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Original Research

Examining the link between thoracic rotation and scapular dyskinesis and shoulder pain amongst college swimmers

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ABSTRACT

Objectives: In National Collegiate Athletic Association Division I swimmers, we examined the differences in thoracic spine rotation in swimmers with and without scapular dyskinesis and the relationship between thoracic spine rotation and shoulder pain/dysfunction according to the Kerlan-Jobe Orthopaedic Clinic (KJOC) score.
Design: Cross-sectional.
Setting: Laboratory-based.
Participants: 34 NCAA Division I swimmers (13 males, 21 females).
Main outcome measures: Self-reported upper extremity function and pain assessed with the KJOC questionnaire, thoracic spine range of motion, presence of scapular dyskinesis.
Results: Dyskinesis was present in 15 of 34 (44%) subjects. Thoracic rotation averaged 136.7° and KJOC averaged 87.7 with no differences between swimmers with or without dyskinesis. We observed no correlation between KJOC-identified shoulder pain/dysfunction and thoracic rotation.
Conclusions: In our cohort of NCAA Division 1 swimmers, no differences were found between swimmers with or without scapular dyskinesis and extent of thoracic rotation. We found no correlation between thoracic rotation and the amount of self-reported pain and dysfunction experienced in the upper extremity. The presence of scapular dyskinesis in nearly half of our subjects indicates that swimmers need to be assessed for this abnormality. If observed, rehabilitation should address the dyskinesis and improve thoracic rotation in an attempt to alleviate further upper extremity pain and dysfunction.

1. Introduction

Shoulder pain is often associated with glenohumeral laxity (Chorley, Eccles, & Scurfield, 2017), instability (Bak, 1996), diminished shoulder range of motion (ROM) (Struyf et al., 2017), and scapular dyskinesis (Matzkin, Suslavich, & Wes, 2016). Amongst competitive swimmers, the shoulder is the most common location for pain or presence of musculoskeletal injury (McMaster, 1999; Struyf et al., 2017). In a cross-sectional study of 80 elite swimmers aged 13–25 years, 91% suffered shoulder pain regularly (Sein et al., 2010). Such pain can impact training as noted in McMaster and Troup's survey of age-group (13-14-year-old), developmental (15-16-year-old) and national team members. They stated that a significant proportion (that increased with age) reported that pain impeded adequate training and that the pain could restrict an athlete's ability to compete (McMaster & Troup, 1993; Russ, 1998).

Scapular dyskinesis is a term for any abnormal resting positioning and retraction/protraction of the scapula during shoulder movement (Rabin et al., 2018; Roche et al., 2015). It is broadly defined as alterations to optimal scapular kinematics (Kibler et al., 2009). It largely refers to loss of normal neuromuscular control at the scapula (Kibler et al., 2013), irregularities known to cause winging or dysrhythmia of the scapula (Maor, Ronin, & Kalichman, 2017). In this sense, winging is defined as prominence of any portion of the medial scapular border away from the thorax, while dysrhythmia refers to premature, or excessive, or stuttering motion during elevation or lowering (Kibler et al., 2009). Scapular dyskinesis affects 8.5% of young, elite swimmers mostly impacting the shoulder contralateral to the athletes' preferred breathing side

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(Preziosi Standoli et al., 2018). Studies have demonstrated that the prevalence of dyskinesis increases throughout the duration of a single training session amongst young competitive swimmers (Maor et al., 2017) and more specifically, pain-free competitive swimmers including individuals at the collegiate level, although this may be a consequence of building fatigue (Madsen et al., 2011). Scapular dyskinesis has also been implicated in the risk of developing a potentially more debilitating condition. A recent study concluded that athletes who demonstrated scapular dyskinesis were at 43% higher risk of future shoulder pain than those with typical neuromuscular control (Hickey et al., 2018). A cross-sectional study of 37 female collegiate swimmers demonstrated an association between shorter pectoralis minor muscles leading to a change in scapular positioning and increased shoulder disability and pain (Harrington, Meisel, & Tate, 2014; Struyf et al., 2017; Yesilyaprak, Yuksel, & Kalkan, 2016). With the scapula serving as the connection in the kinetic chain between lower extremities and trunk with the shoulder, it has been described as one of the fundamental elements needed to stabilize the shoulder (Kibler et al., 2013). Consequently, any disruption in scapular stabilization could very well predispose a swimmer to shoulder injury and pain (Kibler, 1998; Kibler et al., 2013).

Despite this seemingly clear association between scapular dyskinesis and pain, a causative relationship has been questioned. In the presence of asymptomatic dyskinesis in swimmers, Madsen and colleagues suggested that dyskinesis simply might not affect progression of shoulder pain, or swimmers have learned to cope with their dyskinesis and not develop pain, or any dyskinesis-related pain might have an unusually slow-onset/progression (Madsen et al., 2011).

Mobility of the thoracic spine, especially rotation, is important in swimming (Blanch, 2004; Johnson, Gauvin, & Fredericson, 2003; Micheli et al., 2014) and has also been shown to play a role in shoulder pain (Pollard & Fernandez, 2004; Walker et al., 2012). Currently, evidence indicating any direct relationship between thoracic rotation and scapular dyskinesis is lacking. Beyond a causative relationship between a kyphotic thoracic spine and scapular dyskinesis (Ferrell, 1999; Kibler et al., 2013), there is little information linking extent of thoracic mobility and rotation to presence of scapular dyskinesis in swimmers. To our knowledge, a direct relationship between the two has not been studied, specifically within the college swimmer population. Knowing the existence of a connection might be helpful when designing swim training and supplemental training to reduce or prevent shoulder dysfunction, while also slowing pain development or progression from becoming sufficiently symptomatic so as to limit training and performance.

Current literature suggests that a decrease in thoracic mobility in swimmers can exacerbate shoulder dysfunction and predispose a swimmer to shoulder pain (Sueki, Cleland, & Wainner, 2013). Studies have also shown that restrictions in thoracic spine ROM can force a larger compensatory response from both the scapulothoracic and glenohumeral joints, likely raising the probability of shoulder pain and injury (Blanch, 2004; Furness et al., 2018). To our knowledge, there are no studies demonstrating an association between thoracic mobility and shoulder pain in elite collegiate swimmers.

The purposes of this study were twofold. Firstly, we wanted to examine the relationship between thoracic spine rotation and presence of scapular dyskinesis in National Collegiate Athletic Association Division I swimmers. We hypothesized that swimmers with limitations in thoracic rotation were at increased likelihood of having scapular dyskinesis. If true, training could be adjusted accordingly to diminish the extent of dyskinesis and subsequently improve shoulder stability. Secondly, we wanted to determine if there was a relationship between thoracic spine rotation and shoulder pain/dysfunction, as measured by the Kerlan-Jobe Orthopaedic Clinic (KJOC) score in the same cohort of collegiate swimmers. The KJOC questionnaire has been shown to be reliable (Oh et al., 2017), valid (Gaudet, Begon, & Tremblay, 2019), and useful for assessing function in athletes of overhead sports (Alberta et al., 2010). We hypothesized that swimmers with limitations in thoracic rotation were more likely to experience upper extremity pain based on lower KJOC scores. If decreased thoracic rotation is implicated in the development of shoulder pain/dysfunction, measures can be taken during training to decrease risk of symptom progression and subsequently, improve a swimmer's ability to compete.

2. Methods

This descriptive, cohort study was approved by our local Institutional Review Board. All participants provided written informed consent prior to undergoing any data collection procedures. All testing was carried out by a certified athletic trainer or research assistant proficient in the study procedures.

2.1. Participants

Male and female varsity collegiate swimmers at one NCAA Division I institution were recruited for participation. All subjects were screened against the inclusion and exclusion criteria, after which those who met all criteria were enrolled in the study. Inclusion criteria were as follows: 1) swimmers ranging in ages from 18 to 26 years old, 2) currently on the roster of a varsity level college swimming team, and 3) cleared by medical personnel (certified athletic trainer, team physician, or both) for full participation in training and competition. Subjects were excluded if 1) one scapula exhibited some level of scapular dyskinesis (subtle or obvious), while the other was classified as normal (to avoid any potential confounding interactions) or 2) they suffered an injury within the four weeks prior to testing. A total of 34 NCAA Division I swimmers (13 males, 21 females) qualified for this study (Table 1).

2.2. Procedures

Each participant went through one test session of about 60 min duration within the four weeks prior to the beginning of the NCAA Division I swimming season. During each session, an upper extremity injury history questionnaire and a KJOC questionnaire were collected, and thoracic rotation ROM and scapular dyskinesis were assessed.

2.2.1. Shoulder musculoskeletal injury history

Each swimmer self-reported all shoulder musculoskeletal injuries sustained throughout his/her lifetime. If under the care of an athletic trainer at time of injury and if the swimmer's injury information was collected during a pre-participation physical, or both, the athletic trainer responsible for the swimmer's care confirmed these self-reported injuries.

2.2.2. KJOC questionnaire

The KJOC is a visual analog scale of ten questions concerning upper extremity health and function. Its validity, responsiveness and reliability in assessing overhead athletes, including swimmers, has been established (Alberta et al., 2010) (Gaudet et al., 2019). Reliability (test-retest intraclass correlation coefficient) is reported to be 0.881. Each swimmer began their session completing the KJOC by marking an “x” on a 10 cm line associated with each question. The position of the “x” on the line was a measure of the athlete's

Table 1
Means (SD) of subject demographics and clinical test results by sex and presence of dyskinesis.

Male				Female			
	with dyskinesis (n = 6)	without dyskinesis (n = 7)	overall male (n = 13)	with dyskinesis (n = 9)	without dyskinesis (n = 12)	overall female (n = 21)	Overall (N = 34)
Demographics							
Age (y)	19.7 (1.21)	20.0 (1.15)	19.8 (1.14)	19.6 (1.24)	19.4 (1.31)	19.5 (1.25)	19.6 (1.2)
Stature (cm)	183.08 (4.47)	185.03 (7.18)	184.1 (5.93)	174.46 (4.71)	171.17 (6.95)	172.58 (6.18)	177.00 (8.27)
Mass (kg)	79.38 (4.08)	82.64 (9.36)	81.1 (7.32)	71.88 (6.31)	76.24 (24.26)	74.37 (18.56)	76.96 (15.47)
Clinical resultS							
Thoracic spine ROM (°)	136.45 (17.18)	122.23 (16.60)	128.79 (17.75)	144.32 (19.40)	139.64 (22.47)	141.65 (20.83)	136.73 (20.44)
KJOC	90.40 (13.29)	95.74 (3.49)	93.28 (9.35)	80.44 (23.17)	86.99 (18.43)	84.19 (20.31)	87.66 (17.38)

ROM=range of motion; KJOC=Kerlan-Jobe Orthopaedic Clinic score

perceived current performance, function, or both at the time of testing. The further to the right the "x" was placed, the higher the swimmer's perception of their upper extremity performance and function. The sum of the distances measured for all ten KJOC questions (out of a maximum possible of 100) was the unit of analysis.

2.2.3. Scapular dyskinesis test

A refinement of Kibler's qualitative test of scapular dysfunction (Kibler et al., 2002) has been shown to be reliable and valid (McClure et al., 2009). We chose to test each swimmer at rest to avoid any potential confounding interaction with fatigue. Each swimmer was positioned standing with their back parallel to the focal plane of a video camera fixed on a tripod. A 1.4 kg weight (for athletes under 68.1 kg) or a 2.3 kg weight (for athletes over 68.1 kg) was held in each hand with the arms at their side (Fig. 1). Pilot data from another study showed that athletes with up to moderate symptoms were able to lift these respective weights through their complete ROM, repeatedly. As such, these weights were used (McClure et al., 2009). The subject was instructed to flex and abduct their upper extremity over the head and then return to the starting position five times. This motion was recorded on the video camera. Videos were assessed by an athletic trainer trained in evaluating scapular dyskinesis; both shoulders were rated separately. Each swimmer's shoulder was classified as normal (no signs of dyskinesis), subtle (if abnormalities were questionable), or obvious (visible scapular dysrhythmia, winging, or both). Swimmers rated as normal bilaterally were included in the control group. Those with any level of bilateral scapular dyskinesis (subtle or obvious) were included in the dyskinesis group.

2.2.4. Thoracic rotation ROM

Thoracic rotation was assessed with the lumbar-locked thoracic rotation test (Johnson & Grindstaff, 2010) using an AccuMASTER digital inclinometer (Calculated Industries; Carson City, Nevada). In healthy adults between 18 and 45 years of age, inter- and intratester reliability is reported to range from 0.84 to 0.95 (Furness et al., 2018; Johnson et al., 2012). Concurrent and criterion-related validity has been established (Furness et al., 2018; Bucke et al., 2017; Hwang et al., 2017). It has also been shown to be reliable in competitive swimmers aged 10–18 years old (Feijen et al., 2018). Fig. 2 presents this test. Each swimmer assumed a four-point kneeling position, sitting back on the heels. The elbows were positioned directly in front of and touching the knees, while the forearms extended straight ahead. The tester palpated the T1-T2 interspinous space and placed the digital inclinometer horizontally over this level to zero the inclinometer. The swimmer placed one hand on the back of the neck (to keep the head aligned with the rotation of the trunk) and slowly rotated the thoracic spine so that the elbow was elevated as much as possible. Throughout this motion, the inclinometer remained at the same position while the swimmer's buttocks remained the heels and without extending the lumbar spine. The amount of rotation (in degrees) was read off the inclinometer by the examiner at the peak of rotation and recorded by another individual (Feijen et al., 2018; Johnson & Grindstaff, 2010). This was repeated 3 times and the average of three trials was the unit of analysis. The test was repeated for the contralateral arm as before. If the sitting position was lost, the scapula was retracted, the lumbar spine position was lost, one or both arm positions were misplaced, or any combination, the trial was redone (Johnson et al., 2012; Johnson & Grindstaff, 2010). The sum of the ROM (right + left) was the unit of analysis.

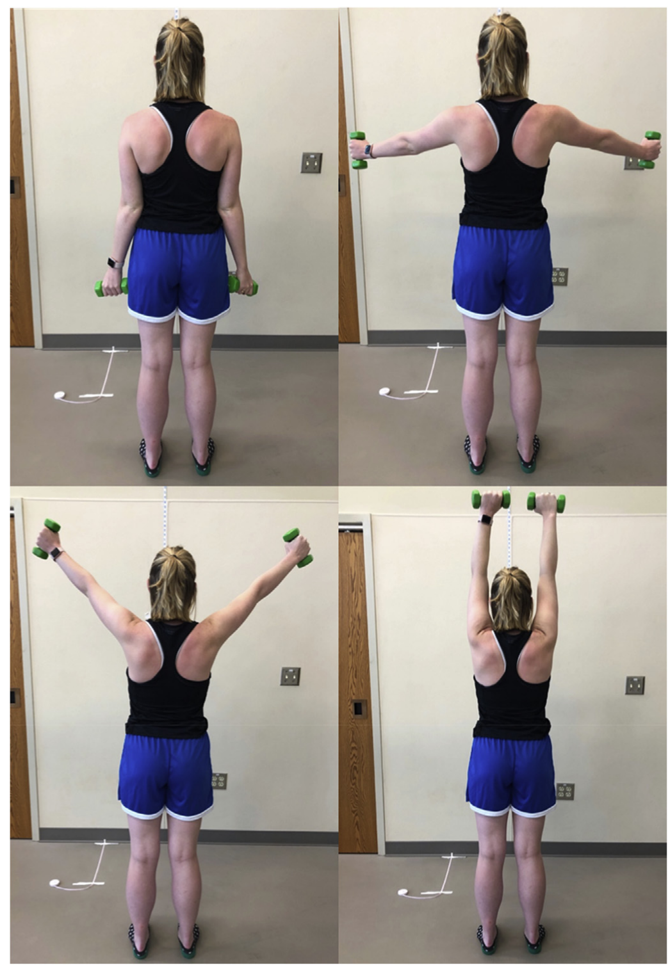

Fig. 1. Scapular dyskinesis test motion.

Fig. 2. Lumbar-locked thoracic rotation test.

2.3. Data analysis

All statistical analysis was performed using IBM SPSS 24 (IBM Corp.; Armonk, NY). Routine descriptive statistics were used to summarize subject demographics. Each variable was assessed for normality using the Shapiro-Wilk test. Group differences (with vs. without dyskinesis) were determined using independent t-tests (normally distributed variables) or Mann-Whitney U tests (non-normally distributed variables). Pearson's or Spearman's correlation were determined where appropriate. Statistical significance of <0.05 was set a priori. Individual P-values will be reported.

3. Results

Subject demographics are presented in Table 1. The mean age at testing was similar between males and females ($P = .39$). As expected, males were taller ($P < .001$) and heavier ($P = .001$) than females. Table 1 also shows the number of participants of each sex that were classified as exhibiting scapular dyskinesis; there was no difference in the presence of dyskinesis by sex. Overall, 15 subjects of the 34 swimmers (44%) presented with (subtle or obvious) bilateral scapular dyskinesis, while 19 did not have scapular dyskinesis ($P = .85$). Thoracic ROM was similar in swimmers with or without dyskinesis (141.2° and 133.3° respectively, $P = .267$; Table 1). There were no differences in KJOC scores between swimmers with or without dyskinesis (84.4 and 90.2 respectively; $P = .323$). In addition, there was no relationship between KJOC scores and total thoracic ROM overall (Spearman's $r = -0.08$) or by sex (Fig. 3a) or by presence of dyskinesis (Fig. 3b). We did notice a ceiling effect for the KJOC in our subjects (Fig. 3), with approximately 71% of our subjects scoring between 91 and 100.

4. Discussion

Given the prevalence of shoulder issues amongst swimmers (Kerr et al., 2015; McMaster, 1999; Struyf et al., 2017), we sought to determine the prevalence of scapular dyskinesis in collegiate swimmers and to see if there were relationships between thoracic rotation and presence of scapular dyskinesis and between thoracic rotation and self-reported pain. We hypothesized that swimmers with scapular dyskinesis would experience reduced thoracic rotation and that a positive correlation between thoracic rotation and KJOC scores would exist. Should greater limitations in thoracic rotation be associated with increased upper extremity pain and dysfunction (as represented by lower KJOC scores), prevention strategies should be developed. Our results, however, did not support either of these hypotheses.

Athletes who participate in overhead sports have been observed to have a higher prevalence of scapular dyskinesis than non-overhead athletes (Burn et al., 2016). Scapular dyskinesis has been identified in the setting of many shoulder injuries yet there is no consensus on the definitive effects it has on shoulder function (Kibler et al., 2013). In overhead sports such as baseball and tennis, restrictions in ROM at the glenohumeral joint have been linked to scapular dyskinesis (Burkhart, Morgan, & Kibler, 2003). Unfortunately, data linking ROM of the thorax with scapular dyskinesis in the overhead athlete, as well as in swimmers, is lacking. There is limited evidence that restricted thoracic ROM can result in asymmetry in muscle and strength due to increased compensation at the scapulothoracic and glenohumeral joints (Blanch, 2004). Given these limited observations, we anticipated that limitations in thoracic rotation would be associated with the presence of scapular dyskinesis and pain.

Prior research has suggested a link between mobility of the thoracic spine with both shoulder function and symptoms amongst swimmers and in the general population (Blanch, 2004). One study of swimmers of age groups 8–11, 12–14, and 15–19 years of age plus a group at Masters level showed that although dyskinesis was observed in all the groups, it was not more prevalent in those with shoulder pain (Tate et al., 2012). Our study is in agreement with Tate's work and adds a college-age group of swimmers (18–22 years) not previously mentioned in the literature.

Mounting evidence indicates that manipulating the thoracic spine can potentially alleviate presenting shoulder symptoms such as pain (Mintken et al., 2010; Strunce et al., 2009). One study demonstrated that treating restricted thoracic mobility with manipulative therapy resulted in a reduction in shoulder pain and improvement in shoulder ROM immediately afterwards (Strunce et al., 2009). In addition, there appears to be some evidence describing the role of the adaptation of CB-1 receptors in alleviating pain (Fine & Rosenfeld, 2013; Madden et al., 2018), which could potentially play a role in augmenting shoulder ROM. Most of the current literature, however, addresses orthopaedic issues such as spinal cord injury, multiple sclerosis etc (Hama & Sagen, 2011; Madden et al., 2018; Smith, 2004; Vaney et al., 2004). There is less available data addressing core orthopaedic conditions such as shoulder pain, back pain and the like (Madden et al., 2018). As such, more studies are needed to expand upon the role of CB-1 receptors in improving symptoms that accompany such musculoskeletal conditions (Madden et al., 2018). With this information, the prospect of identifying a link between greater limitations in thoracic

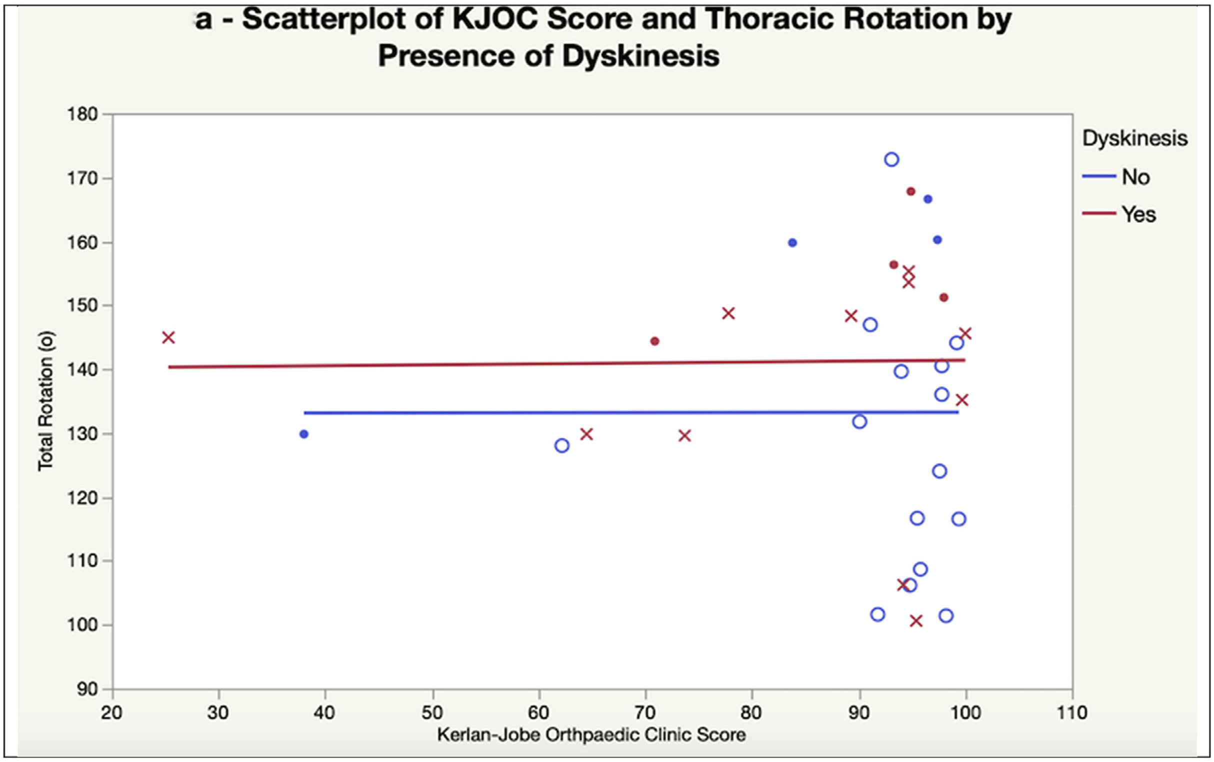

Fig. 3a. Scatterplot of KJOC score and thoracic rotation by presence of dyskinesis.

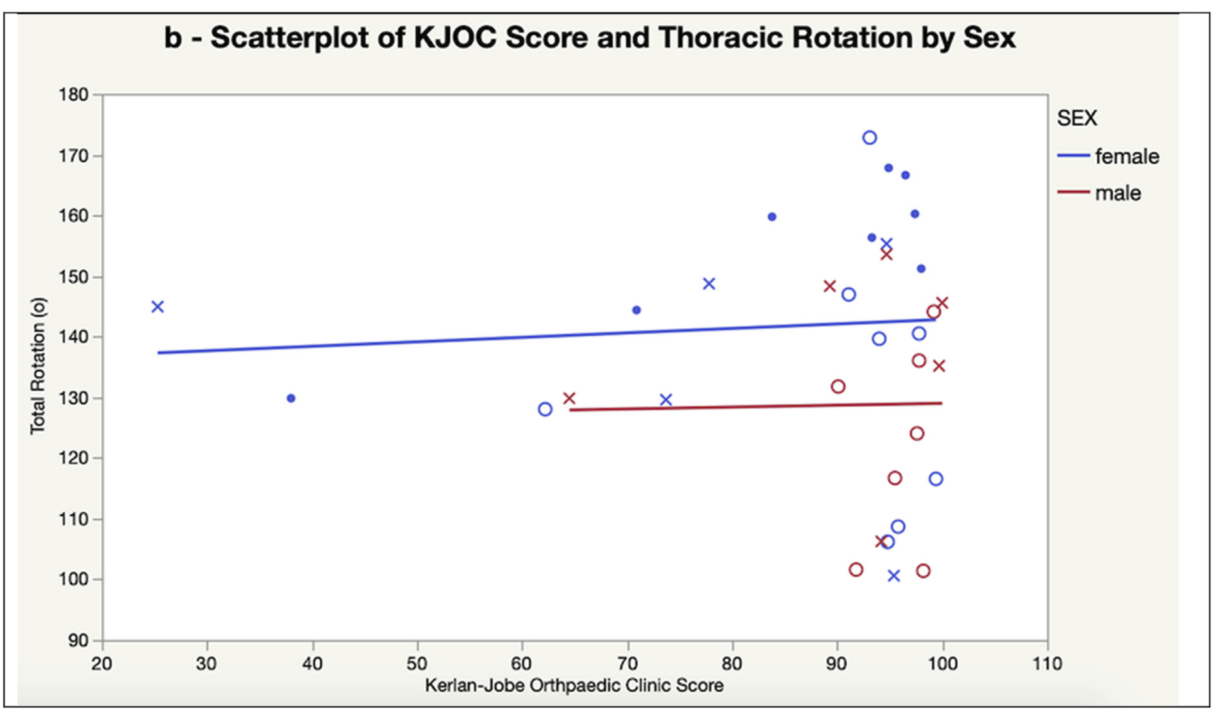

Fig. 3b. Scatterplot of KJOC score and thoracic rotation by sex.

rotation and increased upper extremity pain and dysfunction was plausible.

Subjective shoulder function of athletes participating in various overhead sports has been assessed using the KJOC. For instance, healthy professional baseball players (average of 94.82 ± 1.88) (Kraeutler et al., 2013) as well as healthy uninjured female youth softball players (average of 90.9 ± 6.2) (Holtz & O'Connor, 2018) have been studied previously and shown to exhibit high baseline function, averaging a KJOC score greater than 90. In examining baseline function amongst collegiate swimmers, one study concluded that healthy athletes in other overhead sports like baseball had higher levels of shoulder function as explained by higher baseline KJOC scores than the active swimmers, who averaged a KJOC score of 79.0 ± 18.7 (Wymore & Fronek, 2015). Additionally, these active swimmers appeared to report KJOC scores similar to injured athletes of other overhead sports (Wymore & Fronek, 2015), such as previously injured female softball pitchers (average score of 79.5 ± 13.8) (Holtz & O'Connor, 2018). Compared to uninjured active swimmers (84.4 ± 13.6) (Wymore & Fronek, 2015), our study's cohort of active college-aged swimmers recorded a higher average KJOC (87.7 ± 17.4). It should be noted that, while our subjects were all swimmers at the same institution, the afore-mentioned group of uninjured active swimmers represented five different NCAA Division 1 schools (Wymore & Fronek, 2015). Our exclusion of swimmers who had suffered an acute injury could imply that our cohort was relatively healthier. This could contribute to our greater self-reported function and lower pain.

This study is not without limitations. As all swimmers were very close in age and members of the same NCAA Division I team, our subjects might be a fairly homogeneous sample. Despite being a Division I NCAA team, it remains unclear if the training volume or performances undertaken by our swimmers is consistent with other institutions. Regardless, any results obtained from this study may not be representative of recreational swimmers and elite-level swimmers outside of the college-age range, and cannot be generalized to other demographics within the general population. Additionally, any effects of previous injury on the variables tested were not assessed in this study and could have contributed to the variance in the data obtained. Furthermore, the scapular dyskinesis test was performed while the swimmers were rested and as such, did not take into account the scapular dyskinesis expected to develop with fatigue (Madsen et al., 2011). ICCs and SEMs were not calculated for the testers assessing scapular dyskinesis and thoracic rotation. Future studies should aim to evaluate a larger number of overhead sports athletes, athletes from different expertise levels, institutions and age ranges while taking history of previous injury into account. Injuries should be specific and categorized according to severity and symptom duration. Additionally, details on training characteristics at time of test such as volume of training, tapers, and championships should be considered. Testing swimmers both pre- and post-season could provide more insight into changes as the season progresses.

5. Conclusion

For a cohort of elite, college-aged swimmers, we found no relationship between presence of scapular dyskinesis and extent of thoracic rotation. Furthermore, we also found no correlation between thoracic rotation and amount of KJOC-based self-reported pain and dysfunction experienced in the upper extremity. Given the ceiling effect we observed, it is possible that the KJOC was unable to accurately discriminate pain and dysfunction amongst those swimmers in this particular cohort with the highest KJOC scores. Nevertheless, these findings do not suggest the absence of any relationships or correlations among swimmers. That a link was not demonstrated should not be an endorsement to not assess scapular dyskinesis in swimmers. The presence of scapular dyskinesis in elite swimmers should still be assessed, and, if observed, supplemental training should address the dyskinesis and improve overall shoulder mechanics in order to alleviate any possible upper extremity pain and dysfunction (Kibler, 1998; Kibler et al., 2013). Early detection of scapular dyskinesis in the asymptomatic swimmer could allow for earlier intervention to prevent progression to shoulder pain and dysfunction (Preziosi Standoli et al., 2018).

Conflicts of interest

The authors declare no potential conflicts of interest.

Ethical statements

This descriptive, cohort study was approved by our local Institutional Review Board.

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Appendix A. Supplementary data

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