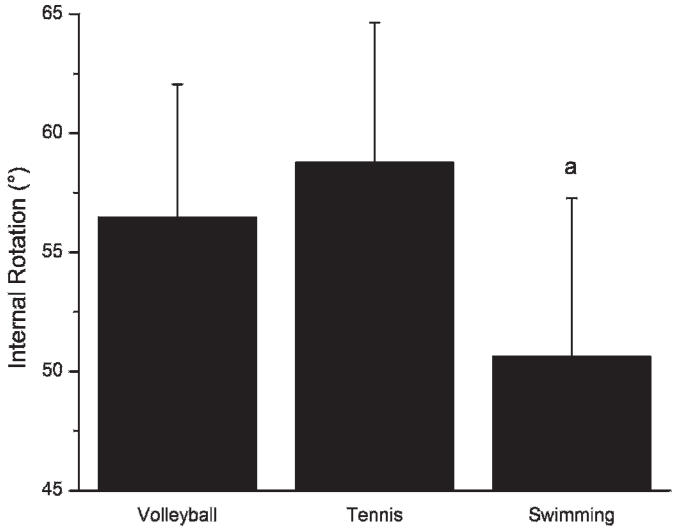

Figure 4. Overall glenohumeral internal rotation means for volleyball, tennis, and swimming athletes. [a] Indicates swimming was different from volleyball and tennis ($P < .05$).

Glenohumeral Total Motion

Means and SDs for glenohumeral total motion are presented in Table 3. Post hoc Tukey testing revealed that glenohumeral total motion was different among sports ($F_{1,2} = 9.632$, $P = .001$). Total motion was greater in both volleyball and tennis players than in swimmers ($P = .012$ and $P = .001$, respectively) (Figure 6). A time × sport interaction ($F_{1,2} = 5.667$, $P = .005$) was identified. Post hoc paired-samples t tests revealed that, from preseason to postseason, total motion decreased for swimmers ($t_9 = 2.434$, $P = .001$) and tennis players ($t_9 = 2.321$, $P = .019$). Total motion in the dominant arm was not affected. We found no other differences.

Table 2. Preseason to Postseason Glenohumeral External Rotation (Mean ± SD)

Sport	Preseason, °	Postseason, °
Swimming	91.89 ± 4.08	88.58 ± 3.54[a]
Volleyball	86.32 ± 6.82	91.17 ± 4.33
Tennis	91.06 ± 5.73	91.42 ± 2.71

[a] Difference between preseason and postseason ($P < .05$).

Scapular Upward Rotation

Means and SDs for scapular upward rotation are presented in Table 4. A time × sport interaction was identified ($F_{1,2} = 3.097$, $P = .003$). Post hoc paired-samples t tests demonstrated that, from preseason to postseason, scapular upward rotation at 90° of glenohumeral abduction increased for swimmers ($t_9 = -3.675$, $P = .003$) and decreased for volleyball players ($t_{15} = 3.884$, $P < .001$). Scapular upward rotation in the dominant arm was not altered at any of the abduction positions. We found no other differences.

Scapular Protraction

Means and SDs for scapular protraction are presented in Table 5. A significant main effect for time was identified. For all participants, preseason to postseason scapular protraction at 45° of glenohumeral abduction decreased ($F_1 = 7.716$, $P = .007$). Scapular protraction in the dominant arm was not altered at any of the abduction positions. We found no other differences.

DISCUSSION

We found that female high school overhead athletes presented with altered glenohumeral and scapular range of motion after only 12 weeks of competition. Internal rotation decreased in all athletes; however, ER decreased in swimmers and remained unchanged in volleyball and

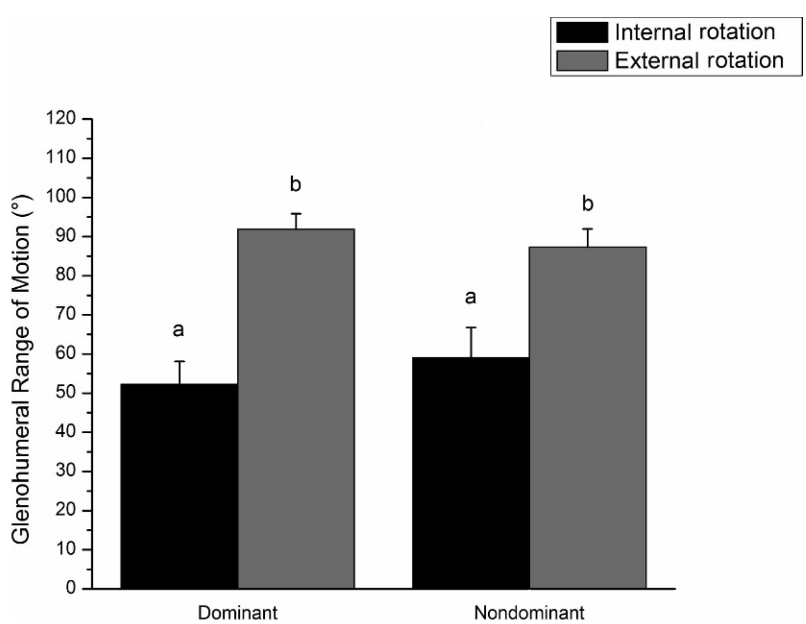

Figure 5. Dominant and nondominant glenohumeral range-of-motion means (degrees). [a] Indicates the difference between internal rotation in dominant and nondominant shoulders ($P < .05$). [b] Indicates the difference between external rotation in dominant and nondominant shoulders ($P < .05$).

Table 3. Preseason to Postseason Glenohumeral Total Motion (Mean ± SD)

Sport	Preseason, °	Postseason, °
Swimming	141.25 ± 7.84	138.85 ± 6.52[a]
Volleyball	143.51 ± 10.21	146.42 ± 7.80
Tennis	151.48 ± 7.50	147.40 ± 7.12[a]

[a] Difference between preseason and postseason ($P < .05$).

Table 4. Preseason to Postseason Scapular Upward Rotation (Mean ± SD)

Sport	Position, °	Preseason, °	Postseason, °
Swimming	0	0.41 ± 2.80	1.13 ± 1.74
	60	14.05 ± 2.98	15.22 ± 2.08
	90	24.83 ± 2.91	26.98 ± 2.69[a]
	120	40.70 ± 2.50	41.53 ± 3.12
Volleyball	0	1.50 ± 3.44	1.96 ± 3.68
	60	15.00 ± 5.84	15.02 ± 4.56
	90	28.09 ± 4.99	26.02 ± 4.41[a]
	120	41.85 ± 4.92	40.62 ± 4.15
Tennis	0	−0.33 ± 2.72	0.19 ± 3.57
	60	13.53 ± 5.97	13.88 ± 5.78
	90	23.96 ± 6.51	24.09 ± 3.48
	120	37.90 ± 3.32	38.08 ± 3.63

[a] Difference between preseason and postseason ($P < .05$).

tennis players. We also found an increase in scapular upward rotation at 90° of glenohumeral abduction in swimmers and a decrease in volleyball players. Scapular protraction at 45° of glenohumeral abduction decreased in all athletes after their seasons.

In most overhead sports, the role of the passive and dynamic restraints for shoulder stability and mobility seems to be consistent.[23,24] The ligaments and capsule assist with joint centering, whereas the dynamic restraints move the arm and also assist with force dissipation.[8,23,24] Specifically, the internal rotators function to propel the arm forward, such as in the volleyball serve or the pull-through phase of swimming.[8,13,14,16,25–28] The role of the external rotators is to center the humeral head and to decelerate the humerus.[27,29,30] Deceleration is achieved through repetitive eccentric contractions of the posterior portion of the rotator cuff. This typically occurs during the follow-through phase of the overhead motion or recovery phase of swimming. Several authors[1,2,13,15,16,25,31] agree that a combination of overhead repetition and chronic stress may predispose the shoulder girdle to injury.

Passive Glenohumeral IR

Motion differences in overhead athletes are well documented and correspond with the results of the bilateral comparison in our study. These compensatory actions that often occur clinically have also been identified in individuals with shoulder disorders.[3,5–7,10,11,13,25,32–35] However, the cause of these changes remains debatable. We found that passive IR decreased after only one 12-week female high school sports season (swimming, volleyball, and tennis). However, when examining the mean values for each sport, we found that the values for volleyball and tennis decreased, but those for swimming did not decrease. The decrease in IR was about 2°; whether this value is clinically important is unclear at this point. However, prospectively, Spigelman et al[15] also found similar IR deficits in preadolescent swimmers. Additionally, Burkhart et al[36] suggested that chronic eccentric loading of the posterior rotator cuff has 2 effects. First, it causes early fatigue of the posterior rotator cuff that results in a deceleration stress on the posterior capsule. Second, it may cause posterior capsular tightness that presents as IR deficits and also may cause posterior-superior translation of the humeral head.[37,38] Any of these compensatory changes could predispose the shoulder to superior labrum anterior-posterior (SLAP) lesions and rotator cuff tears.[1,32,39] Our findings, coupled with those of others,[1,15] may support the notion that the static changes to IR may be linked to increased repetition.

The differences in passive internal rotation measures among the 3 sports that we examined were also significant. Overall, swimmers presented with less internal rotation compared with both volleyball and tennis players. This difference for swimmers again may be related to the number of repetitions performed, even at the high school level. The traditional swimming practice at the collegiate or masters level is about 10 000 to 14 000 m/d (6–8 miles/d).[13,16,28,31] Swimming practice provides very little room for change, even within strokes, because the role of the external rotators remains constant. This is in contrast to the game of tennis, in which players use forehand and backhand strokes during practice and matches and use a variety of muscles and techniques.[29] Volleyball also allows

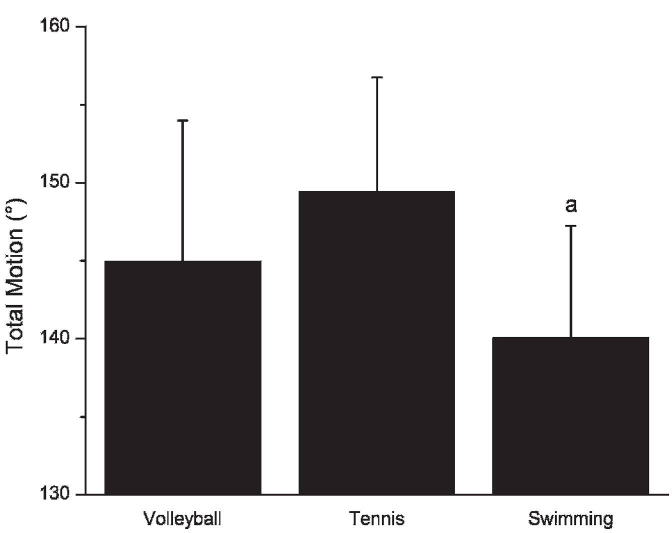

Figure 6. Overall glenohumeral total motion means for swimming, volleyball, and tennis athletes. [a] Indicates swimming was different from volleyball and tennis ($P < .05$).

Table 5. Preseason to Postseason Scapular Protraction (Mean ± SD)

Sport	Position, °	Preseason, cm	Postseason, cm
Swimming	0	6.93 ± 1.20	6.60 ± 1.40
	45	7.19 ± 1.10	7.21 ± 0.93
	90	8.77 ± 1.17	8.71 ± 1.18
Volleyball	0	8.01 ± 1.28	7.70 ± 0.96
	45	8.71 ± 1.44	8.08 ± 1.24
	90	9.34 ± 1.32	9.33 ± 1.33
Tennis	0	7.49 ± 0.70	7.47 ± 0.93
	45	8.24 ± 1.04	7.76 ± 0.93
	90	9.14 ± 0.57	8.73 ± 0.38

for variation in the overhead technique for offensive and defensive strategies, so the repetition is not as consistent.

Passive Glenohumeral ER

Passive ER decreased from preseason to postseason in swimmers. This finding contrasts with what several other researchers[5–7,26,33,40] have found while examining range-of-motion measures in overhead athletes. Some authors[2,41] have suggested that repetitive overhead motions cause anterior capsule stretching, which is demonstrated by increases in ER. Other authors[42,43] have suggested that the ER torque placed on the humeral epiphyseal plate in young overhead athletes increases humeral retroversion, causing a shift in the total arc of motion into increased amounts of ER. Edelson[44] showed that during the years of skeletal development, the humerus starts in a large amount of retroversion and slowly moves into anteversion until the age of approximately 19 years. This finding indicates that the ER torque during overhead sports may decrease the anteversion process, thereby allowing the humerus to be in a more externally rotated position. This differs from the former hypothesis[42,43] in that the ER torque forced the humerus into larger amounts of humeral retroversion. In our study, the decrease in ER indicates that swimming may not be the direct cause of increased ER adaptations common to the other overhead athlete populations but, in fact, may be a compensatory response to acquired IR deficits.[1,15] A tight posterior capsule is thought to cause an increase in glenohumeral horizontal abduction during the late cocking or recovery phase, thereby increasing stress on the anterior capsule. Over time, this increased stress on the anterior capsule may develop into the commonly seen increase in ER. However, we believe that adaptation occurs over several years of competition, and this gradual adaptation is why we did not observe the development in our study. Another possible cause for the decrease in ER may have been muscular strength gains; however, these were not measured in our study. Increases in IR strength throughout a high school swimming season may cause a decrease in ER motion because of muscular tightness[13,25,26]; however, more prospective studies are warranted. Although the increase in ER for volleyball players was not significant because of the higher SD, this change may be clinically important. Further investigation is needed. We also observed a greater amount of ER in the dominant arm than in the nondominant arm overall. This observation corresponds with the findings of many other investigators,[6,7,33,40,45] although the bilateral difference was much less than the results of previous studies.

Scapular Upward Rotation

Scapular dyskinesis is commonly linked to glenohumeral joint disorders in overhead athletes.[1,3,8,17,18] A decrease in scapular upward rotation is thought to decrease the subacromial space and possibly to cause subacromial impingement at higher degrees of glenohumeral abduction.[35,46–50] Using digital inclinometers, several researchers[21,49,51,52] recently have begun to objectively measure scapular upward rotation in overhead athletes. However, to date, no investigators have assessed scapular upward rotation throughout a competitive overhead sports season.

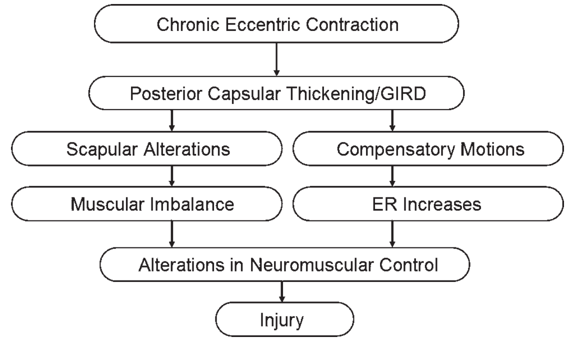

Figure 7. Possible progression of overuse glenohumeral joint injuries in the overhead athlete. Abbreviations: GIRD, glenohumeral internal rotation deficit; ER, external rotation.

The results of our study revealed that scapular upward rotation at 90° of glenohumeral abduction in swimmers increased from preseason to postseason. This may be a positive sports adaptation. Clinically, the finding indicates that overhead athletes in this age group are not developing adverse alterations to their scapular stabilizers, specifically the muscles of the upward rotation force couple, by participating in the sports we studied. Our results also demonstrated a decrease in upward rotation at 90° of glenohumeral abduction in volleyball players from preseason to postseason. This change could have a detrimental effect on the shoulder joint, causing conditions such as impingement and rotator cuff tears. This observed loss of upward rotation may have resulted from the decrease in IR from preseason to postseason. Scapular upward rotation and IR alterations have been documented[10,35,51,52] retrospectively in both injured and healthy athletes. However, because adaptations to IR motion have already occurred, close monitoring for loss of upward rotation may be warranted for the prevention of injury. This finding is important because it may indicate that identification and early treatment of IR deficits could offset or prevent deleterious motion alterations (decreased scapular upward rotation and increased glenohumeral ER) in the overhead athlete (Figure 7).

Scapular Protraction

Scapular protraction is critical to overall performance in overhead sports. During the deceleration and follow-through phases of the overhead motions, the scapula must protract around the thoracic wall to help dissipate large forces that are placed on the glenohumeral joint.[3,8] In an attempt to supply an objective measure to scapular protraction, Kibler[17] developed the lateral scapular slide test. To date, this is the only reliable clinical assessment method to evaluate scapular stabilizing strength.[3] Authors of more recent studies[19,20] have demonstrated that increased scapular protraction causes a decrease in rotator cuff strength. This decrease occurs because the scapula is not acting as a stable base of support for the rotator cuff to function, which predisposes the glenohumeral joint to injury.

In our study, protraction with the hands-on-hips position decreased from preseason to postseason. This indicates that the scapula moved into a more retracted position, which is beneficial for the overhead athlete because it enables optimal function.[20] Our findings showed that female high school overhead athletes are not demonstrating the scapular protraction alterations that are often observed in more advanced overhead athletes or in an injured population.

Limitations

Our study had several limitations. First, because swimming involves the use of both arms overhead and because volleyball at times involves the use of both arms overhead, we combined the dominant and nondominant arms for our preseason-to-postseason comparisons and our sport comparisons. This is a potential limitation because of the effect of tennis as a sport that involves the use of 1 arm overhead. However, high school female tennis players commonly perform 2-handed backhand strokes, which could potentially cause adaptations to the nondominant arm as well. Next, a correlation was not calculated to show the relationship between motion alterations and injury findings. This test could directly link motion alterations to overuse shoulder injuries. However, authors[7,11,47,53–55] of previous biomechanical studies have demonstrated specific glenohumeral and scapular motion alterations (decreased IR, increased ER, decreased scapular upward rotation, and increased scapular protraction) that would increase stress on certain anatomic joint structures, which potentially could cause injury over time.

CONCLUSIONS

Competitive female high school overhead athletes demonstrated decreases in internal rotation after their traditional 12-week seasons. Our findings indicate that an IR deficit may be the clinical marker that results in other compensatory motion alterations often identified in overhead athletes. Over time, IR deficits may cause changes to ER, scapular upward rotation, and protraction; however, more longitudinal research is needed. Our study also demonstrated positive alterations in scapular upward rotation for all sports except volleyball and positive alterations in scapular protraction for all athletes. This may indicate that as the seasons progressed, the scapular muscles developed increased neuromuscular control, allowing these athletes to enhance performance and function at the glenohumeral joint. Overall, our results indicate that close monitoring of passive IR is warranted in female high school overhead athletes. A proper preventive stretching program for the posterior capsule may prevent injuries.

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