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original research

Anterior Glenohumeral Laxity and Stiffness After a Shoulder-Strengthening Program in Collegiate Cheerleaders

Kevin G. Laudner, PhD, ATC, FACSM; Betsy Metz, ATC; David Q. Thomas, PhD, FACSM

Illinois State University, Normal

Context: Approximately 62% of all cheerleaders sustain some type of orthopaedic injury during their cheerleading careers. Furthermore, the occurrence of such injuries has led to inquiry regarding optimal prevention techniques. One possible cause of these injuries may be related to inadequate conditioning in cheerleaders.

Objective: To determine whether a strength and conditioning program produces quantifiable improvements in anterior glenohumeral (GH) laxity and stiffness.

Design: Descriptive laboratory study.

Setting: University laboratory.

Patients or Other Participants: A sample of 41 collegiate cheerleaders (24 experimental and 17 control participants) volunteered. No participants had a recent history (in the past 6 months) of upper extremity injury or any history of upper extremity surgery.

Intervention(s): The experimental group completed a 6-week strength and conditioning program between the pretest and posttest measurements; the control group did not perform any strength training between tests.

Main Outcome Measure(s): We measured anterior GH laxity and stiffness with an instrumented arthrometer. We conducted a group × time analysis of variance with repeated measures on time ($P < .05$) to determine differences between groups.

Results: A significant interaction was demonstrated, with the control group having more anterior GH laxity at the posttest session than the strengthening group ($P = .03$, partial $\eta^2 = 0.11$). However, no main effect for time ($P = .92$) or group ($P = .97$) was observed. In another significant interaction, the control group had less anterior GH stiffness at the posttest session than the strengthening group ($P = .03$, partial $\eta^2 = 0.12$). Main effects for time ($P = .02$) and group ($P = .004$) were also significant.

Conclusions: Cheerleaders who participate in a shoulder-strengthening program developed less anterior GH laxity and more stiffness than cheerleaders in the control group.

Key Words: instability, conditioning, injury prevention

Key Points

- Collegiate cheerleaders who participated in a 6-week strength and conditioning program developed less anterior glenohumeral laxity and maintained more stiffness than did a control group of cheerleaders from a competition team.
- Such a shoulder strength and conditioning program may be beneficial in reducing the risk of shoulder injuries associated with excessive anterior laxity and decreased stiffness.

Participation in cheerleading is continually growing. In 1990, an estimated 1 million athletes were involved in cheerleading at the elementary, high school, collegiate, and professional levels.[1] In 2002, the number of participants was estimated to be 3.2 million, and in 2003, the numbers were up to more than 3.5 million participants.[2]

As the number of cheerleading participants increases, so does the number of injuries sustained. Nearly 62% of all female cheerleading participants have suffered an injury during their cheerleading careers, with the number of injuries per cheerleader[3] ranging from 0 to 12. From 1990 to 2002, injuries that required visits to the emergency room more than doubled among cheerleaders between the ages of 5 and 18 years.[4] Furthermore, cheerleading injuries have been reported to result in 3 to 28 days of lost participation.[3,5] In fact, cheerleading-related injuries require more days lost from competition than other popular sports, such as football, baseball, soccer, and basketball.[5]

Approximately 8% of the injuries sustained by high school and collegiate cheerleaders involve the shoulder.[3] These injuries are most likely the result of the forces accumulated by the shoulder during upper extremity weight-bearing maneuvers that are performed routinely in cheerleading.[6] Not only do cheerleaders use their arms to lead cheers, but they also have to lift fellow cheerleaders off the ground, supporting them with their shoulders, and propel themselves across the floor during tumbling passes. Due to these types of maneuvers and the forces created, injuries such as subacromial impingement, strains, and glenohumeral (GH) sprains have been reported to be the most common types among cheerleaders.[6,7] Furthermore, GH sprains may result in increased laxity and decreased stiffness, which have been related to the development of several subsequent conditions,[8,9] and proprioceptive disabilities, which may result in increased dysfunction and soft tissue damage.[10–12]

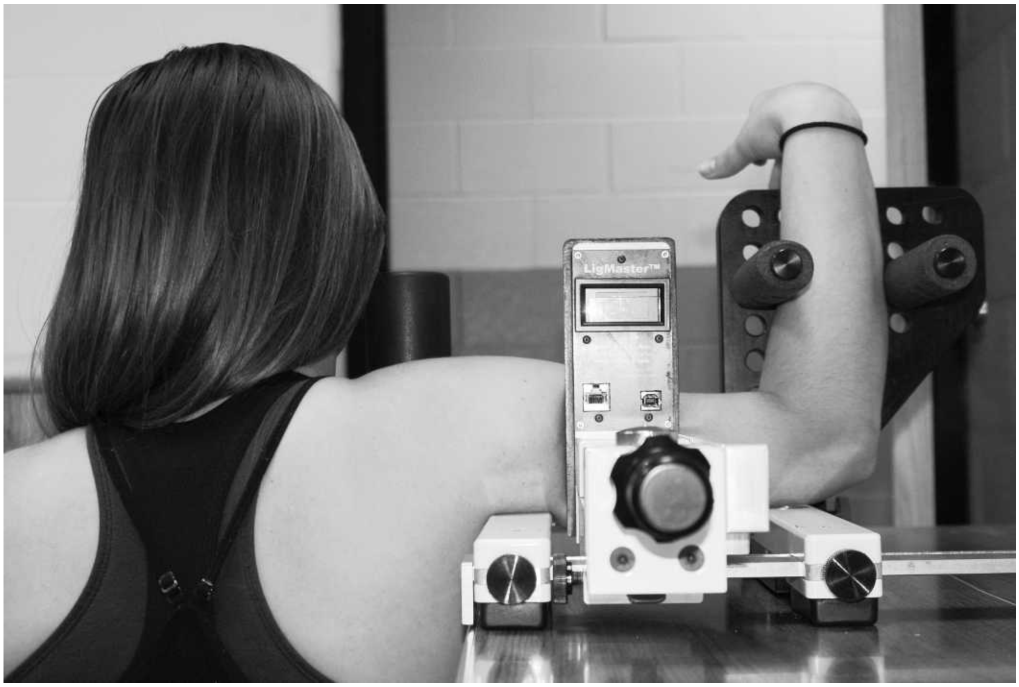

Figure. Measurement of anterior glenohumeral laxity using the instrumented arthrometer.

In an effort to build overall strength, thereby increasing joint stiffness and reducing the risk of injury associated with excessive laxity, cheerleading coaches and advisors have recommended that cheerleading teams implement strength and conditioning programs.[1,13] However, no current data detail the effect of a shoulder-strengthening program in collegiate cheerleaders. Therefore, the purpose of our study was to determine whether a standard upper extremity strength and conditioning program designed for collegiate cheerleaders produced quantifiable improvements in shoulder stability.

METHODS

Participants

A total of 41 collegiate cheerleaders from the same National Collegiate Athletic Association Division I university volunteered for this study. The cheerleaders were selected based on a sample of convenience. The experimental group consisted of 24 participants from the varsity athletic cheer team (age = 19.6 ± 1.8 years, height = 163.8 ± 9.9 cm, mass = 60.7 ± 16.3 kg), and the control group consisted of 17 participants from the competition team (age = 18.8 ± 0.9 years, height = 161.3 ± 4.7 cm, mass = 56.1 ± 6.2 kg). To test the assumption of initial equivalence on the dependent variables, independent t tests were conducted based on the pretest measurements and showed no differences between groups for laxity ($P = .13$) or stiffness ($P = .10$). In addition, both teams were coached by the same person and pursued similar practicing schedules. No participants had a recent history (in the past 6 months) of upper extremity injury or any history of upper extremity surgery. An *upper extremity injury* was defined as any injury to the upper limbs that caused a cheerleader to miss any practices or competitions, limited participation, or required treatment by an allied health care professional. Missing more than 1 training session during the 6-week period was grounds for exclusion for those in the strength and conditioning group, but no participants did so.

Each participant voluntarily attended pretest and posttest measurement sessions in the biomechanics laboratory at Illinois State University. All participants provided informed consent as mandated by the university's institutional review board, which approved the study. All testing was performed by the same investigator, and none was conducted after an extensive cheerleading or weight-training session.

The experimental group completed a 6-week strength and conditioning program between pretest and posttest measurements; the control group did not. Both groups continued their regular practice and competition routines throughout the study.

Instrumentation

We measured anterior GH laxity and stiffness with the LigMaster arthrometer (Sport Tech Inc, Charlottesville, VA). This device uses a modified Telos GA-II/E stress system and specialized software to calculate a force-response curve, which provides the total amount of soft tissue compression and stiffness of the joint restraints. The software then calculates the amount of joint displacement (mm) and stiffness (N/mm). Previous authors[14] have shown the LigMaster to have excellent within-session and between-sessions reliability for both anterior GH laxity (intraclass correlation coefficient [ICC] = 0.84, SEM = 0.53 mm, and ICC = 0.83, SEM = 0.43 mm, respectively) and stiffness (ICC = 0.84, SEM = 0.52 N/mm, and ICC = 0.88, SEM = 0.37 N/mm, respectively). These SEM values equate to a minimum detectable change (MDC) of 1.1 mm for laxity and 1.0 N/mm for stiffness.[15] Crawford and Sauers[14] described unpublished work conducted by Rijke et al that validated the instrument through cadaveric verification, which compared terminal stiffness with ligament

Table 1. Exercise Protocol for the Strength and Conditioning Program, Repetitions

Phase I					Phase II		
	Week					Week	
Day/Exercises	1	2	3	4	Day/Exercises	5	6
Monday							
Seated dumbbell shoulder presses	4 × 10–12	4 × 10–12	4 × 8–10	4 × 8–10	Flat-bench dumbbell presses	3 × 10–12	3 × 10–12
Lateral pull-downs (overhand grip)	4 × 10–12	4 × 10–12	4 × 8–10	4 × 8–10	Plate rows	3 × 10–12	3 × 10–12
Dips (body weight or assisted)	3 × maximum	3 × maximum	3 × maximum	3 × maximum	Seated single-arm presses	3 × 10–12	3 × 10–12
Wednesday							
Incline barbell presses	4 × 10–12	4 × 10–12	4 × 8–10	4 × 8–10	Incline dumbbell presses	3 × 10–12	3 × 10–12
Seated rows	4 × 10–12	4 × 10–12	4 × 8–10	4 × 8–10	Single-arm rows	3 × 10–12	3 × 10–12
Standing cable reverse flies	3 × 15–20	3 × 15–20	3 × 12–15	3 × 12–15	Standing upright rows	3 × 10–12	3 × 10–12
Friday							
Standing barbell military press	4 × 10–12	4 × 10–12	4 × 8–10	4 × 8–10	Seated dumbbell presses	3 × 10–12	3 × 10–12
Incline dumbbell reverse flies	4 × 12–15	4 × 12–15	4 × 10–12	4 × 10–12	Lateral pull-downs	3 × 10–12	3 × 10–12
Push-ups	3 × max	3 × max	3 × max	3 × max	Swiss ball dumbbell presses	3 × 10–12	3 × 10–12

transsection ($R^2 = 0.98$). However, no evidence of the validity of this measurement has been published.

Anterior GH Ligament Laxity and Stiffness Measurement

We measured anterior GH laxity and stiffness of the dominant arm with each participant seated and the shoulder positioned in 90° of abduction and 90° of external rotation while the elbow was in 90° of flexion and full pronation (Figure). We applied 12 daN of anterior force to the posterior proximal humerus at a rate of approximately 1 daN/s based on the recommendations of the arthrometer manufacturer. *Glenohumeral laxit*y was calculated as the difference in displacement between the inflection point, which was calculated by the LigMaster software as the end of soft tissue compression and the initiation of humeral head translation for each participant, and the final amount of displacement recorded at 12 daN of anterior force.[14] *Stiffness* was calculated as the amount of force between the inflection point and the terminal force (12 daN) divided by the amount of laxity (displacement) (12 daN).[14]

Strength and Conditioning Program

The specific exercises and number of sets and repetitions for each exercise were distributed over 2 phases of the strength and conditioning program; these are listed in Table 1. The amount of resistance used for each exercise varied among participants. Each cheerleader was instructed to choose a weight that she could use to complete the designated minimum number of repetitions without exceeding the maximum number of repetitions and while maintaining proper form. All exercises were monitored by the head cheerleading coach to ensure proper form and consistency with the program.

Data Analysis

We used a 2 × 2 (group × time) analysis of variance with repeated measures on time to determine differences in anterior GH laxity and stiffness (dependent variables) between the experimental and control groups. We analyzed all data using PASW software (version 18.0; IBM Corp, Somers, NY), with the α level set a priori at .05.

RESULTS

The means and standard deviations for anterior GH laxity in both groups are presented in Table 2. Glenohumeral laxity showed a significant interaction effect, with the control group being more lax at the posttest session than the strength and conditioning group *($F_{1,39} = 4.86$, $P = .03$*, partial $\eta^2 = 0.11$*)*. This change reflects a small to moderate partial η^2 and exceeds both the SEM (0.53 mm) and the MDC (1.1 mm), indicating a clinically significant interaction. The main effects for time ($F_{1,39} = 0.01$, $P = .92$, partial

Table 2. Pretest and Posttest Anterior Shoulder Laxity

Group	Anterior Shoulder Laxity, mm (Mean ± SD)		Difference, mm	*P* Value	Partial η^2
Experimental	13.5 ± 3.1	11.6 ± 5.8	2.0 ± 6.6	.03	0.11
Control	11.7 ± 4.1	13.5 ± 4.4	−1.8 ± 2.8		

Table 3. Pretest and Posttest Anterior Glenohumeral Joint Stiffness

Group	Anterior Glenohumeral Joint Stiffness, N/mm (Mean ± SD)		Difference, N/mm	*P* Value	Partial η^2
Experimental	9.4 ± 0.61	9.4 ± 1.0	0.01 ± 1.0	.03	0.12
Control	9.0 ± 0.78	8.3 ± 1.3	0.8 ± 1.1		

$\eta^2 = 0.001$) and group ($F_{1,39} = 0.001$, $P = .97$, partial $\eta^2 = 0.001$) were not significant.

The means and standard deviations for anterior GH stiffness in both groups are presented in Table 3. Glenohumeral stiffness showed a significant interaction effect, with the control group having less stiffness at the posttest session than the strength and conditioning group ($F_{1,39} = 5.35$, $P = .03$, partial $\eta^2 = 0.12$). This change reflects a small to medium partial η^2 and exceeds both the SEM (0.52 N/mm) and the MDC (1.0 N/mm), indicating a clinically significant interaction as well. The main effects for time ($F_{1,39} = 5.65$, $P = .02$, partial $\eta^2 = 0.13$) and group ($F_{1,39} = 9.60$, $P = .004$, partial $\eta^2 = 0.20$) were also significant.

DISCUSSION

With the high incidence of shoulder-related injuries among competitive cheerleaders, cheerleading officials and sports medicine organizations, such as the American Association of Cheerleading Coaches & Administrators[16] and the National Center for Catastrophic Sport Injury Research,[13] have encouraged the implementation of strengthening programs in an effort to minimize such injuries. We are the first to examine the effects of such conditioning programs. Our results indicate that a strength and conditioning program may decrease anterior GH laxity and increase stiffness in collegiate cheerleaders.

Hutchinson[6] suggested that shoulder instability is seen more often as the cheerleaders progress in age and level of performance, which may be a direct result of the more demanding stunts and lengths of practices necessary. Although our study was not conducted over subsequent years, we did see increases in shoulder laxity over the course of a single competitive season in the control group. This increased laxity may result from the increased stress and trauma placed on the shoulders as cheerleaders participate in more and more practices and competitions.

Jacobson et al[3] showed that the average number of daily practices per year for high school cheerleaders was 233 but ranged from 120 to 335. The high end of that range leaves only 30 days per year free without cheerleading activities, which does not allow much time for rest and recovery. In a similar study, Jacobson[17] focused on collegiate cheerleaders. The average number of daily practices per year was 205 days but ranged from 120 to 252 or more days. Comparing these studies shows that, ironically, the younger age group participated in more practices and subsequently had less recovery time than their college-aged counterparts. Regardless of age, Shields and Smith[7] demonstrated that this high number of practices is the most common cause of injury, with most injuries being diagnosed as sprains and strains. As such, we believe that the accumulation of destructive forces imparted on the shoulder during practices and competitions may partially explain why excessive shoulder laxity is common among cheerleaders, as seen in our control group. Based on their findings, Shields and Smith[7] also suggested that cheerleaders participate in a strength and conditioning program to reduce such injuries. Our findings of significantly greater laxity and less stiffness in the control group compared with the strength and conditioning group support this suggestion.

We examined cheerleaders over a 6-week period. In this short amount of time, the control group experienced an increase in anterior GH laxity and a decrease in stiffness. Clinicians have stated that as shoulder laxity increases, athletes such as cheerleaders may experience a higher risk of instability-related injuries, such as subluxations and dislocations,[18,19] superior labrum anterior-to-posterior (SLAP) lesions,[19,20] Bankart lesions,[21] Hill-Sachs lesions,[19,21] subacromial impingement,[19] adhesive capsulitis,[19] and pathologic internal impingement.[22] We showed that an appropriate shoulder-strengthening program can decrease the development of anterior GH laxity and maintain stiffness during the collegiate cheerleading season.

Several possible explanations should be considered for why the laxity and stiffness of the strength and conditioning group remained relatively constant while the control group's laxity increased and stiffness decreased. First, the maintained laxity in the strength-training group may have been from the increased dynamic support provided by the shoulder muscles after the strengthening program, resulting in decreased stress being placed on the static restraints, such as the shoulder capsuloligamentous structures. The strengthening program may have also contributed to increased muscle tone.[23,24] Several authors[25,26] have reported that decreased muscle tone contributes to increased laxity. Therefore, having cheerleaders participate in a strength and conditioning program may reduce laxity and increase stiffness during the course of a competitive season. Furthermore, this reduced laxity and increased stiffness could potentially minimize the development of the various shoulder conditions[8,9] and dysfunctions[10–12] associated with increased GH laxity. However, future research is needed to show the effects of such a strength and conditioning program on injury rates.

The strength and conditioning program used by the experimental group in our study focused on common exercises. Specific exercises such as seated rows, plate rows, and reverse flies target the posterior shoulder muscles and more specifically the rhomboids, trapezius, and posterior deltoid, which act to retract the humerus.[27,28] Strengthening these muscles may assist in resisting anterior humeral head translation by pulling the humerus more posteriorly during retraction.[29] Exercises such as seated, inclined, and standing dumbbell presses and the standing upright row assist in strengthening the anterior and middle portions of the deltoids,[30,31] which have been shown to be weak in patients diagnosed with instability.[32] Finally, exercises that mimic the rowing motion activate the long head of the biceps brachii muscle, which is an anterior stabilizer of the humeral head.[33–35]

As with any study, we recognize several limitations in our investigation. First, we only tested collegiate cheerleaders. Cheerleaders at different levels (eg, youth, high school, professional), as well as athletes in other overhead sports such as baseball, softball, swimming, tennis, and volleyball, may have different results. However, we believe that if a strength and conditioning program can maintain laxity in collegiate cheerleaders, similar findings might be expected among other age groups and overhead-sport athletes who are exposed to the accumulation of forces directed to the shoulder. Further research in this area is necessary.

Second, the results of our study are specific to the strength and conditioning program used. We cannot determine which exercises were the most or least beneficial. Therefore, programs using different exercises would most likely produce varying results. In addition, changes in shoulder strength were not a variable of interest before our research. However, demonstrating such changes could potentially add to the strength of our results and should be addressed in future studies.

Third, our study resulted in a small partial η^2 for laxity (0.11). However, the effect sizes for both the experimental (0.33) and control (0.41) groups were of moderate size, and an analysis indicated 80% power. The effect sizes for the experimental and control groups for stiffness were 0.01 and 0.6, respectively, with a power of 75.4%. This shows that the changes in laxity and stiffness observed between the pretest and posttest sessions could be viewed as both clinically and statistically significant. Yet the small effect size for stiffness in the experimental group does not appear to be clinically significant. This finding may support the hypothesis that the strength and conditioning program maintained the stiffness among the experimental cheerleaders, potentially through increased muscle tone, thereby reducing the stress placed on the capsuloligamentous structures. Conversely, the control group showed a statistical and clinical reduction in stiffness, which may have increased the stress placed on the capsuloligamentous structures during the cheerleading season and resulted in increased anterior GH laxity. As previously mentioned, increased muscle tone may have contributed to the increased stability in the strength and conditioning group compared with the control group, but several other static restraints also play a role in this stability, including the bony architecture, glenoid labrum, and intra-articular pressure. Therefore, our measurement of anterior GH laxity does not reflect capsuloligamentous laxity alone but rather all of the aforementioned static stabilizing structures of the anterior GH joint. Furthermore, the validity of the arthrometer used for measuring laxity has not been published, although this technique has been used in multiple studies.[14,36,37] Finally, although specific instructions were provided, we cannot determine whether all participants were completely relaxed during testing.

CONCLUSIONS

Collegiate cheerleaders who participated in a 6-week strength and conditioning program developed less anterior GH laxity and maintained more stiffness than did a control group of cheerleaders. Therefore, such programs may be helpful in reducing the likelihood of various shoulder injuries associated with excessive anterior shoulder laxity and decreased stiffness.

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Address correspondence to Kevin G. Laudner, PhD, ATC, FACSM, Illinois State University, Campus Box 5120, Normal, IL 61790. Address e-mail to klaudne@ilstu.edu.