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A Cross Sectional Study Examining Shoulder Pain and Disability in Division I Female Swimmers

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Abstract

Introduction—The prevalence of shoulder pain in the competitive swimming population has been reported as high as 91%. Female collegiate swimmers have a reported shoulder injury rate 3× greater than their male counterparts. There has been little information on how to best prevent shoulder pain in this population. The purpose of this study is to examine if differences exist in shoulder range of motion, upper extremity strength, core endurance, and pectoralis minor length in NCAA Division I female swimmers with and without shoulder pain and disability.

Methods—NCAA Division I females (n=37) currently swimming completed a brief survey that included the pain subscale of the Penn Shoulder Score (PSS) and the Sports/Performing Arts Module of the Disabilities of the Arm, Shoulder, and Hand (DASH) Outcome Measure. Passive range of motion for shoulder internal rotation (IR) and external rotation (ER) at 90° abduction was measured using a digital inclinometer. Strength was measured using a hand held dynamometer for scapular depression and adduction, scapular adduction, IR, and ER. Core endurance was assessed using the side bridge and prone bridge tests. Pectoralis minor muscle length was assessed in both a resting and stretched position using the PALM palpation meter. All measures were taken on the dominant and nondominant arms.

Results—Participants were classified as positive for pain and disability if the following 2 criteria were met: 1) the DASH sports module score was greater than 6/20 points and 2) the PSS strenuous pain score was ≥4/10. If these criteria were not met, participants were classified as negative for pain and disability. Significant differences were found between the two groups on the dominant side for pectoralis muscle length at rest ($p=0.003$) and stretch ($p=0.029$).

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Conclusions—The results provide preliminary evidence regarding an association between a decrease in pectoralis minor length and shoulder pain and disability in Division I female swimmers.

Keywords

Swimming; shoulder pain; female

The prevalence of shoulder pain in the competitive swimming population has been reported as high as 91%.[1] One study found that 69% of National Collegiate Athletic Association (NCAA) Division I Swimmers experienced shoulder pain.[2] This shoulder pain can be so severe that it may lead to functional impairments and even cessation of swimming participation.[3] The reported injury rate in collegiate swimmers ranges from 2.12 – 3.78 per 1,000 per athlete exposure and 35–44% of those injuries were to the shoulder/ upper arm.[4,5] This indicates swimming has an overall lower risk of injury compared to other sports, but a high risk for shoulder injury. In addition, one study found that competitive swimmers with a history of shoulder pain were 4.1 times more likely to have a future shoulder injury.[6]

Females are of particular interest when it comes to examining shoulder pain and disability in overhead competitive sports for three main reasons. First, in a study conducted by Sallis and colleagues, collegiate female swimmers were found to have a significant increase in reported shoulder injuries when compared to males (21.05 per 100 swimmers compared to 6.55).[7] Second, research has found that females demonstrate more generalized glenohumeral joint hypermobility than men.[4,8] Hypermobility has been described as a potential risk factor for injuries during sporting activities.[9,10] Finally, participation in female collegiate swimming has doubled over the last 20 years, indicating a steady rise in popularity.[11] Currently, there are over 500 collegiate female swim teams in the United States (U.S.) and swimming ranks seventh overall in female sport participation.[11]

Unfortunately, even with the high shoulder injury rate in competitive swimming, a clear understanding of how to prevent and treat shoulder pain in collegiate female swimmers is lacking. Several studies have investigated risk factors for shoulder pain in swimmers[2,3,6,12–15] two of which limited their investigation to the collegiate population.[2,14] Since subacromial impingement is the most common underlying condition responsible for swimmer's should pain and injury, various physical characteristics that are associated with subacromial impingement have been compared between swimmers with and without shoulder pain and injury. These factors include: scapular kinematics, internal and external rotation strength, ER/IR strength ratio, joint laxity, yardage, flexibility, shoulder range of motion, and types of training.[2,3,6,12–16] However, the results from the previous studies have been inconsistent. Beach and colleagues found no significant correlations between shoulder flexibility, strength ratios, and shoulder pain in 28 NCAA Division I swimmers and four club swimmers.[2] Based on data collected in a survey, Stocker and colleagues concluded that collegiate and master's swimmers did not subjectively report an association between shoulder pain and shoulder flexibility.[14] The authors went on to postulate that pain was perceived to increase with swim training intensity with a possible relationship between muscle fatigue and shoulder pain.[14] It is important to note that these studies were conducted over 18 years ago and both on land and in water collegiate swim training has changed drastically during this time. Additionally, the results of these studies should be interpreted cautiously due to methodological variability.

Due to these limitations and gaps in the research, the investigators sought to explore relationships between different physical measures and shoulder pain. Bak recently discussed the etiology of swimmer's shoulder related to intrinsic and extrinsic factors.[16] Intrinsic factors included: joint hypermobility, scapular dyskinesis, glenohumeral internal rotation deficit, rotator cuff imbalance, lack of flexibility/ stiffness, posture, core stability, and increased thoracic kyphosis.[16] A recent study conducted by Tate and colleagues examined several of these risk factors associated with shoulder pain and disability across the lifespan of female competitive swimmers and found potentially modifiable variables that could be used as a basis to test the effectiveness of a shoulder injury prevention program in the age groups studied. However, collegiate swimmers were not included in the study and despite the high incidence of shoulder pain in female collegiate swimmers, there is a lack of recent research on factors associated with shoulder pain and disability in female Division I swimmers.[3].

Due to the high rate of shoulder pain and disability in this cohort, it is important to discern the clinical impairments that exist in collegiate swimmers with pain and disability in order to assist with creating injury prevention and rehabilitation programs. Therefore, the purpose of this study is to examine if differences exist in shoulder Range of motion (ROM), upper extremity strength, core endurance, and pectoralis minor length in NCAA Division I female swimmers with and without shoulder pain and disability. Based on the findings of Tate et al and Bak, we hypothesize that female collegiate swimmers who report significant shoulder pain and disability will demonstrate increased shoulder ROM, decreased upper extremity strength, decreased core endurance and decreased pectoralis minor length when compared to those swimmers who do not report significant shoulder pain and disability.

METHODS

Design

A cross-sectional design was used.

Participants

The participants consisted of females from 2 NCAA Division I swim programs (n=37, age=19.5±1.19) who were at least 18 years old, currently participating in full team practices, and had no history of shoulder surgery in the past 12 months. Recruitment occurred through emails sent to NCAA Division I swim coaches who would be conducting winter training in the state of XXX. See Table 1 for demographics.

Procedures

Participants reported for a single testing session lasting 40 minutes located at a designated area near the swimming pool. All participants read and signed an informed consent form approved by the XXX Institutional Review Board. Participants completed a brief survey titled "Sports and Symptom Survey Form" used by Tate et al to capture basic demographic information about the swimmer, sport participation, and pain or shoulder symptoms.[3] (Appendix A). This survey included a subscale of the Penn Shoulder Score.[17] Pain was rated at rest, with normal activities (eating, dressing, bathing), and with strenuous activities (sports, reaching, lifting) on a numeric rating scale of 0 (no pain) to 10 (worst possible pain). Shoulder function during swimming was assessed using the Sports/Performing Arts Module of the Disabilities of the Arm, Shoulder, and Hand Outcome Measure (DASH).[18] The DASH sports module asks participants to rate 4 items (physical ability with sports technique, participation, satisfaction, and frequency) using a 5-point scale, with 1 signifying no difficulty and 5 signifying unable over the past week. Next, shoulder passive shoulder ROM, shoulder strength, core endurance, and pectoralis minor muscle length was measured by the same licensed physical therapist.

Bilateral shoulder passive ROM was measured in degrees using a digital inclinometer (The Saunders Group, Inc., Chaska, MN) in the following order: supine external rotation (ER) at 90° of abduction and supine internal rotation (IR) at 90° of abduction per Norkin.[19] Two trials of passive ROM were performed and the average was used for data analysis. Intra-tester reliability was previously established for passive ROM ($ICC_{3,1}$ 0.92 & 1.0, SEM = 0.67 & 1.54 degrees).

Bilateral shoulder peak muscle force in kilograms was measured by means of a maximal voluntary isometric contraction (MVIC) using a hand held dynamometer (Lafayette Instrument®, Lafayette, IN) and was normalized to each participant's body mass. Strength was assessed using methods described by Daniels and Worthingham for bilateral shoulder IR, shoulder ER, scapular depression and adduction and scapular adduction in a randomized order to minimize the effects of fatigue.[20] Thirty seconds rest occurred between each trial and a 1 minute rest period occurred between each testing position. Each measurement was taken twice and the average was used for data analysis. Intra-tester reliability was previously established during pilot testing for all shoulder girdle strength measures ($ICC_{3,1}$=0.72–0.99, SEM=0.80–1.35% MVIC).

Core endurance was assessed with the side bridge test[21] (Figure 1) and the prone bridge test[22] (Figure 2) used previously by Tate and colleagues.[3] Participants were asked to hold each test for as long as they could and duration was recorded in seconds. In order to assure proper technique for the core endurance tests, a 12 inch ruler was held by the tester vertically from the mat to the lowest portion of the hip. If the hip lowered, the participant was provided verbal instructions to try and resume the correct straight position. If the hip dropped a second time, the test was ended. Participants performed 1 trial of each core endurance position in a randomized order: prone, dominant side, nondominant side. Reliability of core stability related measures has been previously reported ($ICC_{2,1}$=0.74 & 0.96, SEM=8.32 & 10.29 seconds).[23]

Bilateral pectoralis minor muscle length was assessed in both a resting and stretched position using the PALM palpation meter (Performance Attainment Associates, St. Paul, MN). Pectoralis minor length was obtained by placing the PALM's caliper tips on the medial coracoid process and the 4th intercostals space adjacent to the sternum.[24] Testing positions of rest (Figure 3) and stretch (Figure 4) were selected based on previously reported methodology.[3] Normalized pectoralis minor length at rest and stretch was obtained by dividing the pectoral length by the participant's height and multiplying by 100. This normalization has been previously used by Borstad et al. and termed pectoralis minor index.[25] Reliability and validity of the PALM to measure pectoralis minor length have been previously established ($ICC_{3,1}$=0.98 & 0.99, SEM=0.32 & 0.29 cm).[24]

Statistical Analysis

Participants were divided into groups based the Penn Shoulder Score strenuous numeric rating score and a total score for swimming disability using the DASH sports module (range, 4–20, with 4 indicating no swimming disability).[3] Participants were classified as positive for pain and disability (+) if the following 2 criteria were met: 1) the DASH sports module score was greater than 6/20 points and 2) the Penn Shoulder Score strenuous numeric rating score was ≥4/10. Additionally, our groups were further categorized by whether the combination of pain and disability occurred on the dominant or nondominant arm. If these criteria were not met, participants were classified as negative. The cutoff markers were created in order to compare those with no or minimal shoulder pain and disability with those incurring substantial shoulder pain and disability. We utilized the same cutoff as Tate and colleagues for the DASH Sports module , as a score of 6 or more requires at least mild difficulty in 3 of the 4 areas surveyed.[3] However, we used a different cutoff for pain because the swimmers in our study had higher levels of pain during strenuous activity (swimming).[3] Additionally, of the 37 participants in our study, only 8 participants (21%) reported no pain (0/10) on either their dominant or nondominant shoulder with strenuous activity, whereas in Tate's cohort a greater percentage of swimmers had no reported pain (0/10) on the dominant (39%) or nondominant (47%) shoulder.[3] For the other 29 participants in our study, the responses for pain with strenuous activity varied from 1/10 to 9/10. Due to the low number of swimmers reporting 0/10 pain with strenuous activity and the high prevalence of pain in competitive swimmers, a cut-off needed to be created that emphasized a clear distinction between those with and without significant shoulder pain and disability. The Penn Shoulder Score strenuous numeric rating score has been shown to have a standard error of measurement (SEM) of 1.0 and a minimal detectable change (MDC) of 1.4.[26] Therefore, a score of ≥4/10 on the Penn Shoulder Score for pain with strenuous activity was selected to represent significant pain as it is well above the standard error of measurement, but includes 70% of the response options (4/10 – 10/10). The following 2 comparisons were made: 1) + or − for pain and disability on the dominant arm and 2) + or − for pain and disability on the nondominant arm. Means and standard deviations were calculated per group for all variables of ROM, shoulder strength, core endurance, and pectoralis minor length.

Based on previous literature and variables the authors were most interested in (pectoralis minor length and IR ROM), it was estimated that 9–16 participants (Effect Size = 0.71 and 0.94) (positive for pain and disability and negative for pain and disability) were required in each group for this study to obtain a power of 0.80.[3] A one-way analysis of variance (ANOVA) was conducted to determine if differences existed between the groups on the dominant extremity (+ for pain and disability or − for pain and disability) on each of the dependent variables of ROM, shoulder strength, core endurance, and pectoralis minor

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length. The same analysis was conducted on each dependent variable between the groups on the nondominant extremity (+ for pain and disability or − for pain and disability). SPSS® statistical software (version 19.0, SPSS Inc., Chicago, IL) was used to analyze all data. Statistical significance levels for all comparisons was set a priori of alpha = 0.05.

RESULTS

A total of 37 Division 1 female swimmers participated in this study. The number of participants grouped as + was 12 for dominant arm and 14 for nondominant arm, 8 of which were + on both the dominant and nondominant arms. Participant demographics can be seen in Table 2. The ANOVA revealed a statistically significant difference between groups (+ or −) on the dominant arm for pectoralis minor length at rest ($F_{1,35} = 10.265$, $p = 0.003$) and stretch ($F_{1,35} = 5.164$, $p = 0.029$) with significantly decreased muscle length at both rest and stretch for those + participants as shown in Table 3. No other statistically significant measures were found for the other dependent variables on either the dominant or nondominant arms. (Table 4)

DISCUSSION

This purpose of this study was to determine if differences exist in shoulder ROM, upper extremity strength, core endurance, and pectoralis minor length in Division 1 female swimmers with and without shoulder pain and disability. Our results were in partial agreement with our hypotheses and indicate that NCAA Division I female swimmers who reported shoulder pain and disability demonstrated decreased resting and stretched pectoralis minor length on their dominant arm when compared to those female swimmers who did not report significant shoulder pain and disability on their dominant arm. However, our results did not indicate a difference between strength or ROM between the two groups. This is in agreement with a study conducted by Beach and colleagues who also did not find a correlation between pain and shoulder ROM or strength in NCAA Division I swimmers.[2] It is important to note that all participants were currently competing at the NCAA Division I level during data collection, which on average required 18.8 hours of swimming each week. It is possible that individuals with impaired strength and ROM are not be able to tolerate the intense demands of such rigorous practice and hence do not compete at this elite level, but prospective studies would be needed to determine this.

Shortened pectoralis minor length has been associated with altered scapular kinematics. A change in scapular resting position has been hypothesized to decrease subacromial space due to increased anterior tilt and internal rotation of the scapula.[25] Most studies have not examined muscle length as a factor which can contribute to shoulder pain, but instead focused on overall shoulder ROM. Our observations were in partial agreement with the study conducted by Tate et al, which demonstrated that resting length of the pectoralis minor was significantly reduced in thigh school swimmers who had pain and disability. Although the Tate et al study did not include a cohort of female Division I athletes.[3]

While we are not aware of a reported clinical meaningful difference using the PALM to measure pectoralis minor length, the significant differences found in the present study on the dominant arm (0.68cm for stretch and 0.53cm for rest) are greater than the reported measurement error of 0.32cm.[24] Our findings of significant differences in pectoralis muscle length at rest and stretch on the dominant arm indicates that muscle length may play a key role in contributing to shoulder pain and disability in Division 1 female swimmers.[25] Borstad et al. reported that individuals with shortened pectoralis minor length are at a greater risk for shoulder impingement with increased exposure to elevation, force, and repetition.[25] Collegiate swimmers are exposed to each of these factors repeatedly throughout each practice and competition. Since competitive swimmers are unable to alter their exposure to shoulder elevation, force, and repetition, increasing pectoralis minor length may be an important modifiable variable that could potentially increase the subacromial space and possibly decrease risk of shoulder pain in swimmers. To date, there is limited research on pectoralis minor stretching interventions in swimmers with shoulder pain and disability using a valid and reliable clinical tool.

The term “Swimmer’s shoulder” was first coined by Neer and Welsh in 1977 to describe secondary shoulder impingement in swimmers who breathe to one side.[27] Secondary impingement is used to describe shoulder pain resulting from overuse and is typically reversible. Allegruci and colleagues further defined secondary impingement in swimmers as resulting from either “disruption of static stabilizers…or fatigue and weakness of the dynamic stabilizers”.[28] Unfortunately, this definition does not consider the impingement occurring from tightening or shortening of dynamic stabilizers. This agonist-antagonist muscle imbalance between tight pectoral muscles and elongated weak scapular muscles has been addressed in several swimming intervention studies aimed to reduce the postural abnormalities found in swimmers.[29–31] Although these studies incorporated stretching of the pectorals and scapular strengthening, none of these studies measured pectoralis minor muscle length directly with a validated technique or used an entirely female subject pool so direct comparisons to our study is not possible.

While these studies incorporated pectoral stretching in an intervention program designed to alter posture and scapular kinematics in elite swimmers, the results have been varied.[29–31] Hibberd et al found no significant scapular kinematic differences amongst the intervention and control groups. Although neither the Kluemper nor Lynch studies assessed pectoral length using the same method as in our study, both reported favorable improvements in forward shoulder translation and shoulder posture after the interventions. The latter study also reported that 79% of their intervention group had improvement in shoulder pain after the intervention program.[31] Results also showed a decrease in forward shoulder translation without differences in scapular muscle strength.[31] Forward shoulder translation, a component of posture, is believed to be caused by a muscular imbalance between a lengthened middle trapezius and a shortened pectoralis minor.[31] Therefore it could be inferred that the improvement in posture found in the Lynch et al study may be related to lengthened pectoral musculature. While a cause and effect relationship cannot be determined from their data, reduced pain ratings were also found with a pectoral stretching program. Prospective studies using direct pectoral measures may allow better understanding of the mechanism(s) responsible for the reduction in shoulder pain.

A recent study by Williams and colleagues is the first competitive swimming study to our knowledge that considers both scapular kinematics, which has been considered an indirect muscle length measurement, and direct muscle length measurement.[32] Participants were divided into either a control group, intervention group one which received a focused pectoralis minor stretch, or intervention group two which received a gross pectoral stretch.[32] There were no significant changes in scapular kinematics, but significant gains in pectoral length were found in the group who performed the gross pectoral stretch.[32] Based on these findings, it may be inferred that changes in pectoralis minor muscle length may not be detected when evaluating scapular kinematics, but can be distinguished with direct measurements of the muscle length indicating that these two methods of measurement are not equivalent. Nevertheless, more research is needed to determine the most effective method of increasing pectoralis minor muscle length and its effect on decreasing shoulder pain in competitive female swimmers.

This present study found no significant differences between upper extremity strength, core endurance, and shoulder ROM on both the dominant and nondominant arms. We found no significant difference on the nondominant arm for resting or stretched pectoralis minor muscle length. These non-significant differences could be due to the limitations within this study that include a small sample size and utilizing only two Division 1 swim teams. It is possible that some swimmers underreported their pain and were not included in the appropriate group. As Hibberd and colleagues state “Swimmers have been taught that shoulder pain is normal in the sport, and shoulder pain is often unreported until it is debilitating”.[29] We cannot exclude the fact that other factors that were not measured in this study such as joint laxity and stroke technique may contribute to shoulder pain and disability in this population. It is important to highlight that there was no preferred breathing pattern in any group and it remains unclear why those with pain and disability on the nondominant arm did not demonstrate a significant decrease in pectoralis minor length. Since this was a cross-sectional study, cause and effect is unable to be determined. Therefore, it is not known if a shortened pectoralis minor influenced shoulder pain and disability or whether pectoralis tightness emerged as a result of the shoulder pain and disability. In order to determine this relationship, future research should utilize a prospective, longitudinal design. Additional recommendations include: a larger sample size, a blinded the researcher, and a repeated pectoralis minor measure (pre and post pectoral stretching) using a valid, reliable, and standardized clinical tool, such as the PALM. This would assist with making more definitive conclusions regarding the effect of pectoral muscle length on shoulder pain in competitive swimmers.

CONCLUSION

This study found that there is a significant difference in dominant arm resting and stretched pectoralis minor muscle length between NCAA Division I female swimmers with and without shoulder pain and disability. This is the first known study to utilize a validated clinical tool to measure pectoralis minor length directly in female Division 1 swimmers with shoulder pain and disability. To better evaluate female swimmers with shoulder pain or prospectively screen these competitive athletes, rehabilitation professionals should use a direct measurement of the pectoralis minor muscle length using a valid and reliable tool, such as the PALM palpation meter. Further research is needed to explore possible interventions to lengthen the pectoralis minor muscle.

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