Clinical Biomechanics 73 (2020) 166–171

Contents lists available at ScienceDirect

Clinical Biomechanics

journal homepage: www.elsevier.com/locate/clinbiomech

Comparison of scapular kinematics and muscle strength between those with a positive and a negative Scapular Assistance Test

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ARTICLE INFO

Keywords:
Dyskinesis
Scapula
Shoulder
Physical therapy

ABSTRACT

Background: The Scapular Assistance Test was suggested to directly assess the influence of scapular motion on pain and indirectly measure the function of the scapular rotators. However, it is still not clear if individuals with a positive Scapular Assistance Test actually present changes in scapular motion and muscle strength. This study compared scapular kinematics and muscle strength between those with a positive Scapular Assistance Test and those with a negative Scapular Assistance Test.

Methods: Fifty individuals with shoulder pain were randomly allocated to: positive (n = 25) or negative Scapular Assistance Test (n = 25) group. Scapular kinematics was measured during elevation and lowering of the arm. Strength of the serratus anterior and lower trapezius was also measured. Two-way analysis of variance was used to compare kinematics between groups. Unpaired Student's *t*-test and Mann-Whitney test were used to compare strength of serratus anterior and lower trapezius, respectively.

Findings: There were no differences ($P > 0.05$) in scapular internal rotation and upward rotation between both groups. For scapular tilt, there was group main effect ($P < 0.05$) during elevation and lowering of the arm, whereas the positive Scapular Assistance Test group presented greater scapular anterior tilt. There was no difference ($P > 0.05$) in strength between groups.

Interpretation: Individuals with a positive Scapular Assistance Test are more likely to present decreased scapular posterior tilt in those with shoulder pain. Strength of the scapular muscles seems to be same in those with a positive and a negative Scapular Assistance Test.

1. Introduction

Different conditions of shoulder pain are frequently associated with alterations in scapular kinematics (Hebert et al., 2002; Kijima et al., 2015; Lawrence et al., 2014; Ludewig and Cook, 2000; Lukasiewicz et al., 1999; McClure and Michener, 2015; Mell et al., 2005; Ogston and Ludewig, 2007; Turgut et al., 2016). These alterations typically include increased scapular internal rotation, decreased scapular upward rotation and decreased posterior tilt (Hebert et al., 2002; Lawrence et al., 2014; Ludewig and Cook, 2000; Lukasiewicz et al., 1999). However, it is still not known if altered scapular motion is cause or consequence of shoulder pain (Kibler et al., 2013; Lefèvre-Colau et al., 2018).

The Scapular Assistance Test (SAT) is a commonly used maneuver to assess whether scapular motion may be associated with shoulder pain. The therapist manually assists the scapula into upward rotation and posterior tilt while the patient elevates the arm (Rabin et al., 2006). A previous study has demonstrated increased scapular upward rotation and posterior tilt, and a greater acromiohumeral distance in static arm elevation during application of the SAT (Seitz et al., 2012a, 2012b). However, it is not clear yet if scapular motion differs between those with a positive and a negative SAT. A positive SAT occurs when the patient refers a reduction in shoulder pain of 2 or more points on the 11-point numeric pain rating scale during assisted elevation as compared to elevation without assistance (Rabin et al., 2006). This result may indicate lack of adequate upward rotation and posterior tilt of the scapula during elevation of the arm. In addition, according to Kibler (1998), a positive SAT also suggests poor strength and/or activation of the serratus anterior (SA) and lower trapezius (LT) muscles, which are important scapula movers (Camargo and Neumann, 2019; Neumann and Camargo, 2019). This may be because changes in scapular motion and positioning likely alter the effective line of force of the scapulothoracic muscles (Kim et al., 2019; Park et al., 2014). Kibler (1998) also suggests that the examiner simulates the SA/LT force couple while assisting upward rotation and posterior titl of the scapula as the patient

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https://doi.org/10.1016/j.clinbiomech.2019.12.030
Received 21 March 2019; Accepted 31 December 2019

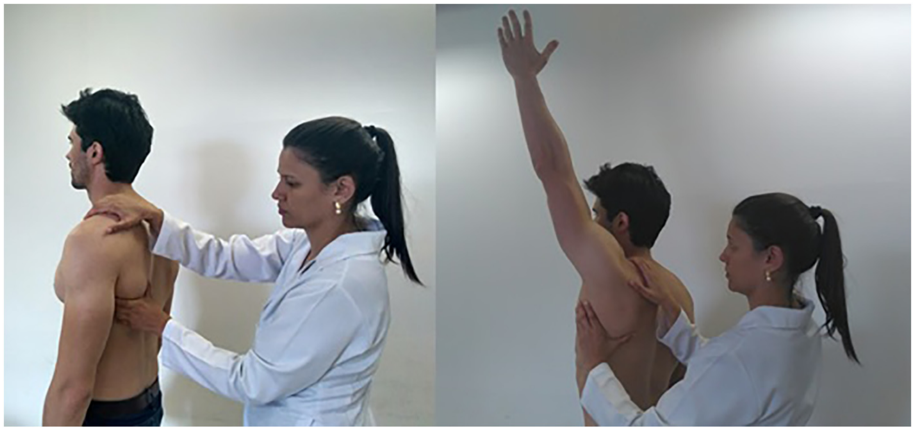

Fig. 1. Scapular Assistance Test during flexion of the arm.

elevates the arm.

Based on the above and because this is a recommended symptom alteration test used in clinical practice (Rabin et al., 2018; Struyf et al., 2014), more research is necessary to assess if possible differences in scapular kinematics and muscle strength exist between individuals with a positive and a negative SAT to better understand the mechanisms that may be associated to a positive SAT. Results of this study will enhance understanding of clinicians about the use the SAT as a test to better guide decisions about specific approaches to improve scapular motion in the treatment of individuals with shoulder pain. Therefore, the primary objective of this study was to compare scapular kinematics between those with a positive SAT and those with a negative SAT. The secondary objective was to compare muscle strength between the groups. We hypothesized that individuals with a positive SAT would present reduced scapular upward rotation and posterior tilt, and decreased muscle strength as compared to those with a negative SAT.

2. Methods

2.1. Participants and study design

The sample size was calculated based on previous studies (Borstad, 2006; Borstad and Ludewig, 2005; Ludewig and Cook, 2000) that estimated at least 25 individuals per group to detect a significant clinical difference of 5° in scapular kinematics between groups with a significance level of 0.05 and a power of 0.80. Fifty individuals with unilateral shoulder pain were allocated to one of the two groups: positive SAT (n = 25) and negative SAT (n = 25).

All participants were evaluated by a physical therapist with five years of experience who assessed the eligibility criteria. Inclusion criteria were the presence of self-reported unilateral shoulder pain during flexion of the arm for at least four weeks, scapular dyskinesis and active shoulder flexion range of motion ~150° as measured by a digital inclinometer. Scapular dyskinesis was assessed by clinical observation of scapular motion during bilateral, active and non-weighted elevation of the arm in the sagittal plane. It was considered present when the prominence of the medial scapular border, inferior angle or rapid scapular downward rotation could be observed in 3/5 trials of arm elevation (McClure et al., 2009). A specific diagnosis of shoulder pain was not considered in this study because no cluster or individual provocative test is truly able to accurately differentiate among shoulder conditions (Hanchard et al., 2013; Hegedus et al., 2012). As such, individuals could present numerous diagnoses as pain during flexion is common in rotator cuff diseases, labral tears and/or bursitis (Ludewig et al., 2013). Individuals with history of fracture or previous surgery in the upper limbs, recurrent glenohumeral joint dislocations in the last two years, presence of neck-related pain determined by the Spurling's and cervical quadrant tests, shoulder pain reproduced by the Upper Limb Tension Test for the median nerve, and body mass index over 30 kg/m^2 were excluded.

All participants received verbal and written explanation of the objectives and methodology of the study, and those who agreed to participate signed an informed consent. This is a cross-sectional study that was part of a larger project that was submitted and approved by the Human Research Ethics Committee of Universidade Federal de São Carlos (protocol number 1.394.925). All outcomes were collected at the Laboratory of Analysis and Intervention of the Shoulder Complex, Department of Physical Therapy. All measurements were performed in two days within the same week. On the first day, the SAT was applied followed by the muscle strength. Scapular kinematics was assessed on the second day.

2.2. Scapular Assistance Test

The SAT was applied in all individuals by a single examiner. The maneuver was performed with the examiner assisting the scapular upward rotation by pushing upward and laterally on the inferior angle, and the scapular posterior tilt by pulling the superior aspect of the scapula posteriorly while the individual was actively elevating the arm in a standing position (Fig. 1) (Rabin et al., 2006). This test has acceptable interrater reliability, with Kappa coefficient and percent agreement of 0.62 and 91%, respectively (Rabin et al., 2006). The test was considered positive when individuals reported a decrease of at least two points on the numerical pain rating scale during the assisted elevation as compared to the elevation without assistance (Rabin et al., 2006). The SAT was applied only to the painful shoulder.

2.3. Scapular kinematics

The capture and analysis of the 3-D scapular kinematics were performed using the hardware (*Ascension Technology Corporation, Burlington, VT*) *Flock of Birds®* (*miniBird®*) with the *MotionMonitor™*software (*Innovative Sports Training, Inc. Chicago, IL*). The electromagnetic receivers were attached to the sternum, the acromion of the scapula, and a thermoplastic cuff attached to the distal humerus to track humeral motion using double-sided tape (Fig. 2). The 3-D position and orientation of each sensor were tracked simultaneously at sampling rates of 100 Hz. These surface sensors positions were previously used (Habechian et al., 2014; Haik et al., 2014a; Ludewig and Cook, 2000; McClure et al., 2006; Rosa et al., 2017).

Individuals stood with their arms relaxed while bony landmarks in the thorax, scapula and humerus were palpated and digitized following recommendations from the International Society of Biomechanics (Wu et al., 2005). Local coordinate systems were established for the trunk,

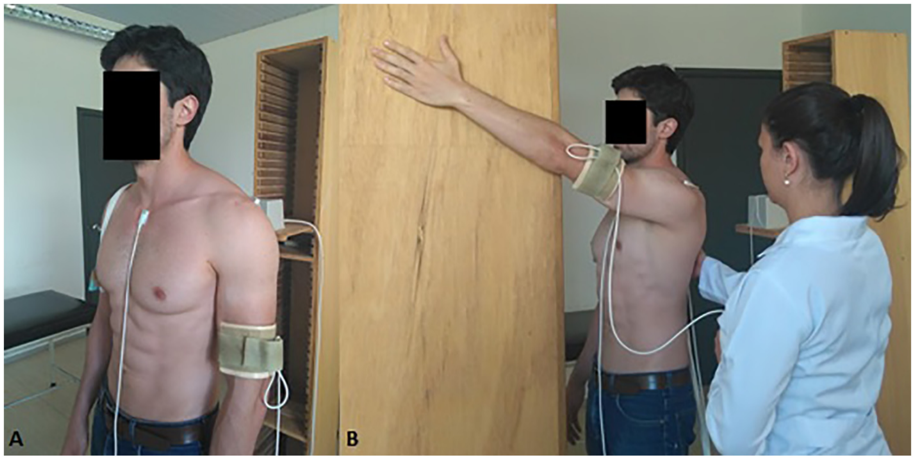

Fig. 2. Assessment of scapular kinematics. A: Sensors positioning. B: Data collection during flexion of the arm.

scapula and humerus using the digitized landmarks. The z-axis was pointed laterally, the x-axis anteriorly and the y-axis superiorly. Afterwards, individuals were asked to maintain a slight contact between the fingertips and a smooth wooden flat surface during elevation and lowering of the arm so that the arm remained in the assessed plane (Fig. 2). They were instructed to both elevate and lower the arm in the sagittal plane at a rate of approximately three seconds for each motion for a total of six seconds (three seconds up and three seconds down). Three complete cycles of movement were completed. One cycle of movement consisted of elevating followed by lowering of the arm. The sensors were not removed or replaced between the repetitions. This procedure is reliable during elevation and lowering of the arm (Haik et al., 2014a). In addition, these electromagnetic surface sensors have been previously validated as compared to bone-fixed scapular tracking data (Karduna et al., 2001).

Kinematic motion analysis was based on scapular orientation data measured at the humerothoracic angles (humeral position with reference to the trunk) of 30°, 60°, 90° and 120° during elevation and lowering of the arm. The YXZ sequence was used to describe the scapular motions in relation to the trunk in the following order: internal/external rotation, upward/downward rotation and posterior/anterior tilt. The position of the humerus relative to the trunk was determined using the sequence Y′XY″. The first rotation defines the elevation plane; the second defines the humeral elevation angle; and the third defines internal/external rotations. The rotation sequences to describe scapular and humeral motions were previously used (Borstad and Ludewig, 2002; Camargo et al., 2015; Habechian et al., 2016; Haik et al., 2014b; Ludewig et al., 2002; Ludewig and Cook, 2000; Ogston and Ludewig, 2007; Rosa et al., 2016, 2019; Wu et al., 2005).

2.4. Muscle strength

Muscle strength of the SA and LT was measured with a manual dynamometer (Lafayette Instrument Company, Lafayette, IN, USA) (Fig. 3). These muscles were selected for being the main muscles responsible for the upward rotation and posterior tilt of the scapula (Camargo and Neumann, 2019; Neumann and Camargo, 2019). For the SA, individuals were positioned in supine with the elbow and arm at 90° (Michener et al., 2005; Pires and Camargo, 2018). The dynamometer was placed on the elbow and the force was applied to the ulna perpendicular to the table. For the LT, individuals were positioned in prone with the elbow in extension and arm at 140° of abduction. The dynamometer was placed on the lateral third of the scapula between the acromion and the root of the spine (Michener et al., 2005).

For familiarization, individuals performed 3 submaximal repetitions of each test prior to data collection. Next, 3 repetitions of maximal isometric contractions of 5 s each were performed for each test, with a resting time of 30 s between the repetitions. The mean of 3 repetitions was used for data analysis. A standardized verbal encouragement to develop maximal strength in all contractions was given by the principal investigator in a consistent manner to all participants during the testing procedure. Resistance was manually applied by the examiner who had to keep a constant resistance during the test. The normalized value was calculated by dividing the strength by body mass. The order of assessment of each muscle was randomized.

2.5. Statistical analysis

Statistical analysis was conducted with Statistical Package for the Social Sciences (SPSS Inc., Chicago, IL) version 21.0. The Shapiro-Wilk test was used to evaluate data distribution. Chi-squared tests were used to compare sex and affected shoulder. Unpaired Student's *t*-tests were

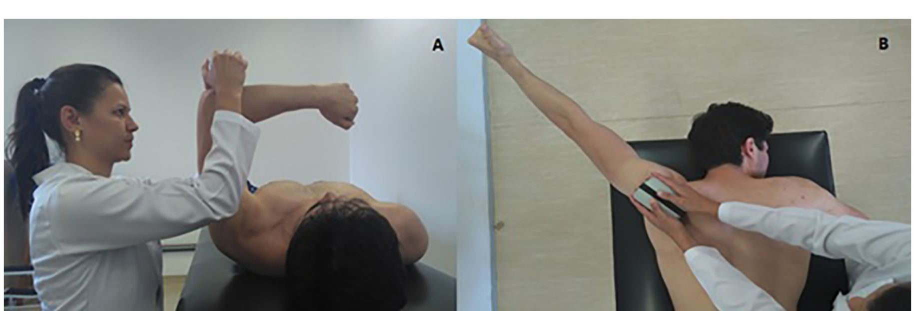

Fig. 3. Assessment of muscle strength. A: Serratus Anterior. B: Lower Trapezius.

used to compare body mass, height, and strength of the SA between groups. Mann-Whitney tests were used to compare age, duration of pain and strength of the LT between groups. A separate 2-factor mixed analysis of variance was conducted for each scapular rotation (internal rotation, upward rotation and tilt) during elevation and lowering of the arm. For each analysis, group (positive SAT and negative SAT) was the between-subject factor and angle (30°, 60°, 90°, 120°) was the within-subject factor. The group x angle interaction was the main interest. If no interaction was observed, the main effect of group was analyzed. A significance level of 5% was considered for all statistical analyses. Intrarater reliability between repeated measurements for assessing scapular kinematics and muscle strength was calculated using an $ICC_{3,1}$ and standard error of measurement (SEM). The effect size was also determined between groups using the Cohen *d* coefficient (Armijo-Olivo, 2018). An effect size > 0.8 was considered large, about 0.5 moderate, and < 0.2 small (Cohen, 1988).

3. Results

A total of 209 individuals were recruited. One-hundred of them were not included due to absence of pain during elevation of the arm in the sagittal plane (n = 55), bilateral pain (n = 23), active range of motion during elevation < 150° (n = 12), and absence of scapular dyskinesis (n = 10). One-hundred and nine were included, and 59 were excluded due to history of fracture or surgery (n = 10), luxation (n = 5), cervicobrachialgia (n = 37), and body mass index > 30 kg/m^2 (n = 7). Fifty individuals completed the study.

Groups were considered similar (P > 0.05) regarding the demographic characteristics (Table 1). Table 2 shows the reliability data for the scapular rotations and muscle strength.

3.1. Scapular kinematics

Table 3 shows the results of scapular kinematics during elevation and lowering of the arm for both groups. For internal rotation, the group x angle interaction was not significant (elevation: $F_{3,192} = 1.27$, $P = 0.28$; lowering: $F_{3,192} = 0.62$, $P = 0.60$), nor was the main effect of group (elevation: $F_{1,192} = 0.64$, $P = 0.42$; lowering: $F_{1,192} = 1.95$, $P = 0.16$). For upward rotation, the group x angle interaction was not significant (elevation: $F_{3,192} = 0.10$, $P = 0.95$; lowering: $F_{3,192} = 0.10$, $P = 0.96$), nor was the main effect of group (elevation: $F_{1,192} = 0.20$, $P = 0.65$; lowering: $F_{1,192} = 1.04$, $P = 0.30$). For scapular tilt, there was no significant interaction of group x angle (elevation: $F_{3,192} = 0.63$, $P = 0.59$; lowering: $F_{3,192} = 0.14$, $P = 0.93$). However, there was group main effect (elevation: $F_{1,192} = 13.85$, $P < 0.001$; lowering: $F_{1,192} = 6.86$, $P = 0.01$), where the positive SAT group showed greater anterior tilt of the scapula than the negative SAT group.

3.2. Muscle strength

The muscle strength data are presented in Table 4. There were no significant differences (P > 0.05) between the groups for the SA and LT.

Table 1
Characteristics of the positive and negative SAT groups.

	Positive SAT group (n = 25)	Negative SAT group (n = 25)	*P*-value
Sex	11 women 14 men	12 women 13 men	0.77
Age (years)	33.7 (10.4)	38.9 (13.8)	0.23
Body mass (kg)	73.3 (11.1)	73.8 (16.9)	0.90
Height (m)	1.72 (0.09)	1.71 (0.10)	0.71
Affected shoulder	19 dominant 6 non-dominant	18 dominant 7 non-dominant	0.74
Duration of pain (months)	39.0 (60.0)	30.40 (43.0)	0.96

Results are mean (standard deviation).

Table 2
Reliability of the outcome measures.

	$ICC_{3,1}$ (95% IC)	SEM
Elevation of the arm		
Scapular internal rotation	0.98 (0.98; 0.99)	1.15 [a]
Scapular upward rotation	0.99 (0.99; 0.99)	1.53 [a]
Scapular tilt	0.99 (0.99; 0.99)	0.86 [a]
Lowering of the arm		
Scapular internal rotation	0.97 (0.97; 0.98)	1.54 [a]
Scapular upward rotation	0.98 (0.98; 0.99)	2.24 [a]
Scapular tilt	0.99 (0.99; 0.99)	1.28 [a]
Strength		
Serratus anterior	0.95 (0.93; 0.97)	0.01 [b]
Lower trapezius	0.96 (0.94; 0.98)	0.01 [b]

[a] Degrees.
[b] No unit.

4. Discussion

This study compared the scapular kinematics and strength of the SA and LT between individuals with a positive and a negative SAT. Overall, our findings indicate that individuals with a positive SAT are more likely to present increased scapular anterior tilt during elevation and lowering of the arm in the sagittal plane. In addition, the results also suggest that individuals with a positive and a negative SAT present similar strength of the SA and LT.

Alterations in scapular kinematics such as decreased upward rotation and posterior tilt, and increased internal rotation have already been described in individuals with shoulder pain (Hebert et al., 2002; Ludewig and Cook, 2000; Ludewig and Reynolds, 2009; Lukasiewicz et al., 1999; Turgut et al., 2016). The SAT is performed to assist scapular upward rotation and posterior tilt during active and dynamic elevation of the arm in individuals with shoulder pain. Seitz et al. (2012a, 2012b) have shown that SAT during static humeral elevation appears to increase scapular upward rotation and posterior tilt. However, the authors (Seitz et al., 2012a, 2012b) cannot guarantee that skin motion during application of the SAT did not contribute to the findings because skin-mounted sensors were used to assess scapular motion. The main difference of the current investigation from the previous studies (Seitz et al., 2012a, 2012b) is that scapular kinematics were not assessed during application of the maneuver in this study, but during dynamic arm elevation in those with a positive and a negative SAT. This fact eliminates skin movement artifact induced with manual scapular assistance of the SAT, which was only used to separate the individuals in two groups: those with a positive SAT and those with a negative SAT. Interestingly, the present study showed that individuals with a positive SAT did not present alteration in the scapular upward rotation, but a decrease in the posterior tilt as compared to those with a negative test. As such, these findings may suggest that the SAT seems to be more related to the assistance in increasing the posterior tilt than scapular upward rotation.

Despite the limited amount of evidence to support the theories that alterations in scapular positioning contribute to the narrowing of the subacromial space, decreased posterior tilt has been previously reported as a factor that may influence its reduction due to a more anterior position of the acromion (Ludewig and Cook, 2000; Lukasiewicz et al., 1999). As the SAT was already shown to increase the subacromial space (Seitz et al., 2012a, 2012b), it possibly reduces the excessive contact between the coracoacromial arch and the subacromial structures, leading to a positive test. Considering the findings of the current study, we can suggest that a positive SAT may help clinicians to identify individuals that are more likely to present decreased scapular posterior tilt as a contributing factor for their shoulder pain. Future

Table 3
Mean difference between groups in scapular kinematics during elevation and lowering of the arm in the sagittal plane.

	Positive SAT group (n = 25)	Negative SAT group (n = 25)	Mean difference (95% IC) †	*P*-value	Pooled standard deviation †	Effect size, Cohen *d*
Internal rotation †						
Elevation of the arm	46.09 (8.60)	45.22 (8.00)	0.86 (−1.26; 3.00)	0.42	8.30	0.10
Lowering of the arm	44.81 (9.80)	43.07 (8.00)	1.73 (−0.71; 4.19)	0.16	8.94	0.19
Upward rotation†						
Elevation of the arm	−18.92 (14.65)	−19.50 (16.0)	0.58 (−1.97; 3.14)	0.65	15.33	0.04
Lowering of the arm	−17.48 (15.72)	−18.88 (16.22)	1.40 (−1.30; 4.10)	0.30	15.97	0.09
Tilt †						
Elevation of the arm	−3.96 (8.70)	0.22 (8.17)*	−4.19 (−6.41; −1.97)	< 0.001	8.43	0.50
Lowering of the arm	−4.04 (10.11)	−0.86 (8.22)*	−3.17 (−5.56; −0.78)	0.01	9.21	0.35

Results are mean (standard deviation). † degrees; * $P < 0.05$, when compared to the positive SAT group. Negative numbers indicate increased upward rotation and anterior tilt.

Table 4
Normalized muscle strength for both positive and negative SAT groups.

	Positive SAT group (n = 25)	Negative SAT group (n = 25)	Mean difference (95% IC)	*P*-value	Pooled standard deviation	Effect size, Cohen d
Serratus anterior	0.24 (0.07)	0.21 (0.08)	0.03 (0.11; 0.15)	0.18	0.07	0.40
Lower trapezius	0.13 (0.04)	0.11 (0.06)	0.02 (0.03; 0.08)	0.07	0.05	0.39

Results are mean (standard deviation).

studies are needed to determine whether exercises focused on this deficit are effective to reduce pain and increase posterior tilt.

No differences were found between groups for the strength of the SA and LT. Seitz et al. (2012a) reported no difference for the external rotation and elevation strength during the application of the SAT. It should be highlighted that many individuals with shoulder pain do not have muscle weakness, but a lack of endurance or motor control instead. Proper activation of the SA and LT muscles is essential for scapular control (Camargo and Neumann, 2019; Johnson et al., 1994; Kibler, 1998; Neumann and Camargo, 2019; Paine and Voight, 2013). Studies have related decreased scapular posterior tilt to reduced activation of the SA (Lin et al., 2005; Ludewig and Cook, 2000). Thus, we can suggest that individuals with a positive SAT may present decreased activation of the SA. However, studies with electromyography are still necessary to confirm this hypothesis.

The present study has some limitations. The evaluator was not blinded to group allocation of the individual. The results cannot be extrapolated to individuals with acute shoulder pain. Although the decrease of at least two points on the numerical pain rating scale during the assisted elevation was used as the criterion to determine the SAT as positive, the pain score was not registered to compare the level of pain between the groups. Further studies should investigate if the level of pain has influence on the test.

5. Conclusion

A positive SAT may be a way to identify individuals for whom decreased scapular posterior tilt during elevation and lowering of the arm may be a contributing factor for shoulder pain. Similar shoulder strength is observed in those with a positive and a negative SAT.

Declaration of competing interest

We affirm that we have no financial affiliation or involvement with any commercial organization that has a direct financial interest in any matter included in this manuscript, except as disclosed in an attachment and cited in the manuscript. Any other conflict of interest (i.e., personal associations or involvement as a director, officer, or expert witness) is also disclosed in attachment.

Acknowledgement

We would like to thank Coordenação de Aperfeiçoamento de Pessoal de Nível Superior and Fundação de Amparo à Pesquisa do Estado de São Paulo (2016/21813-8) for the support.

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