Range of Motion Changes in Female Elite Swimmers Throughout a Competitive Season

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ABSTRACT

Upper extremity injuries are the most common injury in swimming athletes specifically in the collegiate setting. Females in particular, are more likely to suffer these injuries when comparing to male collegiate swimmers. "Swimmer Shoulder", a generic term for overuse shoulder injuries in the swimming population occurs with high rate and intensity of training. Significant factors that have been found to contribute to this pathology are deficits in internal rotation, lack of stability, and increased demands on the shoulder. The aim for this clinical outcomes project was to evaluate changes in range of motion (ROM) total arc of the shoulder, and patient-perceived function in female elite swimmers throughout a competitive season. Shoulder total arc ROM was measured passively with the student-athlete supine. A digital inclinometer was used to make it simpler for the clinician to assess ROM on their own. The Kerlan-Jobe Orthopedic Clinic Shoulder and Elbow Score (KJOC) was used to measure self-perceived upper extremity function in sport. It consisted of a set of demographic and participation questions followed by 10 visual analogue scale questions about upper extremity function during sport. Upper extremity stability was also measured using the closed-kinetic chain upper extremity stability test (CKCUE). Results showed shoulder ROM (total arc) restrictions occurred during times of increased training intensity and volume. When patients had smaller total arc measurements, the student-athletes reported lower KJOC scores for sport related function. There was an increase in ROM at a time where intensity, and distance of training were decreased. Overall upper extremity stability gradually improved over the course of a competitive season.

Key Phrases
Clinician-rated outcome, college and university patient population, patient-reported outcomes

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INTRODUCTION

Upper extremity injuries, specifically to the shoulder, neck, and back, are the most common injury in swimming athletes specifically in the collegiate setting.[1,2] Sallis et al.[3] established that females sustained shoulder injuries three times more often and are five times more likely to sustain neck and back injuries than men. When these injuries occur, drop off in performance and participation can occur due to their debilitating nature. Factors such as technique, yardage, training, and intensity are contributing factors to such injuries. Physical factors like posture, technique, strength, and range of motion (ROM) may also contribute to higher risk of injury.[2] Intrinsically, factors like integrity of the ligaments of the shoulder girdle, core and scapular muscle control, muscle imbalances in the shoulder and scapulothoracic region and extrinsically, factors like high-level, high-intensity training in and out of the pool, sports specialties, history of injury, and age all contribute to an increased risk of injury in swimming.[2]

The shoulder joint is complex, allowing for substantial mobility, while sacrificing stability. Both the dynamic and static stability are reliant on the coordination of the rotator cuff muscle and complimentary ligaments.[4] Any movement, especially repetitive movement, requires coordination of these static and dynamic stabilizers to maintain proper joint position to avoid injuries derived from overuse. ROM abnormalities have been associated with pain, decreases in performance, and the development of shoulder pathologies.[5] "Swimmer Shoulder" is a pathology that occurs with high rate and

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intensity of training,[6] and is a generic term for shoulder overuse injuries in the swimming population.[2,3,7]

Swimming athletes have unique mechanics and movement patterns and a better understanding of dysfunction and pain within this population is needed in order to develop prevention strategies to avoid overuse injuries. We aimed to understand ROM changes and characteristics of disease through measures of ROM, upper extremity stability, and changing perceptions of function over the course of a season. Although there are many factors that could contribute, deficits in internal rotation, lack of stability, and increased demands on the shoulder have all been theorized to increase risk of injuries.[8] Also, previous research in collegiate overhead throwing athletes showed changes in rotational ROM, over the course of a season.[9] However, these changes and potential pathology that often come from excessive ROM have not been explored in swimmers. The purpose of clinical outcomes research is to describe patient- and clinician-reported outcomes measured in clinical practice. The measurements were part of clinical practice as a means of assessing various changes in student-athletes over the course of a season, to help the clinicians working with these student-athletes identify when they were at an increased risk for injury.

PATIENTS

Twenty female swimmers (age = 19 ± 1 years, height = 85.78 ± 34.26 in., weight = 123.65 ± 41.40 lbs.) from a Midwestern National Collegiate Athletic Association Division I institution were followed over the competition season. Each student-athlete was cleared to participate in sport, per department guidelines that each student-athlete is required to be seen by various medical personnel as part of a mass pre-participation screening. All student-athletes continued to be active in their sport and training regimens throughout the season, including weight lifting, conditioning, whole body musculoskeletal injury prevention, and core-focused workouts. None of the student-athletes were excluded from measurement sessions due to injuries suffered before or during the competitive season. The main objective of the outcomes assessment was to observe changes over the duration of the season; one student-athlete was excluded from statistical analysis for absence from more than two measurement sessions. Student-athletes who experienced injuries sought treatments and inventions on an individual basis with the athletic training staff. Because outcomes research is a collection of outcomes in clinical practice, interventions were not controlled.

OUTCOMES MEASURES

Measurement sessions occurred seven times over the course of the season by the same clinician. Measures were collected monthly with the sessions lasting around one hour for the whole team. We collected measurements from the start to the end of the NCAA collegiate swimming season (lasting 7 months). The first collection (September) occurred before the first official meet and the last collection (March) was after post-season competition was complete. Each collection was completed on a similar day and time each month in order to replicate the state of tissue. Many factors could not be controlled such as activity outside of sport and voluntary additional practice. The day and time chosen each week month fell on a day that the team had only a single practice session. Collection was done before the student-athletes participated in any team activities. On each measurement session day, one clinician completed glenohumeral total arc measurements and the closed-kinetic chain upper extremity stability test (CKCUES) as well as asked the student-athlete to complete the Kerlan-Jobe Orthopedic Clinic Shoulder and Elbow Score (KJOC) on a paper form.

Glenohumeral ROM

Glenohumeral ROM can be measured in a variety of ways. The use of goniometry is the gold standard for measuring joint ROM.[10] Due to the shoulder's vast mobility and wide ranges of motion, finding the correct position to measure glenohumeral motion alone can cause some difficulties. Collecting passive ROM for the shoulder in external and internal rotation can sometimes cause difficulties for a single clinician. Attempts to avoid inconsistency in student-athlete positioning can be tasking for clinicians while trying to move the shoulder through the ROM with

Figure 1. Digital Goniometer Measure of External ROM

the goniometer. A standard goniometer has two working arms that need to be positioned precisely with the body and the limb being measured in order to gather an accurate measurement. This becomes a process that can be challenging to recreate consistently. Other options for measuring ROM include digital inclinometer,[11] bubble inclinometer, and video analysis.[7] We used a digital inclinometer (Saunders Baseline Digital Inclinometer, The Saunders Group Inc, Chaska, MN) and a nylon fabric strap glued on to protective guards to attach the device to the forearm (**Figure 1**). This aided the clinician to ensure proper positioning throughout the ROM measurement. During measurement sessions, the clinician measured bilaterally for glenohumeral ROM. We calculated total arc of motion by combining measures of external ROM and internal ROM while the patient was lying in the supine position. The student-athlete was positioned in 90° of glenohumeral abduction position as shown in **Figure 1**. The practitioner passively moved the patient through the ROM and end-range ROM was decided based on the firm end-feel of the glenohumeral joint and the rise of the scapula off the table.[10]

Closed-Kinetic Chain Upper Extremity Stability Test (CKCUES)

We measured upper extremity stability with the CKCUES. The CKCUES test is an easy-to-use clinical test that has been validated on a variety of populations. It requires very little equipment and a brief commitment to complete. The student-athlete was placed in a pushup position (**Figure 2**) with their hands 36 inches apart (designated with tape on the floor), where they were asked to touch the supporting or weight-bearing hand with the unattached hand and alternate as many times as possible within 15 seconds. They completed this functional outcome measure three times for 15 seconds each.[12,13] Every touch was recorded as one toward the score for that trial. The patients completed a 45-second rest between trials. The average of the three trials are recorded as the final measure.[13] Although swimming is an open kinetic chain activity, this functional movement outcome measure mimics a number of other training activities such as dry land activities and strength programs. For healthy individuals, there is great intersession reliability.[14]

Figure 2. Starting Position for CKCUES

Kerlan-Jobe Orthopedic Clinic Shoulder and Elbow Score (KJOC)

The KJOC is a patient-rated outcome measure created for highly functioning individuals participating in sport. In comparison to other similar measures, the KJOC has less of a ceiling effect allowing for it to measure changes for higher functioning individuals.[15] Although it was originally created for throwing athletes, the wording of the questions do not address throwing directly, and is therefore applicable to all overhead athletes. The first part of the tool addresses history of injury and sport participation. The second part is a series of 10 visual analogue scale questions about current pain or dysfunction. The left side of the line represents high levels of pain or dysfunction while the right side indicates no pain or dysfunction. The tool is scored based on an average of the 10 visual analogue scale measure from 0 to 10 cm.[15] Research studies done on the KJOC in other high-level athletes demonstrate that this tool is more sensitive to athletes compared to other upper extremity patient-rated outcome tools.[16] This same study found that there was a high predictability of lower scores if the patient missed practice or game(s) in the last year.[16] The researchers also found that time of administration had no effect on the outcome.[16] No minimal clinically important difference (MCID) has been established for this tool. This was also collected at each measurement session.

RESULTS

Student-athlete demographic data was analyzed using means, standard deviations, frequencies, and percentages. Means and standard deviations were calculated for the bilateral total arc ROM, CKCUES (average of three trials), and KJOC (total score) for each month (**Table 1**). We analyzed the outcome measures using three separate repeated measures ANOVAs and significance was set a priori at <0.05.

We identified a significant main effect for time and total arc ROM in the right arm ($p<0.001$), and specifically we identified that months one, two, and five deviated more than 5° below 180° associating restriction. Months six and seven mean measures deviated 7° more than 180° suggesting possibly hypermobility. We also identified a significant main effect for time and total arc ROM in the left arm ($p<0.001$). Month one deviated 10° below 180° and month seven deviated 7° above 180° in the left arm. There was a gradual increase in CKCUES touches through the duration of the outcomes assessment ranging from an average of 13.7 touches in the first month to 20 touches in the last month ($p<0.001$). The KJOC scores indicated high levels of function among the student-athletes over the course of the competitive season (mean = 88.16 ± 3.29 points [total score possible 100 points]). Month two was significantly different compared to the other months with a mean score of 81.14 points ($p<0.001$).

Table 1. Monthly Outcome Measures

Month	KJOC	Total Arc (R)	Total Arch (L)	CKCUES
1	88.4±16.1	172.7±14.6	169.7±11.4	13.8±2.5
2	81.1±19.9	169.1±13.0	177.1±9.4	15.6±2.9*
3	88.2±12.3	180.4±14.9	178.3±12.5	17.8±1.5*
4	88.9±13.7	180.2±18.4	178.6±11.8	19.2±3.2
5	88.8±14.8	175.3±16.5	170.3±15.4	19.4±2.7
6	90.9±13.2	188.7±12.0	187.0±16.9*	19.5±2.8
7	90.7±13.5	187.6±21.9	179.4±12.6	20.5±3.5

Values are expressed in the mean ± standard deviation.
*Significantly different from previous month (*P*<.05).

DISCUSSION

The primary purpose of this outcomes assessment was to evaluate changes in passive glenohumeral total arc, closed-kinetic chain upper extremity stability, and self-perceived function over the course of a competitive season in collegiate female swimmers. Clinical outcomes research is meant to help clinician's measure patient- and clinician-rated outcome measures and to use those measures to improve their own clinical practice. Sample size and techniques to control data collection are not necessary in clinical outcomes research and were therefore not utilized here. However, based on our data, we were able to monitor patients over the course of a season and future prevention programs may be developed.

Since the reliability of goniometry measurement is varied and often hard to complete with one clinician, we chose an alternative method using a digital inclinometer. Methods of collection helped to free the hands of the clinician in order to assure proper passive ROM and to make it more clinically applicable. The intra-rater reliability of the digital inclinometer is excellent (ICC (3,k) =0.94-0.98).[18] Other ways to measure ROM of the shoulder include bubble inclinometers and emerging used of cellphone application. Advances in technology and future research on electronic goniometer could help in incorporate these measures into clinicians' practice more frequently. Changing methods are helping to ensure that measurements, especially in the shoulder, could be collected efficiently and independently.

Largely, we saw more variation on the right arm ROM than the left. Month one, two, and five had significant restrictions. Restrictions in internal rotation ROM has been connected to increased rate of internal impingement and posterior shoulder limitations.[19] Decrease of total arc greater than 25° increases the likelihood of a patient to experience an upper extremity injury by four times.[5] Another consideration when measuring total arc is humeral torsion. Posterior fibers of the rotator cuff and posterior capsule have been hypothesized to change orientation with significant humeral torsion. This can affect ROM measurements[19] because the fiber changes effect placement of the humeral head on the glenoid over time, possibly causing injury. Age also plays a factor in identifying these changes and addressing postural corrections can help aid in prevention.

The CKCUES is an easy and low-cost clinician-rated outcome measure used to assess upper extremity stability in a close-kinetic chain position. Although closed-kinetic chain is not a characteristic of the swimming motion itself, dry land training and other conditioning activities are completed in the closed-kinetic chain postures.[20] Anecdotally, patients complained of more discomfort and

strength deficits when completing closed-chain activities compared to swimming activities. In the previous study, active females, positioned in a kneeling stance, produced mean scores ranging from 27 to 31 touches. The men in the study, whose procedures matched ours, ranged from 24 to 27 touches on average.[14] The mean touch counts for the student-athletes in this outcomes assessment was well below where other active females and males have scored despite positioning.[14] A connection can be made that due to the physical adaptions in open-chain training, participating in closed-chain exercise is more difficult and therefore could possibly be a cause for injury risk or a reduction in performance. Patients showing instability or dysfunction while completing this stability test should be considered for changes in dry-land training and an assessment of these deficits before returning to previous activity status. It is evident that there could be a learned effect when completing the test so frequently. The test-retest means found by Tucci et al[14], saw increases in all populations possibly justifying a similar improvement among the student-athletes in this study. In total, the CKCUES may not be a great indicator of injury in open-chain activities but should be used to help guide closed-chain training.

The KJOC was a tool developed for specific high functioning individuals participating in sport. It has sensitivity and reliability and is thought to demonstrate more subtle changes in high functioning individuals. The student-athletes we monitored scored 88 points for all seven months with a significant decrease in month two. Measurements returned to the 88-point range after month two. Kraeutler et al.[21] reported normalized values in asymptomatic professional baseball players well above 90 points. Out of 44 players, only seven reported scores below 90.[17] Our population was significantly below the 94.8 points reported previously.[21] The differences could be attributed to the higher impact that swimming can have on upper extremity function, specifically where baseball involves the use of unilateral shoulder movement, the nature of swimming is bilateral. The sport level may also play a role in the KJOC scores.

CLINICAL APPLICATION

Overall, we observed significant increases in total arc ROM bilaterally, improved upper extremity stability, and consistent perceived function in collegiate female swimmers. Future implementations of these measurements sessions should look to correlate mileage and training intensity to determine the relationships between these changes and workload. It is very likely that the student-athletes developed a learned effect to the upper extremity stability testing and those findings may not inform clinical practice; however, student-athletes did report pain doing this test, indicating that further exploration of swimmers and this test may be necessary. Identifying risks of injury and making decisions on prevention strategies should incorporate many different factors such as ROM, stability, and self-perceived function. Similar clinician-rated outcomes research has examined rotational ROM outcomes in the baseball and softball patients[9] and patient-rated outcomes research with the KJOC scores in elite level baseball players.[9] We found similar changes in rotation ROM described, but found the student-athletes in this population scored substantially lower than elite overhead throwing athletes. Although both populations are considered overhead athletes, swimming includes bilateral use of the upper extremity while throwing utilizes unilateral workloads and the difference in mechanics may require specific considerations when developing prevention strategies.

Prevention strategies for the shoulder and upper extremity in the literature are inconsistent. Practice patterns for prevention among team-based care secondary or tertiary in nature. By conducting similar clinical outcome measures can provide information specific to the population and help to

guide changes in injury prevention on a primary level. Although these are preliminary measures to understand changes over the course of a competitive swimming season, it has described the benefits and limitations of various patient and clinician-rated outcome measures. Once more appropriate measures are identified for this population, future clinical outcomes research could be used to test prevention strategies.

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