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Original research

Influence of pectoralis minor and upper trapezius lengths on observable scapular dyskinesis☆

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Objectives: Although a relationship between short pectoralis minor and upper trapezius and scapular dyskinesis has been postulated, no studies have investigated this theory. Understanding the effect of these muscle lengths on observable scapular dyskinesis may aid in determining risks and therefore making treatment decisions. Being aware of the magnitude of this effect would help gauge the significance of risks involved. Our aim was to evaluate the influence of pectoralis minor and upper trapezius lengths on scapular dyskinesis.
Design: Cross-sectional study.
Setting: University research laboratory.
Participants: Asymptomatic participants ($n = 148$; 296 arms) were evaluated.
Main outcome measures: Scapular Dyskinesis Test (SDT) was used to identify scapular dyskinesis, Pectoralis Minor Index (PMI) and Upper Trapezius Length Testing were used to determine muscle length.
Results: SDT+ arms had shorter pectoralis minor resting length (PMI: 7.49 ± 0.38) ($p < 0.001$) and greater incidence of short upper trapezius (ISUT) (66.7%) ($p < 0.001$) compared to SDT- arms (PMI:8.58 ± 0.75, ISUT:22.5%). With each decrease in PMI, the likelihood of having scapular dyskinesis increased 96% ($p < 0.001$). Arms with short upper trapezius were 2.049 times more likely to exhibit scapular dyskinesis than those with normal length ($p = 0.042$).
Conclusions: Having a shorter pectoralis minor and upper trapezius length substantially increased the likelihood of having visually observable scapular dyskinesis.

1. Introduction

Proper positioning and movement of the scapula on the thorax is crucial for effective shoulder position, motion, stability and muscle performance. The scapula plays several important roles for normal shoulder function. These include forming a link between the humerus and axial skeleton and serving as an attachment site for the rotator cuff and scapulothoracic muscles. Coordinated movement of the scapula and humerus, known as scapulohumeral rhythm, is needed during upper extremity movements (Cools, Struyf, De Mey, Maenhout, Castelein, & Cagnie, 2014; Kibler & Sciascia, 2010; Kibler, Ludewig, McClure, Michener, Bak, & Sciascia, 2013). In individuals without shoulder pain or dysfunction, the scapula upwardly rotates, tilts posteriorly and rotates internally or externally during humeral elevation, whereas decreased upward rotation and posterior tilting, and increased internal rotation has been found in those with shoulder impingement (Borstad & Ludewig, 2005; Forthomme, Crielaard, & Croisier, 2008; Ludewig & Reynolds, 2009; Lukasiewicz, McClure, Michener, Pratt, & Sennett, 1999).

Alterations in scapular kinematics such as changes in the normal position or any abnormal motion pattern of the scapula during active motions have been termed "*scapular dyskinesis*" (Kibler et al., 2013). This impairment may be related to changes in bony posture or injury, muscle weakness/imbalances, muscle inflexibility (shortness/tightness) or pain (Cools et al., 2014; Kibler & McMullen,

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☆ The study protocol was approved by the Dokuz Eylul University Ethics Committee. The authors certify that they have no affiliations with or financial involvement in any organization or entity with a direct financial interest in the subject matter or materials discussed in the article.

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2003; Kibler & Sciascia, 2010; Kibler, Sciascia, & Wilkes, 2012; Kibler et al., 2013; Ludewig & Reynolds, 2009; Manske, Reiman, & Stovak, 2004). Muscle inflexibility specifically has been theorized to play an important role in scapular motion, as it can influence both the position and movement patterns of the scapula. Individuals with short pectoralis minor have demonstrated altered scapular kinematics similar to those with subacromial impingement (Borstad & Ludewig, 2005). Recent research has demonstrated a negative relationship between pectoralis minor length and scapular dyskinesis based on biomechanical measures (Cools et al., 2014; Forthomme et al., 2008; Kibler & Sciascia, 2010; Kibler et al., 2013; Ludewig & Reynolds, 2009). However, to date there have been no studies into the influence of pectoralis minor and upper trapezius lengths on scapular dyskinesis determined by visual observation nor have the direction and magnitude of this effect been investigated. Short pectoralis minor and upper trapezius can restrict normal scapular movement, resulting in a more anteriorly tilted, protracted, internally rotated and elevated scapula during arm elevation (Borstad & Ludewig, 2005; Ellenbecker & Cools, 2010; Kibler et al., 2013; Ludewig & Reynolds, 2009). This can narrow the subacromial space, leading to shoulder impingement (Borstad & Ludewig, 2005). Short muscles can also be associated with decreased muscle activity of the lower stabilizers of the scapula (serratus anterior and lower trapezius muscles) (Falla, Farina, & Graven-Nielsen, 2007; Kibler et al., 2013, 2012; Manske et al., 2004). Whether the change in these muscles' behavior is a contributor to scapular dysfunction or a compensatory response to other weakened axioscapular muscles to stabilize the scapula during upper extremity functions is not clear (Borstad & Ludewig, 2006; Ludewig & Cook, 2000; Zakharova-Luneva, Jull, Johnston, & O'Leary, 2012).

Previous authors have indicated that scapular dyskinesis is associated with common shoulder problems such as subacromial impingement or instability (Kibler & McMullen, 2003; Ludewig & Cook, 2000; Ludewig & Reynolds, 2009; Warner, Micheli, Arslanian, Kennedy, & Kennedy, 1992). Therefore, evaluation of the influence of pectoralis minor muscle and upper trapezius muscle lengths on scapular dyskinesis, is warranted to help us facilitate possible treatment for these subjects. Understanding the direction and magnitude of this effect may facilitate assessment and treatment decision-making for scapular dyskinesis cases (Kibler et al., 2012).

The aim of this study was to evaluate the influence of pectoralis minor and upper trapezius lengths on visually observable scapular dyskinesis in an asymptomatic population, essentially with investigating the question of to what extent are possible predictors for this case.

It was hypothesized that a decrease in pectoralis minor resting length would be associated with an increase in the likelihood of exhibiting scapular dyskinesis and that individuals with short upper trapezius would be more likely to exhibit scapular dyskinesis than those with normal trapezius flexibility. Additionally, we hypothesized that arms with a positive SDT as compared to those with a negative SDT would have a shorter pectoralis minor, and greater incidence of short upper trapezius.

2. Materials and methods

2.1. Participants

In this cross-sectional study, 148 participants (58 female, 90 male; mean age ± SD: 23.34 ± 3.94 years; mean body mass index [BMI] ± SD:22.93 ± 3.10 kg/m^2; 296 arms) were recruited via announcements made in Dokuz Eylül University building during January–July 2013. Inclusion criteria: 1. ≥18 years old; 2. did not participate in regular sporting activity, exercise program, or work requiring overhead movements; 3. Turkish-speaking with the ability to understand the nature of the study and provide informed consent; 4. had full range of active shoulder elevation. Participants were not accepted if they had a medical history of systemic connective tissue, orthopaedic or neurologic disease; pain or limitation in cervical spine range of motion; shoulder pain in the 6 months prior to the study; or history of scapula, clavicle or humerus fracture or surgery. Participants were also excluded if they had more than 50% range of motion loss in ≥2 planes of shoulder motion, rotator cuff tendinopathy, shoulder instability, full-thickness rotator cuff tear or any other known shoulder pathology (Fig. 1).

After questioning of any known shoulder and/or cervical region problem, one of our researchers (a physical therapist with over 10 years of clinical experience in musculoskeletal physical therapy) performed further tests. Pain or limitation in cervical spine range of motion was checked. Rotator cuff disease evaluation was done by impingement tests (Neer's test, Hawkins–Kennedy test), evaluation of painful arc during active arm elevation, pain or weakness with resisted isometric external rotation, internal rotation or scapular plane abduction with humeral internal rotation (Jobe-Empty can test). Rotator cuff tear was evaluated in case of weakness of the rotator cuff muscles, then drop arm test and lag sign test were used to reveal if the rotator cuff was ruptured or intact. Sulcus Sign at 0 degrees were used to determine multidirectional instability/inferior laxity. Anterior apprehension test was used to test anterior shoulder instability, posterior apprehension for posterior instability. In the case of a positive test the tester proceeded to the relocation test. In the case of a positive test or suspicious results from any of these tests mentioned above, the participant was referred to an orthopaedic surgeon. The orthopaedic surgeon confirmed our results and we excluded three participants for rotator cuff tendinopathy and one for shoulder instability.

The study was carried out in accordance with the policies and procedures of the Declaration of Helsinki, and it was approved by the Dokuz Eylül University Ethics Committee. All participants gave written informed consent to participate voluntarily and participant anonymity was preserved.

Prior to initiating the study, a power analysis for logistic regression analysis to determine sample size was computed (Faul, Erdfelder, Lang, & Buchner, 2007). We considered a model with two predictors and as there was no previous study that had similar

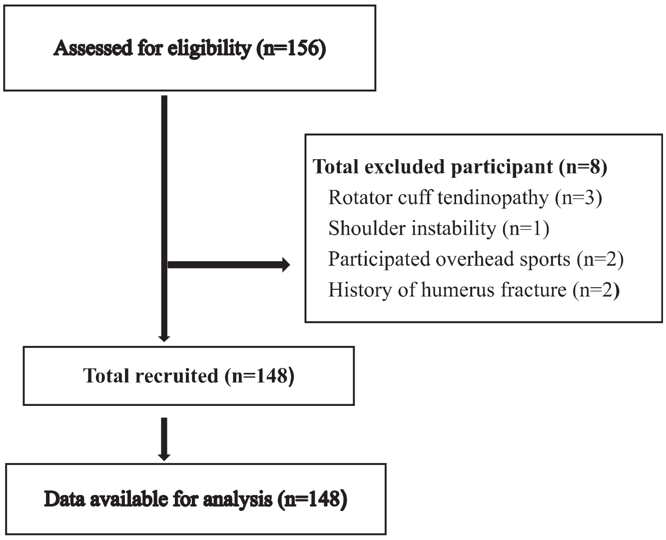

Fig. 1. Diagram of enrolment and flow chart of study protocol.

design to ours we assumed that the event rate under H_0 was $p_1 = 0.5$ and that the event rate under H_1 was $p_2 = 0.6$. The odds ratio (OR) was then OR = 1.5. We estimated that the squared multiple correlation between the covariates to be $R^2 = 0$. A sample size of 208 arms was calculated to be necessary in a two-sided test with $\alpha = 0.05$ and a statistical power of at least 0.80.

2.2. Procedures for data collection

Participants' height and weight were measured and recorded. BMI was calculated (BMI = weight (kg))/(height squared (m^2)). To ensure blindness and limit bias, different examiners conducted the Scapular Dyskinesis Test and pectoralis minor and upper trapezius length measurements, and the order of the assessments was randomized.

2.2.1. Scapular Dyskinesis Test (SDT)

SDT is a reliable and valid dynamic assessment method which is visually based and clinically feasible (Kibler et al., 2013; McClure, Tate, Kareha, Irwin, & Zlupko, 2009; Tate, McClure, Kareha, Irwin, & Barbe, 2009). Inter-rater reliability of SDT with live rating has moderate to substantial agreement (80–81%) and a weighted kappa ranging from 0.55 to 0.58 (McClure et al., 2009), indicating relatively higher reliability than other dynamic tests (Kibler, Uhl, Maddux, Brooks, Zeller, & McMullen, 2002; Uhl, Kibler, Gecewich, & Tripp, 2009). Our examiner (a physical therapist with over 2 years of clinical experience in musculoskeletal physical therapy and over 1 year of experience in performing SDT) underwent standardized web-based SDT training recommended by McClure et al. (2009) (http://www.arcadia.edu/academic/default.aspx?id515080). Intra-rater test–retest reliability of this method was calculated from pilot data collected from forty arms and showed nearly perfect agreement: kappa = 0.90 ($p < 0.001$), standard error = 0.69, 95% CI (0.764, 1.034). In the pilot study, a sub-sample randomly selected from our participants was assessed for the second time. Random number generator (0–1) was used for randomization to include (1) or exclude (0) the participant to the re-test subgroup.

Males were asked to remove their shirts and females wore halter-tops during the assessment to allow observation of the posterior thorax. The examiner explained and demonstrated the movements for bilateral, active, weighted shoulder a. flexion, and b. abduction (frontal plane) used during the test. Then the participants were instructed to practice each movement. Testing began with participants' arms at the side of the body, elbows straight, shoulders in neutral rotation, and in thumbs up position; the examiner observed from behind at a distance of two to three meters from the participant. Participants held dumbbells during the tests according to their body weight: 1.4 kg if the participant's weight was <68.1 kg and 2.3 kg if the participant's weight was ≥68.1 kg.

The written operational definitions and rating scale was used to categorize the test results (McClure et al., 2009). During the SDT, scapular motion was observed for dysrhythmia and winging over five repetitions of weighted shoulder flexion and abduction. Dysrhythmia was noted if the scapula demonstrated premature, excessive, or stuttering motion during elevation and lowering, or rapid downward rotation during arm lowering. Winging was noted if any portion of the medial border and/or inferior angle of the scapula were posteriorly displaced away from the thorax. According to the results of the SDT either in flexion or abduction, scapular motion was rated as 1. *normal* if there was no evidence of abnormality; 2. *subtle abnormality* if there was mild or questionable evidence of abnormality occurs and dyskinesis was not consistently present during the trials; or 3. *obvious abnormality* if there was striking, clearly apparent abnormality, evident on at least 3 of the 5 trials (dysrhythmia or winging of ≥2.54 cm displacement of scapula from thorax). Final rating was performed based on combined test movements of flexion and abduction. Final test results were 1. *normal* – both test motions were rated as normal or one motion was rated as normal and the other as having subtle abnormality; 2. Subtle abnormality – both flexion and abduction were rated as having subtle abnormalities; or 3. Obvious abnormality – either flexion or abduction was rated as having obvious abnormality.

Tate et al. found a strong correlation between SDT assessments of obvious abnormality and scapular kinematic abnormalities measured by three-dimensional electromagnetic kinematics analysis (Tate et al., 2009). Therefore, the test results were categorized as SDT+ for those classified with obvious dyskinesis and SDT- for those classified as normal or subtle dyskinesis (Fig. 2).

2.2.2. Measurement of pectoralis minor resting length

Measurement of the resting length of the pectoralis minor was performed with a cloth tape measure using the coracoid process and fourth rib near the sternum as palpable landmarks. The validity of these landmarks and reliability of using a cloth tape measure for the measurement have been previously reported (intraclass correlation coefficient [ICC] ranges between 0.82 to 0.86) (Borstad, 2008).

Participants were asked to stand in their normal, relaxed posture, arms resting at the side, and looking straight ahead during data collection. The fourth rib landmark was palpated at the anterior-inferior edge of the rib, one finger width lateral to the sternum. The examiner initially located the inferomedial aspect of the first rib at the sternum distal to the medial clavicle, then counted down to the fourth rib. The coracoid process landmark was located at its medial-inferior aspect by palpating below the lateral concavity of the clavicle in the deltopectoral groove. Two measurements of the length between the coracoid process and fourth rib landmarks were taken and the average was recorded. Pectoralis minor length index (PMI) was used to normalize our measurements to the participant's height to determine the relative length of pectoralis minor. PMI was calculated by dividing the resting length (cm) by subject height (cm), and multiplying by 100 (Borstad, 2008; Borstad & Ludewig, 2005). Intra-rater test–retest reliability of this method calculated from pilot data collected from forty arms of the aforementioned sub-sample group revealed excellent reliability ($ICC_{3,2} = 0.92$; $SEM_{90} = 0.32$; $MDC_{90} = 0.45$) (Fig. 3).

2.2.3. Upper trapezius length testing

Testing of upper trapezius length was composed of two parts. First, the participant was seated on a stool without a backrest, feet flat on the floor, neutral trunk posture, head straight and facing forward, and arms resting at the side. The examiner stood behind the participant, laterally flexed the participant's neck away from the side being tested, and rotated the head towards the ipsilateral side while controlling the ipsilateral shoulder. Secondly, the examiner lifted the ipsilateral extremity by grasping the forearm under the elbow while the elbow was at approximately 90° flexion and pronated. The test result was positive and recorded as "short" if visually observable further motion of the head occurred after lifting the upper extremity, as lifting the arm places the upper trapezius on slack and allows further motion if the trapezius is the cause of limited motion (Manske et al., 2004). Intra-rater test–retest reliability of this method calculated from pilot data collected from forty arms revealed substantial agreement: Kappa = 0.72 ($p < 0.001$), Standard error = 0.114, 95% CI (0.498, 0.945) (Fig. 4).

2.3. Data analysis

Continuous data were evaluated for normal distribution with the Kolmogorov-Smirnov test with the Lilliefors Significance

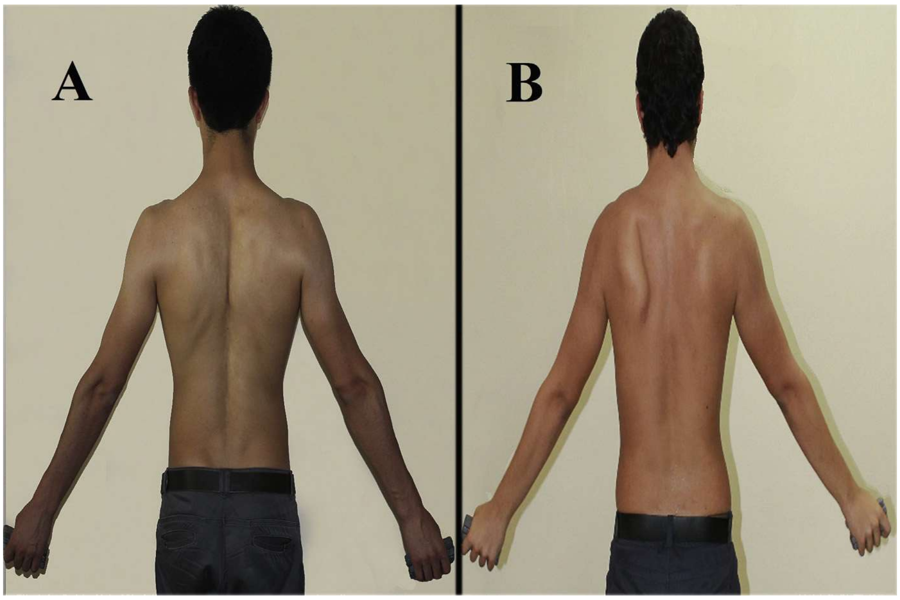

Fig. 2. **A**. The scapular motion pattern was classified as “normal”. **B**. The scapular motion pattern was classified as “obvious dyskinesis” on the left, and “subtle dyskinesis” on the right.

Correction. Data are expressed as mean values followed by standard deviation or percentages as appropriate. Logistic regression analysis was performed to ascertain the effects of pectoralis minor resting length and upper trapezius length on the likelihood that participants had scapular dyskinesis. Before commencing regression analysis, differences in PMI values in SDT+ and SDT- arms were compared using independent t-tests. Chi-square test was used to determine a possible relationship between SDT results and upper trapezius length. Results of these analyses were significant and these predictors were included the model. The software package SPSS 20.0 for Windows was used for statistical analysis (IBM SPSS Inc., Chicago, IL, USA). Statistical significance was set at $p<0.05$.

3. Results

Among the study participants, scapular dyskinesis was identified in 29.4% (87/296) of the arms and short upper trapezius in 35.5% (105/296) of the arms. Mean PMI in arms with positive SDT was lower compared to those with negative SDT ($p < 0.05$). Upper trapezius shortness was seen more often in arms with scapular dyskinesis than in arms without scapular dyskinesis ($p < 0.05$). Descriptive information for pectoralis minor and upper trapezius lengths of the participants are reported in Table 1.

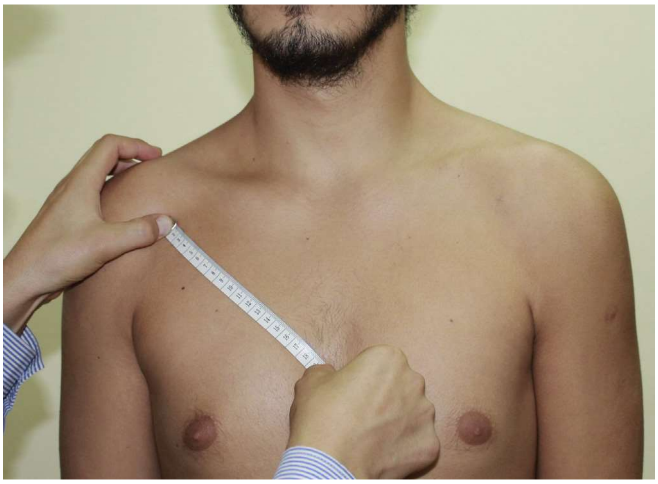

Fig. 3. Measurement of pectoralis minor resting length.

The logistic regression model was statistically significant, $\chi 2 = 155.747$; $p < 0.001$; $df = 2$. The model explained 58.3% (Nagelkerke R^2) of the variance in scapular dyskinesis and correctly classified 84.1% of cases. The Wald criterion demonstrated that both PMI and upper trapezius length made a significant contribution to prediction ($p < 0.001$ and $p = 0.042$, respectively). Increasing PMI was associated with a reduction in the likelihood of exhibiting scapular dyskinesis. For each point increase in PMI, the odds of having scapular dyskinesis decreases 96% (from 1.0 to 0.041). Arms with short upper trapezius were 2.049 times more likely to exhibit scapular dyskinesis than arms with normal upper trapezius length (Table 2).

4. Discussion

Soft tissue shortness is one of the potential contributing mechanisms to abnormal scapular motions (Forthomme et al., 2008; Ludewig & Reynolds, 2009). Our hypothesis was that a decrease in pectoralis minor and upper trapezius lengths would be associated with an increase in the likelihood of exhibiting scapular dyskinesis and our results supported this hypothesis. The shorter the pectoralis minor, the more likely the arm was to have scapular dyskinesis. With each decrease in PMI, the likelihood of having scapular dyskinesis increased by 96%. The likelihood of an individual with short upper trapezius exhibiting scapular dyskinesis was twice that of individuals who had normal upper trapezius length.

The pectoralis minor, based on its attachments from the medial border of the coracoid process to the third through fifth ribs, produces scapular internal rotation, downward rotation, and anterior tilt. It is passively lengthened during the active scapular upward rotation, external rotation, and posterior tilting that occurs with arm elevation in healthy individuals (Ludewig & Cook, 2000). Therefore, excess tension in this muscle could resist these normal

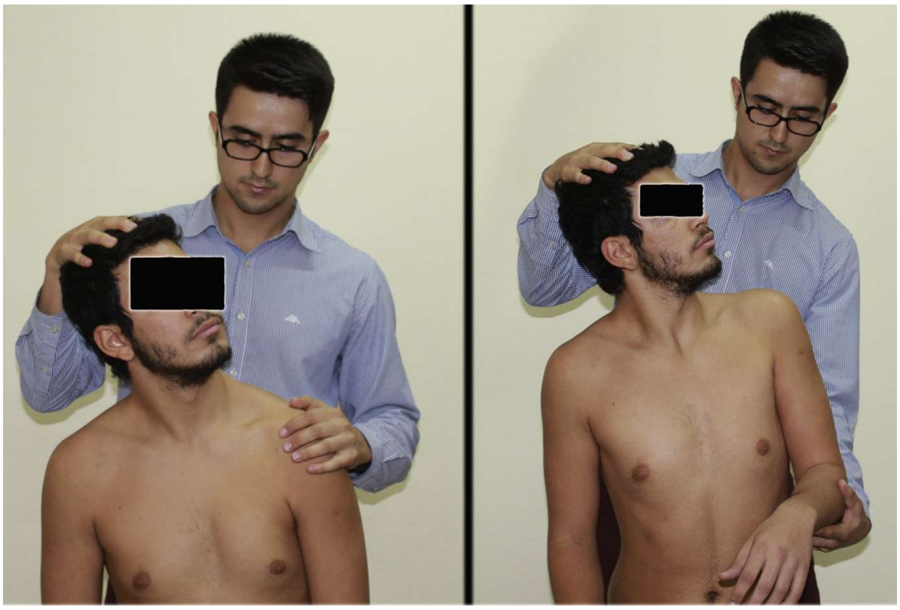

Fig. 4. Upper trapezius length testing.

scapulothoracic motions (Forthomme et al., 2008; Phadke, Camargo, & Ludewig, 2009). In this study participants with obvious dyskinesis categorized as SDT+ had shorter pectoralis minor resting length compared to those categorized as SDT-. Likewise, Borstad and Ludewig compared short versus long pectoralis minor resting length and assessed scapular motions during arm elevation similar to the nature of the SDT (Borstad & Ludewig, 2005). They found that people with shorter pectoralis minor had significantly less scapular posterior tilt and greater scapular internal rotation during arm elevation. They suggested that compared to a relatively longer muscle, the shortened pectoralis minor demonstrated increased passive tension as a result of adaptations such as loss of sarcomeres in series, increased proportions of connective tissue, and loss of passive range of motion. This increase in passive tension as the muscle lengthens during arm elevation might limit motion of the scapulothoracic joint. In contrast, the scapula of individuals with longer pectoralis minor length became further posteriorly tilted at higher arm elevation angles (Borstad & Ludewig, 2005). This can help maintain an open subacromial space, preventing potential soft tissue compression and injury. Similarly, we showed that with each increase in pectoralis minor resting length, the likelihood of having observable scapular dyskinesis decreases 96%. Even though there could be a number of contributing factors to abnormal scapular motions, such as decreased activity of the serratus anterior and/or lower trapezius, which are lower stabilizers of the scapula (Falla et al., 2007; Kibler et al., 2013, 2012) it is a fair assumption that scapular dyskinesis may be improved or prevented through proper interventions to increase muscle length.

Table 1
Pectoralis minor resting length mean ± standard deviations and upper trapezius length (n = 296 arms).

Variables	SDT (+) (n = 87)	SDT (−) (n = 209)	p
PMRL (cm)	12.86 ± 1.04	14.80 ± 1.42	<0.001*
PMI	7.49 ± 0.38	8.58 ± 0.75	<0.001*
Upper trapezius length	58 Short (66.7%) 29 Normal (33.3%)	47 Short (22.5%) 162 Normal (77.5%)	<0.001†

SDT: Scapular dyskinesis test, PMRL: Pectoralis minor resting length, PMI: Pectoralis minor index.
* Indicates statistical significance with independent t test comparisons, p<0.05.
† Indicates statistical significance with Chi-square test, $\chi 2 = 52.379$, p<0.05.

Another possible reason for the association found between muscle shortness and scapular dyskinesis could be due to decreased activity of the serratus anterior and/or lower trapezius (Falla et al., 2007; Kibler et al., 2013, 2012). This is speculation of the mechanism according to findings in the literature, as muscle strength was not assessed in this study. This speculation is supported by Thigpen et al., who found that individuals with forward head and rounded shoulder posture (FHRSP) display greater scapular internal rotation, anterior tilt and less serratus anterior activity during arm elevation in the sagittal plane and during overhead reaching tasks, likely due to shorter pectoralis minor length (Thigpen et al., 2010). We found that short upper trapezius was seen more in arms with observable scapular dyskinesis than in arms without or subtle observable abnormality. Regression analysis revealed that individuals with upper trapezius shortness were 2.049 times more likely to exhibit scapular dyskinesis than people who had normal upper trapezius length. Several alterations in muscle activity and scapular motions have been reported in patients with shoulder impingement, including decreased serratus anterior muscle activation, greater upper trapezius activation, less scapular upward rotation and posterior tilt (Lin et al., 2005; Ludewig & Cook, 2000) and more scapular elevation. There is similarity between these alterations and those found in individuals with short pectoralis minor (Zakharova-Luneva et al., 2012). Therefore, the effect of short upper trapezius on scapular motions might be two-fold. Upper trapezius shortness: 1. may be related to lesser serratus activation, leading to lesser posterior tilt and upward rotation (Cools et al., 2014; Forthomme et al., 2008; Ludewig & Reynolds, 2009); 2. may increase elevation of the scapula through greater clavicular elevation, leading to more anterior tilt (Ludewig & Reynolds, 2009; Phadke et al., 2009). Researchers have found lower amounts of serratus activation and/or greater upper trapezius activation in different patient populations (sedentary individuals as well as athletes) with shoulder problems (Falla et al., 2007; Ludewig & Cook, 2000; Lin et al., 2005; Phadke et al., 2009). Our findings warrant further study to determine the

Table 2
Logistic regression analysis for variables predicting scapular dyskinesis ($n = 296$ arms).

Variables	β	S.E.	Wald	OR	95% CI for OR	p
PMI	−3.182	0.447	50.741	0.041	0.017, 0.100	<0.001*
Upper trapezius length	0.717	0.353	4.124	2.049	1.025, 4.094	0.042*

This model's correct classification rate = 84.1%. Upper trapezius length is a categorical variable and short muscle was coded as 1.
β: Regression coefficient, S.E.: Standard error, OR: odds ratio, CI: confidence interval, PMI: Pectoralis minor index.
* Indicates statistical significance: $p<0.05$.

interaction between these muscle lengths, scapular dyskinesis and scapular muscle activity.

Although the literature indicates a possible relationship between shortness of pectoralis minor or upper trapezius and scapular motion alterations (Kibler & Sciascia, 2010; Kibler et al., 2013; Kibler et al., 2012; Ludewig & Reynolds, 2009; Manske et al., 2004), few studies have investigated the effect of a short pectoralis minor on these alterations and there is no research concerning the role of upper trapezius length. In a study comparing the effects of long versus short pectoralis minor resting length on scapular kinematics, healthy individuals were categorized as having relatively short or long muscle length and their scapular motions were compared using an electromagnetic motion capture system. Individuals with a relatively short pectoralis minor resting length demonstrated scapular kinematic patterns similar to patterns seen in shoulder impingement (Borstad & Ludewig, 2005). To the best of our knowledge, the present study is the first to examine the influence of pectoralis minor and upper trapezius length on scapular dyskinesis, and to determine the direction and magnitude of this effect using regression analysis. Our analysis showed that having shorter pectoralis minor and upper trapezius length appears to be a very significant risk for having observable scapular dyskinesis. However, it should be kept in mind that the Upper Trapezius Length Testing has not been validated previously rather than our pilot testing. Since one of our exclusion criteria was "pain or limitation in cervical spine range of motion", we can assume that limitation in cervical region didn't play a significant role in results. Additionally, it can be argued that this test in part might also be influenced by other neck rotators likely by the levator scapulae length since both upper trapezius and levator scapulae can be stretched with flexion-lateral flexion and rotation. However; upper trapezius is stretched with more lateral flexion while the head is turned towards ipsilateral side whereas levator is stretched with more neck flexion while the head is turned towards the opposite side (Kendall, McCreary, Provance, Rodgers, & Romani, 2005).

Scapular motion alterations occur in 68–100% of patients with shoulder injuries (Kibler & McMullen, 2003). Greater scapular internal rotation and anterior tilt during arm elevation due to short pectoralis minor length (Borstad & Ludewig, 2005) and scapular elevation resulting from short upper trapezius (Kibler et al., 2013) can narrow the subacromial space, impinge the soft tissues and create an environment leading to pathology/injury (Borstad & Ludewig, 2005). Additionally, the kinetic chain may be interrupted as the unstable scapula aberrantly transmits excessive forces generated from the ground through the lower extremities and torso to the vulnerable shoulder (Forthomme et al., 2008; Kibler et al., 2013). Determination of the shortness of these muscles as a routine part of the scapular examination seems highly important to avoid scapular dyskinesis and related future shoulder injuries. Future studies should follow-up for resultant pathologies.

It may be also helpful for treatment decision-making for those with shoulder problems including visually confirmed scapular dyskinesis. Although this study did not evaluate changes in scapular dyskinesis after interventions for shortness of the two muscles, we speculate that the majority of shoulder pathologies may be improved if scapular dyskinesis and soft tissue shortness can be evaluated and improved. Whether scapular dyskinesis may be altered by proper interventions to increase muscle length is not clear (McClure, Bialker, Neff, Williams, & Karduna, 2004). The usefulness of these methods as a part of the overall treatment program of shoulder dysfunction with scapular motion problems and especially the usefulness of these methods alone requires further investigation.

Our participants were young, healthy individuals who spent relatively less time with their arms above shoulder level during work, recreation or sports activities. Approximately 30% of all participants had visually confirmed scapular dyskinesis; 36% of all participants and 67% of SDT+ participants had short upper trapezius, and SDT+ participants had shorter pectoralis minor resting length compared to SDT- participants. However, none of the participants in our study had pain, discomfort or any diagnosed pathology of the shoulder, which may be attributable to young age, demographic, morphologic or chemical factors. In combination with repetitive elevated arm movements, short pectoralis minor length may be a mechanism for shoulder pathology to occur (Borstad & Ludewig, 2005). Therefore, the evaluation of the shortness of these muscles in overhead athletes might be useful for prevention and/or treatment.

4.1. Limitations

We categorized participants as SDT+ for those classified as having obvious dyskinesis and SDT- for those classified as being normal or having subtle dyskinesis. This determination was based on previous evidence that individuals classified as obvious abnormality in the SDT demonstrated scapular kinematic abnormalities (Tate et al., 2009). However, we might have underestimated the effect of having subtle dyskinesis while interpreting the results. A possible reason that 22.5% of upper trapezius shortness was seen in SDT- group could be due to this limitation. Those participants who have short upper trapezius might have also had subtle dyskinesis however we classified them as SDT- according to our predetermined rule for the interpretation of SDT test result. Accordingly, the likelihood of exhibiting scapular dyskinesis in people with short upper trapezius might have actually been more then we found in our study.

Postural abnormalities were not assessed quantitatively as it has been found that individuals with FHRSP display altered scapular motions likely due to shorter pectoralis minor length (Thigpen et al., 2010). Furthermore, scapular muscle activity or strength were not assessed. Determining uncoordinated or insufficient muscle activation, especially in lower stabilizers of the scapula, could have strengthened our arguments on the effects of the inflexibility of these muscles, rather than the mechanisms that we speculated in regard to the literature.

5. Conclusion

It was determined that the shortening of pectoralis minor and upper trapezius lengths increases the likelihood of exhibiting scapular dyskinesis in this asymptomatic population. Having a shorter pectoralis minor and upper trapezius appears to be a very significant risk for having observable scapular dyskinesis. Including the assessment of these two muscle lengths as a routine part of the scapular examination may aid treatment decision-making in visually observable scapular dyskinesis. This investigation should be repeated with overhead athletes, who are at risk for impingement, and symptomatic patients who have shoulder injuries, as scapular motion alterations occur in almost every case of shoulder injury. Future studies are needed to examine the presence of muscle inflexibility in patients with shoulder pain, and evaluate whether interventions to lengthen these muscles in patients with scapular dyskinesis can improve shoulder pain and disability.

Conflict of interest

None declared.

Ethical approval

The study protocol was approved by the Dokuz Eylul University Ethics Committee.

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