

Relationship of Shoulder Flexibility, Strength, and Endurance to Shoulder Pain in Competitive Swimmers

Mary Lee Beach, MS, PT¹

Susan L. Whitney, PhD, MS, PT, ATC²

Steven A. Dickoff-Hoffman, MS, PT, ATC³

The swim season for the competitive swimmer lasts 10–12 months per year. Competitive swimmers practice 5–7 days per week, with twice daily workouts during midseason training. The reported average yardage for midseason swimmers is 8,000 to 20,000 yds per day (2, 20, 26). Counsilman (5) proposed a 4:1 ratio of running to swimming, in which 4 miles of running are exertionally equivalent to 1 mile of swimming. Therefore, the average swimming yardage would be equivalent to running more than 45 miles per day.

The competitive swimmer will also weight train a minimum of three times per week. Common weight training consists of free weights, Nautilus® (Nautilus, Independence, VA, 24348), and a swim bench, which emphasizes internal rotation and shoulder extension (2, 8, 18, 21, 25). This intensity of training places the competitive swimmer at risk of developing musculoskeletal injuries.

Although there are four strokes in competitive swimming (freestyle, butterfly, backstroke, breaststroke), 80% of practice time is spent performing the freestyle stroke. This percentage is independent of the swimmer's specialty stroke, and, therefore, the freestyle stroke is the emphasis of this study (8, 19, 25).

A common complaint of competitive swimmers is shoulder pain. The purposes of this study were to: 1) provide normative data on shoulder flexibility in swimmers, 2) determine if a correlation exists between flexibility and shoulder pain, and 3) determine the correlation between strength and endurance ratios to shoulder pain. The subjects were 28 Division I collegiate swimmers and four club swimmers. Shoulder flexibility measurements were obtained bilaterally using a universal goniometer. Strength and endurance ratios were obtained bilaterally using the Cybex II® isokinetic dynamometer and the Upper Body Exercise Table®. The swimmers completed a questionnaire that included a shoulder pain performance scale. The Pearson product moment correlation coefficient and multiple regression (*R*) analysis were the applied statistics. The results demonstrated that no significant correlation ($p > 0.001$) existed between shoulder flexibility, strength ratios, and shoulder pain. There was a significant ($p \leq 0.001$) negative Pearson's correlation between endurance ratios of external rotation, abduction, and shoulder pain in competitive swimmers. A multiple *R* of 0.78 was obtained for the combination of external rotation and abduction endurance ratios to shoulder pain, which was significant ($p \leq 0.001$). Clinical implications suggest that when evaluating swimmers, clinicians need to be aware of the importance of assessing the endurance ratios of the shoulder abductors and the external rotators at faster speeds. With decreased endurance ratios, competitive swimmers may be more likely to develop shoulder pain.

Key Words: swimmer, muscle strength, flexibility

¹Associate, Metro Physical Therapy, Inc., 1501 Locust Street, Suite C-8, Pittsburgh, PA 15219. At the time this research was conducted, Ms. Beach was a master's candidate in the sports physical therapy track, University of Pittsburgh, PA.

²Assistant professor, Department of Physical Therapy, University of Pittsburgh, Pittsburgh, PA

³Director of Sports Medicine, North Hills Sports Medicine Center, Pittsburgh, PA

This study was supported in part by the School of Health Related Professions Research and Development Fund, University of Pittsburgh, Pittsburgh, PA.

A common complaint of competitive swimmers is shoulder pain. The incidence of shoulder pain in competitive swimmers ranges from 40–80% (2, 8, 26). A number of articles have been written discussing the two most common contributing factors in swimmers' shoulder pain—flexibility and muscle imbalances between the internal and external rotators (12, 14, 18, 20, 21, 26). However, the

literature is limited in demonstrating any type of correlation between these contributing factors and shoulder pain in competitive swimmers. Although training techniques have greatly improved in the past 10 years, the incidence of shoulder pain in swimmers has not declined (18).

Researchers have stated that the primary cause of shoulder pain in swimmers is impingement of the ro-

tator cuff, biceps tendon, subdeltoid bursa, and subacromial bursa under the coracoacromial arch (2, 9, 20, 22). The mechanism of injury is believed to be a result of repetitive stress, overuse, and improper stroke mechanics (2, 9, 21, 23).

Discrepancies in the literature exist regarding flexibility and its role in shoulder injury (11, 14, 18, 21, 26). Some authors (11, 14, 18, 26) have suggested that a lack of shoulder flexibility in swimmers contributes to shoulder injury. On the other hand, McMaster (21) discussed the influence of hyperflexibility in swimmers, which may cause a multitude of shoulder problems. Only one author has shown objective documentation for his/her opinion on swimmers' excessive/limited shoulder flexibility (14). The data collected by Greipp (14) were limited to one measurement of the anterior shoulder compartment. He was able to predict at a 90% accuracy rate at which swimmers, based on their pre-season shoulder flexibility measurement, would develop shoulder pain during that swim season.

Several studies have compared shoulder internal/external rotation strength ratios of baseball players and nonathletes at 60, 180, and 240°/sec (3, 4, 16, 23, 29). The obtained unilateral antagonistic ratios were 3:2 for internal rotation:external rotation and 2:1 for abduction:abduction across a velocity spectrum. There was no significant difference between the dominant and nondominant arm or the speed of testing. In these studies, the test position was supine for internal/external strength ratios. One of two known studies to test swimmers' internal/external rotation strength ratios was completed by Falkel et al (11). He tested the swimmers prone to mimic specificity in sports testing and achieved greater torque production in the prone position compared with supine. Beasley's (1) study supported the preliminary work of Falkel et al (11). She found that exter-

nal to internal rotator concentric ratios at 60°/sec tested in the prone position were significantly greater ($p < 0.05$) for swimmers compared to nonathletes. Falkel and Murphy (12), in an unpublished follow-up study, reported on "endurance ratios" for external rotators vs. internal rotators. Their results showed endurance of 67.8% for external/internal rotation in nonswimmers, 56.1% in swimmers without shoulder pain, and 42.0% in swimmers with shoulder pain (12). The need for further research is apparent.

The purposes of this study were to: 1) provide normative data on elite swimmers' shoulder flexibility, 2) determine if a correlation exists between excessive or limited flexibility and shoulder pain, 3) determine

One male and three females were club swimmers (three of the club swimmers would be competing for a Division I team and the fourth swimmer was a 15-year-old Junior Olympic qualifier). The swimmers were all accepted into the study without screening for prior or present shoulder injury. One individual was excluded from the study secondary to recent shoulder surgery and lack of medical clearance. The University of Pittsburgh intercollegiate swimmers who volunteered for this study were accepted regardless of their current level of shoulder symptoms because swimmers frequently practice with shoulder pain. Therefore, the intent was to test all swimmers, regardless of their present level of shoulder pain. Seventy percent of the University of Pittsburgh male swim team and 91% of the female swim team participated in this study. The age range was 15–21, and the mean was 19 for both males and females. The participants signed an informed consent according to the regulations of the Biomedical Internal Review Board of the University of Pittsburgh.

Eighty percent of practice time is spent performing the freestyle stroke.

the correlation coefficient between external/internal and abduction/adduction strength ratios to shoulder pain, and 4) determine the endurance ratios for 50 repetitions of internal rotation, external rotation, and abduction and adduction, and their correlation to shoulder pain. The null hypothesis for this study was that no correlation existed between shoulder flexibility, shoulder strength, or endurance ratios and pain experienced by swimmers.

METHOD

Subjects

Thirty-two swimmers volunteered to participate in this study. Seven males and 21 females were members of the University of Pittsburgh Division I Swimming team.

Procedure

A questionnaire adapted from the United States Swimming Association (28) was completed by all participants (Table 1). Attached to the questionnaire was a modified version of the shoulder pain performance scale established by Greipp (14) (Table 2).

After completing the questionnaire, each subjects' shoulder flexibility was tested in the supine position using a universal goniometer. The lower extremities were flexed bilaterally to maintain the spine in a neutral position (10) (Figure 1). Standard goniometric tests were performed for active internal/external rotation measured at 90° of shoulder abduction (10, 13, 19). Active horizontal abduction and adduction were measured with shoulder flexion

1. At what age did you first swim competitively?
2. List 100 and 200 times you swim, with current best times.
3. How many workouts per week do you participate in now?
4. How many yards per day do you swim in workouts?
5. How many months will you train this year?
6. Have you ever stretched before workouts?
7. At what age did you first start stretching?
8. Do you stretch before workouts now?
9. If sometimes, how often?
10. Have you ever used surgical tubing to stretch?
11. Do you now use surgical tubing to stretch?
12. If yes, how often?
13. If yes, for how long?
14. Have you ever used weight training in your workouts?
15. Do you use weight training in your workouts now? * If yes what type of weights do you use? Check all that apply:

 - 16. Free Weight
 - 17. Nautilus®
 - 18. Swim Bench
 - 19. Other

20. At what age did you first begin using weights?
21. Have you ever used hand paddles in workouts?
22. Do you use hand paddles in your workouts now?
23. Have you ever experienced shoulder pain?
24. Do you have shoulder pain now? (such that your training has been altered)
25. If yes, how long have you had shoulder pain?

TABLE 1. United States Swimming Sports Medicine Shoulder Pain Questionnaire. (Adapted from Troup (28), with permission).

Please circle the number that corresponds to your present shoulder pain level:

- (0) No pain
- (1) Occasional shoulder pain which lasts less than two hours. No problem.
- (2) Shoulder pain lasting longer than 2 hours following swim practice.
- (3) Shoulder pain experienced on forceful arm movements.
- (4) Shoulder pain which is annoying for perhaps eight hours a day. Could have affected my practice abilities.
- (5) Pain was very annoying. Almost certainly affected my ability to practice hard.
- (6) Severe shoulder pain, lasting at least 12 hours a day (unless I used ice, medication, etc). Almost impossible to practice hard.

TABLE 2. Swimmer's Shoulder Pain Scale. (Adapted from Greipp (14), with permission).



FIGURE 1. Coniometric test position for external rotation.

to 90°, the forearm in the neutral position, and the elbow extended. The position for active shoulder flexion was with the palm of the hand facing upward and the elbow extended with the arm over the side of the table. Active shoulder abduction was assessed with the scapula supported on the table, the elbow extended, and the palm facing upward (10). The end point was determined by the swimmer's maximal active range precluding observable substitution. One bilateral measurement of each of the following active motions was recorded: shoulder flexion, extension, abduction, horizontal abduction, horizontal adduction and internal and external rotation (10, 13, 19). An intratester reliability coefficient of 0.95 was established in a pilot study using 42 physical therapy students and the same procedures for the shoulder flexibility measurements.

Following the flexibility measurements, strength was tested with a Cybex II® (Cybex Division of Lumenex, Inc, Ronkonkoma, NY, 11799) isokinetic dynamometer, an Upper Body Extremity Testing Table® and the Cybex Data Reduction Computer. One of many definitions for strength is the ability of a muscle group to exert a force about an axis. For the purpose of this study, the parameter to indicate strength was peak torque. Strength (peak torque) ratios were obtained for external/internal rotation and abduction/adduction at 60° sec and endurance ratios

for 50 repetitions at 240°/sec, according to the manufacturer's recommendations (7). The strength decrement (endurance ratio) was calculated by dividing the mean of the peak torque for the last three contractions by the mean of the peak torque for the first three contractions × 100. The 240°/sec was selected as an appropriate sport-specific speed based on the following mathematical equation:

$$^{\circ}/\text{sec} = (360^{\circ}/\text{stroke}) \times (\text{number of strokes/arm/sec for 25 yards}),$$

which was obtained from a study completed by Craig (6). Richardson (26) reported that the average number of arm strokes per 25 yds of the pool was 20. An average time (seconds for 25 yards) was obtained for this specific sample during one of their swimming practices. The Cybex II dynamometer was calibrated according to the manufacturer's specifications before testing began (7). The damping was set at two (2), and the paper speed was set at 5 mm per second (30).

The axis of the Cybex II was aligned with the axis of the humerus in the prone position for external/internal rotation with the arm at 90° of abduction (11) (Figure 2). Velcro® straps were used to stabilize the waist and chest. The subjects completed three submaximal repetitions at the specified speed prior to testing. A 30-second rest occurred between warm-up and the initiation of the test. The test included three repetitions of maximum effort at 60°/sec and an endurance trial of 50 repetitions at 240°/sec. One-minute rest periods were provided between testing speeds (27). No verbal encouragement was given. All tests were completed bilaterally, and the testing order was randomized.

Data Analysis

The Pearson product moment correlation coefficient and multiple regression (*R*) analysis were com-



FIGURE 2. Cybex II* prone test position for external/internal rotation.

puted to determine if a relationship existed between the variables. The significance level for all variables investigated was $p < 0.001$. Three paired *t*-test analyses of the data were computed to indicate if there was a significant difference ($p < 0.05$) between right and left range of motion, strength, and endurance ratios.

RESULTS

In the sample of swimmers studied, the average age that the swimmers began competition was 8 ($s = 2$). They now participate in eight practices/week ($s = 2$), with an average yardage/workout of 7,000 yds ($s = 2,000$ yds). The swimmers practice 10 months per year (± 1 month). Ninety-seven percent stretch prior to workout and started stretching at age 10 ($s = 3$). Ninety-one percent of the swimmers are on a weight training program. Ninety-four percent of these individuals train with free weights, 94% train with Nautilus, and 63% use the swim bench. None of the athletes uses any other equipment for strength training. The mean age at which the swimmers started weight training was 14 ($s = 2$). Ninety-four percent of three individuals had ever used hand paddles, with only 41% presently using hand paddles. The percent of swimmers who had ever experienced shoulder pain was 87%. Sixty-nine percent presently experience some degree of shoulder pain, and 31% have shoulder pain that is presently effecting their swimming ability.

The mean shoulder flexibility and standard deviation measurements as well as correlation coefficients for left and right shoulder flexibility to shoulder pain appear in Table 3. There was a low and non-significant correlation between shoulder flexibility and competitive swimmers with shoulder pain ($p > 0.001$). There was no significant difference between the right and left range of motion measurements ($p > 0.05$).

The results of the mean ratios for external/internal rotation and abduction/adduction for left and right shoulder strength as well as correlation for strength ratios to shoulder pain are summarized in Table 4. Mean endurance ratios for external rotation, internal rotation, abduction and adduction, and correlation coefficients for endurance ratios to shoulder pain are summarized in Table 5. There was no significant difference between the right and left shoulder mean percent ratios ($p > 0.05$). Very low and nonsignificant correlations, shown in Table 4, were

found between external/internal rotation and abduction/adduction strength ratios and shoulder pain in swimmers. The correlation coefficients in Table 5 for endurance ratios of 50 repetitions for both external rotation and abduction at 240°/sec showed a significant correlation to shoulder pain ($p < 0.001$). This represents a moderately negative correlation—as the endurance ratios of external rotation and abduction decrease, the reported value on the pain scale increases.

The results of the multiple regression (R) analysis showed a significant multiple regression coefficient of 0.73 for the left and 0.78 for the right for the combined variables of external rotation and abduction endurance ratios to shoulder pain in swimmers ($p < 0.001$). The R^2 was 0.54 left and 0.60 right, which indicates that more than 54% and 60% of the variation in pain rating could be explained by the combination of external rotation and abduction ratios at 240°/sec in the left and right sides, respectively.

Shoulder ROM	Mean Degrees		Standard Deviation Degrees		Correlation (r) to Shoulder Pain	
	Left	Right	Left	Right	Left	Right
Flexion	188°	187°	10°	9°	.29	.17
Extension	62°	59°	16°	14°	.21	-.01
Horizontal abduction	44°	44°	14°	16°	.12	-.15
Horizontal adduction	141°	136°	10°	25°	.12	-.29
External rotation	100°	101°	10°	11°	.08	.26
Internal rotation	49°	45°	14°	12°	.01	-.03
Abduction	196°	195°	14°	15°	-.03	-.27

TABLE 3. Left and right shoulder flexibility in supine and correlation coefficients for shoulder flexibility to shoulder pain.

Strength Ratio at 60°/sec	Mean Peak Torque (ft-lbs)		Standard Deviation (ft-lbs)		Correlation (r) to Shoulder Pain	
	Left (%)	Right (%)	Left (%)	Right (%)	Left	Right
External/internal rotation	71	70	10	9	-.03	-.12
Abduction/adduction	57	56	11	12	.14	-.06

TABLE 4. Left and right shoulder strength ratios of external/internal rotation and abduction/adduction and the correlation coefficients for strength ratios to shoulder pain.

Endurance Ratio for 50 Repetitions at 240°/sec	Mean Peak Torque		Standard Deviation		Correlation (<i>r</i>) to Shoulder Pain	
	Left (%)	Right (%)	Left (%)	Right (%)	Left	Right
External rotation	80	78	23	22	-.61*	-.69*
Internal rotation	106	107	17	17	-.24	-.46
Abduction	55	60	36	37	-.55*	-.63*
Adduction	124	127	25	36	-.01	.07

* Significant at $p < 0.001$.

TABLE 5. Left and right shoulder endurance ratios of external rotation, internal rotation, abduction and adduction and correlation coefficients for endurance ratios to shoulder pain. The endurance ratio was defined as the mean of the peak torque for the last three repetitions divided by the mean of the peak torque for the first three repetitions multiplied by 100.

DISCUSSION

The descriptive findings concur with the study by Richardson et al (26), which reported that the majority of successful swimmers have fewer than 1–2 months of unscheduled practices per year in a swimming career that lasts 10–15 years. The incidence of shoulder pain, the number and amount of workouts, and yardage these subjects completed were representative of the characteristics of the competitive swimmer previously described in the literature (2, 20, 22–24, 26).

The mean range of motion in Table 3 demonstrated that the swimmers in this study were hypomobile in internal rotation compared with published standards, which report that normal internal rotation range of motion is 90° (10). Pappas (25) hypothesized that limited internal rotation was the result of reactive fibrosis of the capsular tissues because of repetitive microtrauma in individuals with shoulder impingement. The mean range of motion for shoulder external rotation and abduction demonstrated hypermobility in these directions when compared with normative data (external rotation = 90°, abduction = 180°).

Individuals competing in overhead sports have often been reported to demonstrate at least a 15° increase in shoulder external rotation and abduction range of motion

(15) compared with published standards (10).

Although most of the literature on rehabilitation of swimmers emphasizes passive stretching into external rotation for the shortened internal rotators, the results of this study show that external rotation range of motion is 10–11° greater than normal (2, 8, 14, 18, 21). The average mean internal rotation was quite limited—45° right and 49° left. The greatest amount of internal rotation measured in any of the swimmers was 70°. None of the treatment protocols presently described in the literature addresses the issue of shortening of the external rotators (11, 14, 18, 20, 26).

In addition, the idea that shoulder mobility may cause shoulder pain may not be important, given that the correlation coefficients of shoulder flexibility to shoulder pain in swimmers were extremely low and nonsignificant (Table 3).

The majority of swimmers in this study were hypermobile in shoulder abduction, external rotation and flexion compared with published norms (10), but not all swimmers experienced shoulder pain. Similarly, all of the swimmers were hypomobile in shoulder internal rotation, but not all swimmers experienced shoulder pain. Therefore, there was little correlation between hypermobility or hypomobility and shoulder pain in competitive swimmers.

Previous literature indicates that internal rotation strength is greater than external rotation strength by approximately a 3:2 ratio (3, 4, 29, 16). A 3:2 ratio (67%) and the actual value obtained from the data in this study (71% left and 70% right) are quite similar. In Table 5, the standard deviation was large for the external rotation endurance ratio due to the fact that a few swimmers with a pain scale rating above one were unable to maintain enough torque to register on the computer, and their rating was zero.

The results of the shoulder abduction/adduction strength and endurance ratios, represented in Tables 4 and 5, are similar to "normal" (3, 4, 16, 29) values for abduction/

There was a low and nonsignificant correlation between shoulder flexibility and competitive swimmers with shoulder pain.

adduction. In Table 4, adduction strength was found to be greater than abduction strength by approximately a 2:1 ratio, which corresponds to previous studies by Connelly et al (3), Cook et al (4), Weldon et al (29), and Ivey and Calhoun (16). The actual value obtained from this study (57% on the left and 56% on the right) was very similar to the reported "normal" ratio of 50%. There was no significant correlation between external/internal rotation and abduction/adduction strength ratios and shoulder pain in competitive swimmers (Table 4).

Adduction endurance ratios were greater than 100%, which indicates that the adductors were getting stronger through the testing period while the abductors, with a mean of

60%, were getting weaker (Table 5). The standard deviation is larger for the abduction endurance ratio due to the fact that a few swimmers with a pain scale rating above one were unable to maintain enough torque to register on the computer, and their percent ratios were zero.

The correlation coefficients for the endurance ratios of 50 repetitions for both external rotation and abduction at 240°/sec represented a moderately high negative correlation. The negative correlation indicated that as the endurance ratios of external rotation and abduction de-

Individuals competing in overhead sports have often been reported to demonstrate at least a 15° increase in shoulder external rotation and abduction range of motion.

creased, the reported value on the pain scale increased (Table 5). Falkel and Murphy (12) reported that swimmers with shoulder pain have significantly lower absolute external rotation endurance than swimmers without shoulder pain. Their work is similar to this study's findings of a moderately high negative correlation between endurance ratios of external rotation, abduction, and shoulder pain in swimmers.

The first and second parts of the null hypothesis, which state that there is no correlation between shoulder flexibility and strength ratios for external/internal rotation,

abduction/adduction, and shoulder pain experienced by swimmers, are not rejected. The third part of the null hypothesis, which states that there is no correlation between external rotation, abduction endurance, and shoulder pain in competitive swimmers is rejected as a result of significant correlation ($p \leq 0.001$) to shoulder pain.

The limitations of this study include a relatively small sample size, no distinction between the influence of various pathologies, such as impingement, subluxation, labrum tears, or multidirectional instabilities, and limited familiarity of the subjects with testing procedures. This study illustrates the need for further research. Possible future studies include correlating the effects of different pathologies (ie., impingement, subluxation, and labrum tears) on endurance ratios and shoulder pain in swimmers. A second study incorporating an intervention program of endurance training for the external rotators and abductors could determine if improved endurance ratios decrease the incidence of shoulder pain in swimmers.

CONCLUSION

The results of the multiple regression analysis of external rotation and abduction endurance ratios showed a significant correlation to shoulder pain in competitive swimmers. This suggests that when evaluating swimmers, the clinician needs to be aware of the importance of assessing the endurance ratios of the shoulder abductors and the external rotators at 240°/sec, because as the endurance ratios decreased, the reported level of pain and dysfunction increased. The flexibility data showed an extremely low, nonsignificant correlation to shoulder pain. In light of the data obtained from this study, present treatment protocols that encourage stretching into external rotation should be questioned.

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ACKNOWLEDGMENTS

The authors greatly appreciate the cooperation and support of Stephen Ford and members of the University of Pittsburgh swimming team, their coaches, and the athletic training department in preparation of this study. We also thank Dr. John Bolvin for his guidance and encouragement.

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