Sonographic Stress Measurement of Glenohumeral Joint Laxity in Collegiate Swimmers and Age-Matched Controls

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Background: Glenohumeral laxity that is greater than normal has been implicated as a causal factor in the development of shoulder pain and dysfunction in elite swimmers; however, quantitative evidence demonstrating greater-than-normal glenohumeral joint laxity in swimmers is lacking.

Objective: To quantify glenohumeral joint laxity in elite swimmers and nonswimming controls using stress sonography.

Study Design: Controlled laboratory study.

Methods: Force-displacement measures were performed bilaterally in 42 National Collegiate Athletic Association Division I swimmers and 44 age-matched controls. Of the 42 swimmers, 27 (64%) reported a history of unilateral or bilateral shoulder pain resulting from swimming. Ultrasound imaging was used to measure glenohumeral joint displacement under stressed and nonstressed conditions.

Results: An analysis of variance revealed no significant difference in glenohumeral joint displacement between swimmers (anterior, 2.82 ± 1.7 mm; posterior, 5.30 ± 2.4 mm) and age-matched controls (anterior, 2.74 ± 1.7 mm; posterior, 4.90 ± 2.7 mm). No significant difference in glenohumeral joint displacement was found between swimmers with a history of shoulder pain (anterior, 2.90 ± 1.6 mm; posterior, 5.42 ± 2.3 mm) versus swimmers without a history of shoulder pain (anterior, 2.74 ± 1.8 mm; posterior, 5.14 ± 2.6 mm). Shoulders displayed significantly more glenohumeral joint displacement in the posterior direction compared to the anterior direction ($P < .001$).

Conclusions: Our instrumented technique was unable to identify significantly greater glenohumeral joint displacement in elite swimmers compared to nonswimming controls, and elite swimmers with a history of shoulder pain were not found to have significantly more glenohumeral joint displacement compared to swimmers without a history of shoulder pain.

Clinical Relevance: Objective assessment of glenohumeral joint displacement in athletes participating in overhead-motion sports may be important for injury prevention and management.

Keywords: shoulder; force displacement; sonography; hyperlaxity; ligament

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Shoulder pain in swimmers is a widely reported condition characterized by persistent pain and dysfunction in the shoulder of the competitive swimmer.[9,19,24,25,40] Long training periods and minimal recovery time between training sessions and competitions leave the shoulder of the competitive swimmer vulnerable to overuse trauma.[24,27,28,40] Epidemiologic studies have consistently noted the high incidence and prevalence of shoulder pain and dysfunction in competitive swimmers, with incidence rates being positively correlated with training volume, intensity, and treatment of injuries.[9,13,19,24,28,35] Elite swimmers regularly train 10 to 12 months out of the year, practicing 1 to 2 times per day, 5 to 7 days per week. Distance covered may vary between 8000 to 20 000 yd/d. These numbers translate to up to 16 000 shoulder revolutions per day, with the majority of revolutions being done repetitively without rest or recovery periods. Published research has reported incidence and recurrence rates of shoulder pain as high as

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80% in competitive swimmers in the United States.[9,13,19,24,25,28,35]

Although the true cause of shoulder pain in swimmers is unclear, most published reports suggest that shoulder pain and dysfunction are due in part to glenohumeral joint laxity that is greater than normal.[1,3,4,19,23,27,42] In athletes participating in sports involving repetitive overhead motion, greater-than-normal laxity is thought to predispose the glenohumeral joint to episodes of instability in which the humeral head will subluxate on the glenoid during overhead activity.[1,18,27,29] Greater-than-normal joint laxity does not in itself imply instability; only when joint laxity produces symptoms of giving way is a joint considered to be unstable.[27] Repeated episodes of humeral head subluxation are thought to expose the rotator cuff tendons (specifically the supraspinatus tendon) to mechanical impingement, which eventually progresses to pain and dysfunction.[3,9,18,29,42]

Glenohumeral joint laxity has traditionally been assessed using manual stress tests aimed at gauging the extent of translational movement based on the “feel” of the humeral head.[10] Recent studies using manual laxity tests have noted increased glenohumeral joint laxity in swimmers[23,29,42]; however, other research has found these tests to be nonreproducible and examiner dependent.[14,21,39] Studies using objective measures to quantify glenohumeral laxity in swimmers are currently lacking.[37] Consequently, little scientific evidence exists that quantifies patterns of greater-than-normal glenohumeral joint laxity in swimmers and the relationships these patterns may have to the development of overuse pain and functional impairment. Instrumented arthrometry for the glenohumeral joint, similar to the KT-1000 arthrometer (MedMetric Corp, San Diego, Calif), is currently available and provides a means to quantify translatory or accessory motion.[30,31] Therefore, our objective was to quantify glenohumeral laxity in elite swimmers and nonswimming controls using instrumented arthrometry. The specific aims were (1) to determine whether swimmers have significantly more glenohumeral laxity than do age-matched controls and (2) to determine whether swimmers with a history of shoulder pain have significantly greater laxity than swimmers without a history of shoulder pain.

METHODS

Subjects and Design

A mixed-model (1 between-factor, 1 within-factor) repeated-measures design was used to assess glenohumeral laxity in 42 National Collegiate Athletic Association Division I swimmers (26 men, 16 women) and 44 age-matched controls (26 men, 18 women) (Table 1). All data collection was performed during the preseason or off-season, when swimmers were not actively engaged in intercollegiate competitions. All swimmers were asymptomatic at the time of testing; they reported no interfering pain during overhead activity and displayed full, pain-free active range of motion during shoulder elevation in both the sagittal and scapular planes. Control subjects were also asymptomatic at the time of testing and had no history of long-term participation (>5 years) in overhead-motion sports or occupations.

TABLE 1
Subject Characteristics

Group	Age, y		Height, cm		Weight, kg	
	Mean	SD	Mean	SD	Mean	SD
Women						
Swimmers	19.7	1.0	170	7.2	65.5	4.5
Controls	18.7	0.6	165.3	5.5	62.3	8.5
Men						
Swimmers	19.4	1.6	187.9	6.6	82.3	6.2
Controls	21.5	3.3	179.4	9.7	79.2	16.6

Of the 42 swimmers, 27 (64%) reported a history of unilateral or bilateral shoulder pain resulting from swimming. The breakdown between genders was even, with 16 of 26 men (61%) and 11 of 18 women (62%) reporting a history of shoulder pain. The reported source of pain was multifactorial: 17 athletes reported pain from rotator cuff tendinitis, 5 from biceps tendinitis, 3 from nonspecific sources, 1 from thoracic outlet syndrome, and 1 from a labral tear. Only 1 swimmer reported having arthroscopic surgery in the form of a subacromial decompression to remove scar tissue.

Athletes reported having swum competitively for 11.8 (±2.3) years. On average, swimmers trained between 10 to 12 months per year, during which time they practiced 1 to 2 times per day for 6 days per week, with an average of 2 hours per practice session (~24 hours per week). Average weekly distance covered was reported to be slightly more than 62 000 yd, with a range between 40 000 to 90 000 yd depending on whether the athlete was a sprinter (lower end), middle distance (average), or distance (upper end) swimmer.

Approval for this research study was granted from the University of Michigan’s Institutional Review Board for the protection of human subjects. Each subject read and signed an informed consent document before participating in the study.

Instrumentation

Force-displacement measures were performed bilaterally using a graded stress technique. Shoulders were positioned at 90° of abduction and 60° of external rotation in the scapular plane using the Telos system (Telos, Weiterstadt, Germany).[36] The Telos system consists of a frame for positioning the shoulder, 2 adjustable counterbearings for stabilizing the shoulder girdle, and a stress device for applying forces to the proximal humerus. The anterior counterbearing was placed against the coracoid process and the posterior counterbearing on the scapular spine medial to the acromion process. A portable ultrasound scanner (Model CTS-285 with 5.0 MHz Convex Probe, SIUI, Guangdong, China) was used to dynamically track glenohumeral motion in real time during force application. A board-certified radiologist with 10 years of expe-

Figure 1. Force-displacement measures with the arm positioned and stabilized at 90° of abduction and 60° of external rotation. Force applicator applied anterior-directed (A) and posterior-directed (B) forces to the proximal humerus.

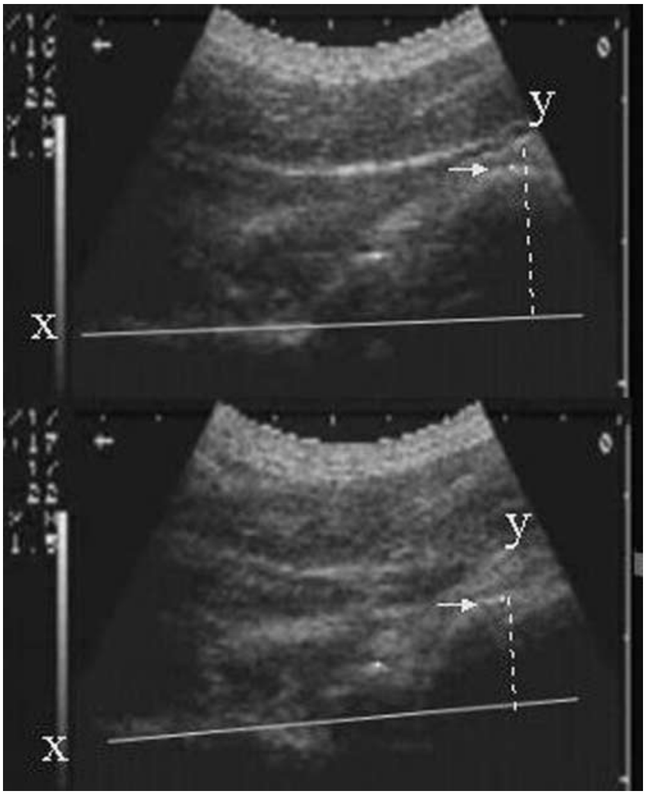

Figure 2. Anterior displacement trial with the x-y anatomical coordinate system marked. The long solid line represents the x-axis and depicts the flat segment of the scapula, whereas the left dot indicates the posterior glenoid and the right dot (with arrow) depicts the posterior humeral head. The broken line represents the y-axis and identifies the distance of the humeral head from the x-axis. Displacement was measured and recorded as the difference in movement between the baseline image (top) and the 15-dN force level (bottom).

rience as a musculoskeletal sonologist (J.A.J.) performed all ultrasound imaging. The sonologist was experienced with this particular stress-measurement technique, having performed more than 100 trials prior to this study.

Test Procedures

The sonographic stress-measurement technique used for this study was found to be reproducible and valid for assessing glenohumeral joint displacement.[5] A posterior approach for dynamically tracking glenohumeral joint motion, similar to that described by Jerosch et al,[17] was used. After the subject was positioned in the Telos device, anterior- and posterior-directed forces of 15 dN (150 N) were applied to the proximal humerus (Figure 1). The test order for side (dominant/nondominant) and direction (anterior/posterior) was performed in a random manner. The ultrasound scan for each trial was video recorded and saved in MPEG format to a laptop computer (Inspiron 7500, Dell Computer Corp, Round Rock, Tex), which was interfaced with the ultrasound scanner using a commercial software program (Studio PCTV, 1.04, Pinnacle Systems Inc, Mountain View, Calif). During video playback, static images were captured at baseline (no force) and at the 15-dN force level. For each image, hyperechoic bony landmarks were consistently identified and marked by the sonologist (J.A.J.) on the scapula and humeral head, creating a biaxial (x-y axes) anatomical coordinate system (Figure 2). The plane of the scapula served as the x-axis and a perpendicular line drawn from the x-axis to a point on the humeral head served as the y-axis. Marked images were later printed and evaluated by the primary author (P.A.B.) in a blinded and randomized fashion. Using the anatomical coordinate system as a frame of reference, the examiner measured the difference in humeral head excursion between the 2 force levels using a digital caliper (Model 700-103B, Mitutoyo, Aurora, Ohio; instrumental error, ±0.2 mm; resolution, 0.1 mm). Displacement was recorded for each direction as the difference between the baseline and 15-dN force levels.

TABLE 2
Mean Glenohumeral Displacement Measurements (in millimeters) Between Swimmers and Controls[a]

	Swimmers		Non-swimmers		Difference	
Measurement	Mean	SD	Mean	SD	Mean	SD
Anterior	2.82	1.7	2.74	1.7	0.08	1.7
Posterior	5.30	2.4	4.90	2.7	0.40	2.5

[a] All arms were positioned and stabilized at 90° of abduction and 60° of external rotation.

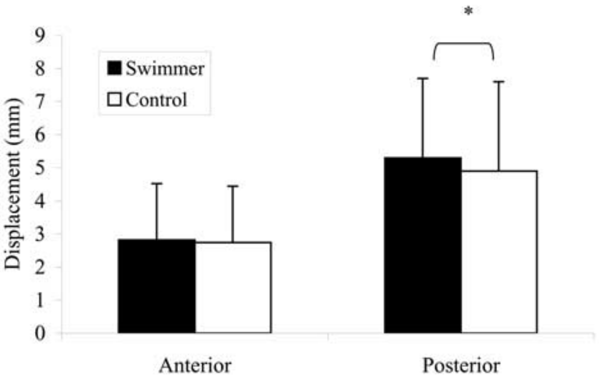

Figure 3. Anterior and posterior glenohumeral displacements between swimmers and controls in response to a 15-dN applied force (mean ± SD). The asterisk (*) indicates that posterior displacement was significantly greater than anterior displacement for both groups ($P < .01$).

Statistical Procedures

The data were analyzed using separate 2-factor analyses of variance (ANOVAs). The first ANOVA was used to determine significant mean differences between group (swimming vs control) and direction of force (anterior vs posterior). The second ANOVA was used to determine significant differences between groups (swimmers with a history of shoulder pain vs swimmers without a history of shoulder pain) and direction of force (anterior vs posterior). In the presence of a significant interaction effect, Tukey least significant difference post hoc analyses (pairwise comparisons) were used to identify simple main effects. All data analyses were performed using SPSS for Windows 11.0 (SPSS Inc, Chicago, Ill). The level of statistical significance was set a priori at the $\alpha = .05$ level.

RESULTS

Preliminary Analysis

Preliminary analyses were performed to determine if there were significant between-gender (male vs female) and side-to-side (dominant vs nondominant) differences in anterior-posterior (AP) glenohumeral joint displacement. Separate repeated-measures ANOVAs were performed on our sample, and we found no significant side-to-side differences in glenohumeral joint displacement ($F_{1,85} = 1.81$, $P = .18$) as well as no significant differences in glenohumeral joint displacement between men and women ($F_{1,85} = 0.78$, $P = .38$). For side-to-side comparisons, AP displacement was found to be 8.24 ± 4.5 mm in the dominant shoulder and 7.52 ± 3.5 mm in the nondominant shoulder. Regarding gender, AP displacement was found to be 8.25 ± 2.8 mm for women and 7.64 ± 3.4 mm for men. Therefore, we proceeded by collapsing the data for side and gender for our primary statistical analysis, using subject type (swimmers vs controls) as the only between-group factor and direction (anterior vs posterior) as the only within-group factor.

Swimmers Versus Controls

The ANOVA revealed no significant difference in glenohumeral joint displacement between swimmers and age-matched controls ($F_{1,84} = 0.47$, $P = .49$) (Figure 3, Table 2). At 15-dN of applied force, anterior displacement was 2.82 ± 1.7 mm and posterior displacement was 5.30 ± 2.4 mm for elite swimmers, compared to 2.74 ± 1.7 mm of anterior displacement and 4.90 ± 2.7 mm of posterior displacement for nonswimming controls. The main effect for direction was significant, with shoulders displaying more glenohumeral joint displacement in the posterior direction (5.10 ± 2.6 mm) compared to the anterior direction (2.78 ± 1.7 mm) ($F_{1,84} = 53.2$, $P < .001$) (Figure 3).

History of Shoulder Pain Versus No History of Shoulder Pain

The ANOVA revealed no significant difference in glenohumeral joint displacement between swimmers with a history of shoulder pain versus swimmers without a history of shoulder pain ($F_{1,40} = 0.17$, $P = .68$) (Figure 4, Table 3). At 15-dN of applied force, anterior displacement was 2.90 ± 1.6 mm and posterior displacement was 5.42 ± 2.3 mm for swimmers with a history of shoulder pain, compared to 2.74 ± 1.8 mm of anterior displacement and 5.14 ± 2.6 mm of posterior displacement for swimmers with no history of shoulder pain. The main effect for direction was significant, with shoulders displaying more glenohumeral displacement in the posterior direction (5.30 ± 2.4 mm) compared to the anterior direction (2.82 ± 1.7 mm) ($F_{1,40} = 33.3$, $P < .001$) (Figure 4).

Post Hoc Power Analysis

Because our statistical findings yielded insignificant results, we performed a power analysis post hoc to determine what a clinically significant difference between the 2 groups would be. Therefore, we estimated a clinically significant between-group mean difference to be 1.5 ± 2.0 mm. Using these values, we calculated an effect size (d) = 0.75. We then used an online power analysis application

TABLE 3
Mean Glenohumeral Displacement Measurements (in millimeters) Between Swimmers With and Without a History of Shoulder Pain[a]

	History		No History		Difference	
Measurement	Mean	SD	Mean	SD	Mean	SD
Anterior	2.90	1.6	2.74	1.8	0.16	1.7
Posterior	5.42	2.3	5.14	2.6	0.28	2.4

[a] All arms were positioned and stabilized at 90° of abduction and 60° of external rotation.

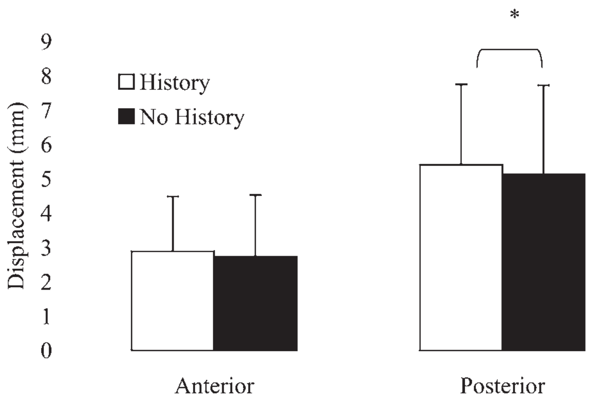

Figure 4. Anterior and posterior glenohumeral displacements between swimmers with and without a history of shoulder pain in response to a 15-dN applied force (mean ± SD). The asterisk (*) indicates that posterior displacement was significantly greater than anterior displacement for both groups ($P < .01$).

(GPOWER version 2.0f, http://www.psycho.uni-duesseldorf.de/aap/projects/gpower/) to perform the analyses. For our first comparison (swimmers vs controls), at $\alpha = .05$ and sample sizes of $n_1 = 44$ (controls) and $n_2 = 42$ (swimmers), our analysis yielded a power of 0.9644 ($t_{84} = 1.66$, $\delta = 3.477$). For the second comparison (swimmers with a history of shoulder pain vs swimmers without a history of shoulder pain), using the same criteria except new sample sizes of $n_1 = 18$ (no history) and $n_2 = 24$ (history), our power was found to be 0.7641 ($t_{40} = 1.684$, $\delta = 2.41$).

DISCUSSION

Preliminary Analysis: Side-to-Side and Between-Gender Differences

In our preliminary analysis, we were able to rule out any significant side-to-side and between-gender differences in glenohumeral joint displacement. Our findings are in agreement with previous studies by Borsa et al[6] and Sauers et al,[30,31] who have consistently documented no significant side-to-side differences in glenohumeral laxity in the shoulders of subjects not engaged in overhead-throwing sports. Glenohumeral displacement was very symmetrical between sides, with a mean side-to-side difference of less than 1 mm (8.24 mm in the dominant shoulder vs 7.52 mm in the nondominant shoulder). Our findings are similar to those of Tibone et al,[37] who found mean side-to-side differences to be 1.4 mm (12.4 mm in the dominant and 13.8 mm in the nondominant shoulders) in a group of swimmers and soccer players. From these results, it does not appear that significant differences in glenohumeral laxity exist between the dominant and nondominant shoulders in swimmers.

Between-gender differences in glenohumeral laxity have also been previously reported by Borsa et al,[7] who found increased glenohumeral laxity in healthy female subjects compared to healthy male subjects. Borsa et al[7] measured glenohumeral laxity with the arm in adduction and neutral rotation, whereas the present study measured laxity with the arm abducted and externally rotated in subjects who participated in overhead-throwing sports and subjects who did not participate in these sports. This difference in results may suggest that between-gender differences in glenohumeral laxity may be dependent on shoulder position. More research is necessary to substantiate these findings.

Glenohumeral laxity in swimmers that is greater than normal is considered by many to be advantageous, given that increased shoulder mobility has been directly correlated with greater stroke length, swimming speed, and overall swimming performance.[40,42] Swimmers are routinely diagnosed with multidirectional shoulder instability without displaying signs of general joint hyperlaxity.[3] Rarely do swimmers complain of the joint giving way or subluxating during overhead activity; rather, the primary complaint is interfering pain and weakness during training.[27] The actual diagnosis of instability is usually made in the presence of positive tests for excessive laxity and apprehension during physical examination.[10,15,27] Debate continues as to whether shoulder hyperlaxity is inherent (genetically endowed) or acquired because of adaptive change. Some researchers speculate that hyperlaxity is inherent, which in turn predetermines athletes to the sport of swimming, whereas others suggest that hyperlaxity develops as a direct result of microtrauma and capsular attenuation.[18,24,25,42]

Between-Group Comparisons: Swimmers Versus Age-Matched Controls

Our findings did not reveal a significant difference in glenohumeral joint displacement between elite swimmers (defined as having Division I collegiate status as well as more than 10 years of experience in competitive swimming) and nonswimming control subjects. Furthermore, our findings do not support the supposition that the glenohumeral joints of elite swimmers are inherently hyperlax and/or acquire hyperlaxity through adaptive change to the joint capsuloligamentous restraints.[¶] Swimmers were compared to an age-matched nonswimming control group and were found to have similar levels of joint displacement

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[¶] References 1, 3, 9, 18, 19, 24, 27, 28, 40, 42.

when assessed in both the anterior and posterior directions. Quantitatively, the between-group difference in joint displacement was 0.08 mm for anterior displacement and 0.4 mm for posterior displacement (Table 2).

In a similar study, Tibone et al,[37] using an electromagnetic spatial tracking system equipped with cutaneous sensors, found significant differences in AP glenohumeral translation between swimmers and soccer players. On average, swimmers were found to have 3 mm more AP translation than soccer players (swimmers, 13 mm; soccer players, 10 mm). The instrumented technique used by Tibone et al was considerably different than the technique used in the present study. Tibone et al[37] had their subjects positioned supine on a treatment table with the arm at 90° of abduction in neutral rotation, whereas our study had subjects seated with the shoulder in 60° of external rotation. In addition, Tibone et al[37] did not use a standard application force; it was instead manually applied, and glenohumeral motion was measured superficially using motion sensors held against the skin. Future research will clarify the reasons for these differences.

Directional Asymmetry

From a directional standpoint, the glenohumeral joint displayed almost twice the amount of posterior displacement than anterior displacement (5.10 mm posterior vs 2.78 mm anterior) in the test position of 90° of abduction and 60° of external rotation in the scapular plane. Glenohumeral translation is known to be position dependent; therefore, the magnitude of translation may vary depending on the position of the joint during assessment.[40] With the humerus in adduction and neutral rotation, researchers have shown quantitatively that AP translation is symmetrical.[6,30,31] Using multiple positions of humeral abduction and rotation during AP-translation measurements may provide a clearer picture of glenohumeral laxity.

From an anatomical and functional standpoint, this particular test position is useful for evaluating the structural integrity of the static restraints that resist humeral head displacement during overhead activity. In this test position, the glenohumeral joint capsule is placed under selective tension, thereby providing increased joint compression and stability during force-displacement maneuvers. The posterior capsule is the thinnest portion of the entire glenohumeral capsule, whereas the anteroinferior capsule and inferior glenohumeral ligament have been described as the thickest and strongest portions.[41] This element may account for the asymmetries found between the anterior and posterior displacement measures. With the shoulder in the functional position of abduction and external rotation, the thick anteroinferior ligaments are able to sufficiently resist humeral head displacement during anterior-directed forces. Conversely, in this test position, the thin posterior capsule may provide less resistance during posterior loading, and as a result, it may allow more posterior displacement to occur. Furthermore, the minimal anterior displacement we found in the abducted and externally rotated position indicates that the primary static restraints to anterior humeral displacement are intact in our swimming group and not attenuated, as previously reported.[18] Jobe et al[18] theorized that repetitive and forceful overhead activity as seen in swimmers causes a gradual stretching out of the anteroinferior capsuloligamentous structures. The theory by Jobe et al[18] suggests that the attenuation of the capsuloligamentous restraints allows the humeral head to subluxate during overhead activity, causing further capsuloligamentous and rotator cuff tendon damage.

Our hypothesis that elite swimmers would display significantly more glenohumeral joint displacement than would nonswimming controls was based upon previous reports citing increased shoulder laxity and hypermobility in swimmers.[3,9,24,27,42] McMaster et al[24] referred to inherent shoulder laxity as the common denominator in competitive swimmers with shoulder pain. McMaster et al[24] further stated that shoulder overuse may have a laxity-potentiating effect on the shoulder capsule. Zemek and Magee[42] noted shoulder hyperlaxity in both recreational and elite swimmers, implicating both inherent and acquired causes. Pink and Tibone,[27] in a recent review, commented on the presence of inherent laxity in swimmers that is seen during clinical examination as increased anterior and inferior translations. Bak and Faunø[3] noted that the majority of competitive swimmers in their study demonstrated increased humeral head translation in the anteroinferior direction. In all of these particular studies, manual laxity tests were used to identify the presence of excessive laxity. The subjective nature of these tests, coupled with the reported lack of reproducibility, underscores the importance of using instrumented techniques when performing range of motion assessments on joints, especially when small bony excursions are elicited.

Our study differs from the previous studies in that we were able to objectively quantify the magnitude of humeral head displacement using a novel force-displacement technique. Through the integration of a force actuator and a sonographic imaging device, we were able to accurately and consistently visualize and record force-induced changes in the position of the glenohumeral joint. The distinct advantages of this technique are direct visualization and dynamic tracking of joint structures during laxity assessments, along with the use of standard forces and joint positions. In addition, the use of ultrasound imaging eliminated patient exposure to ionizing radiation, as would occur with radiography,[8,12,14,26] and it also eliminated the need for invasive procedures such as the pinning of motion sensors directly to bone structures, as has been done in previous kinematic studies.[16,22]

Between-Group Comparisons: Swimmers With a History of Shoulder Pain Versus Swimmers Without a History of Shoulder Pain

Our secondary aim was to test the hypothesis that swimmers with a history of shoulder pain would have significantly greater joint displacement than swimmers without a history of shoulder pain, thus providing insight into a possible relationship between glenohumeral hyperlaxity and history of shoulder pain. Our findings likewise did not show a significant difference in glenohumeral joint displacement between swimmers with a history of shoulder pain and those without a history of shoulder pain. It should be noted that we studied a group of swimmers who were able to return to swimming at the elite level after injury. It may be possible that we would have obtained different results if we had studied a group of swimmers who were disabled by shoulder pain to the point of terminating their careers or undergoing surgery. This would have been a more extreme group, and therefore we may have found more extreme physical findings.

Published reports have commented on the presence of secondary impingement in swimmers, citing hyperlaxity as a possible contributing factor.[3] Our findings suggest that hyperlaxity may not be a causative agent in the development of swimmer's shoulder as previously reported. We feel that a more plausible explanation for the high incidence of swimmer's shoulder could be eccentric tensile overloading of the supraspinatus tendon[2,32,34] and/or mechanical impingement secondary to fatigue-induced scapular dyskinesis.[20] An inability of the scapular muscles to upwardly rotate and posteriorly tilt the scapula may expose the tendon to impingement.[11,20] Likewise, an inability of the humeral dynamic stabilizers to position the humeral head on the glenoid during overhead motion could also expose the tendon to some form of impingement. Scibek and Borsa[33] and Crotty and Smith[11] found deficits in scapular upward-rotation measurements after an intensive practice session when compared to prepractice measurements. Wadsworth and Bullock-Saxton[38] found diminished recruitment patterns of scapular rotator muscles in swimmers with interfering pain. These findings implicate a possible association between scapular dyskinesis and shoulder pain and dysfunction in swimmers. To effectively prevent and treat shoulder pain in swimmers, continued research is necessary to determine the role of glenohumeral joint laxity in overhead motions as well as to uncover the true causal factors for shoulder pain in elite swimmers.

CLINICAL IMPLICATIONS

Maintaining glenohumeral stability during overhead activity is considered by many sports medicine professionals to be essential for functional performance and injury prevention. From a clinical perspective, our findings, coupled with the findings of impaired scapular function during swimming,[11,33,38] suggest that the primary focus be directed toward neuromuscular factors when considering injury prevention, assessment, and treatment of shoulder injuries in swimmers. Injury prevention and intervention strategies should focus on muscular strength, endurance, and neuromuscular control of the scapulohumeral stabilizers and movers for sustained power and scapular control during overhead activity. In addition, special attention may be directed toward the posterior wall muscles to help stabilize the humeral head during overhead activity, thus minimizing excessive posterior humeral displacement.

CONCLUSION

Our findings provide objective evidence that swimmers do not have excessive glenohumeral joint displacement compared to nonswimming controls. In addition, swimmers with a history of shoulder pain do not appear to have significantly more glenohumeral laxity compared to swimmers without a history of shoulder pain. It does not appear that elite swimmers have inherent glenohumeral hyperlaxity, nor do they acquire excessive laxity as a result of long-term participation in a sport with repetitive overhead activity.

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