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Association of Scapular Acromion-table Distance with Upper Quarter Y-balance Test and Trapezius Muscle Activity Patterns

Jeongwoo Jeon[a*]

[a]Digital Healthcare Institute, Sunmoon University, Asan-si, Chungcheongnam-do, Republic of Korea

Objective: This study investigated whether the acromion-table distance is associated with trapezius activity patterns during shoulder movements and the upper quarter Y-balance test (UQYBT). Additionally, it was to determine the correlation between upper, middle, and lower trapezius muscle activity.

Design: Cross-sectional study

Methods: Twenty-eight healthy young males participated in this study. Outcome measures included: (1) acromion-to-table distance, which assesses the scapular position, (2) trapezius muscle activity during shoulder flexion and abduction, and (3) the UQYBT, a measure of upper extremity function measured.

Results: A significant negative correlation was observed between the acromion-table distance and the inferior-lateral direction reach distance of UQYBT (r = -0.499 and $p = 0.007$). There were negative correlations between the upper and lower trapezius during shoulder flexion (r = -0.901, $p < 0.001$) and abduction (r = -0.661, $p < 0.001$), respectively. There was also a negative correlation between the upper and middle trapezius during shoulder abduction (r = -0.466, $p = 0.012$).

Conclusions: The acromion-table distance was related to the UQYBT. Anterior tilt of the scapula and limited range of motion of the shoulder may occur as the acromion-table distance increases. In addition, the acromion-table distance reflects the pectoralis minor muscle shortening, suggesting that the scapula position or the pectoralis minor shortening may influence the upper limb function. Therefore, these factors should be considered when assessing upper limb function using the UQYBT.

Key Words: Scapular position, Trapezius muscle, Muscle activity, Shoulder joint, Upper limb function

Introduction

The shoulder joint is an unstable biomechanical complex due to its anatomical structure [1]. The shoulder's stability is provided by passive stabilizers such as bones, joint capsules, and ligaments, and active stabilizers such as muscles including the rotator cuff [2, 3]. The glenohumeral and the scapulothoracic joint contribute significantly to the movement of the shoulder. In addition, kinematics are also important factors influencing shoulder movement [4, 5]. It is well known that individuals with shoulder-related pathologies, including shoulder instability and pain have altered scapular kinematics and muscle activity patterns [6–13]. In addition, changes in scapular position and abnormal movements may increase the risk of impingement by decreasing the subscapular space and rotator cuff strength and increasing the tensile load on the anterior glenohumeral ligament [14–19].

Clinical evaluation of the scapular position and movement provides information on soft tissues such as muscles, posture, and scapular control [20]. Previous studies have used various evaluation methods in this regard. For instance, the distance between the acromion and the table or the wall in the supine and upright position was used as an indicator of the length of the forward shoulder posture and the pectoralis minor [20–22]. Pectoralis minor muscle shortening may be a

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Corresponding author: Jeongwoo Jeon (**ORCID** https://orcid.org/0000-0003-2390-374X)
Digital Healthcare Institute, Sunmoon University, 70, Sunmoon-ro 221beon-gil, Tangjeong-myeon, Asan-si, Chungcheongnam-do, Republic of Korea
Tel: *** - **** - **** **Fax:** +82-41-530-2727 **E-mail:** doublej_woo@naver.com

factor in causing changes in sustained postures of the scapula [23]. In addition, muscle activities around the scapula were observed using surface electromyography (sEMG) during shoulder movements [24, 25]. Among them, the trapezius muscle plays an important role in maintaining proper shoulder kinematics and stabilizing the scapula [26, 27].

Changes in scapular position and muscle activation during arm movement are factors influencing shoulder instability [6], pain [9–12], reduction of the subacromial space [28], and scapular dyskinesis [25]. In addition, it was confirmed that the reduction in the range of motion of the trunk and shoulders was associated with the tear of the rotator cuff and the development of subacromial impingement syndrome [29, 30]. In other words, previous studies mainly investigated the association of variables such as scapular position and muscle activity patterns with disease conditions or pain. However, determining the relationship between these variables and upper limb functional performances that may be important in daily life or sports activities may be expected to be used as reference data for improving upper limb function. Thus, the relationship between upper limb functional measures, scapular position, and muscle activation must be considered.

The upper quarter Y-balance test (UQYBT) was used to assess upper limb function quantitatively in this study. The combination of scapular stability and mobility, trunk mobility, and core stability is required to achieve maximum arm reach distance during the UQYBT [31]. Therefore, this study aimed to examine whether acromion-table distance is associated with trapezius activity patterns during shoulder movements and UQYBT. Additionally, it was to determine the correlation between upper, middle, and lower trapezius muscle activity during shoulder flexion and abduction.

Methods

Participants

The current study was designed as a cross-sectional study to examine the relationship between scapular position, trapezius muscle activity, and upper limb function. This study recruited consecutively healthy young males aged twenty to twenty-nine years through printed and electronic advertisements on notice boards in the university. Exclusion criteria were as follows: surgery history or trauma to the upper extremity, pain, swelling, limited range of motion, or current inflammatory disease in the shoulder, elbow, or wrist joints. Additionally, individuals were also excluded if they had cardiovascular or neurological disease.

This study was approved by the Sunmoon University Institutional Review Board (Republic of Korea, SM-202004-016-1) and all experimental protocols conformed to the Declaration of Helsinki. All participants provided written informed consent after being informed of the study procedures. Twenty-eight healthy young males participated in this study, and data from all participants were analyzed.

Procedures

Participants were asked to visit the laboratory once to complete the experiment. Participants sequentially performed the acromion-to-table distance in the supine position, which is an assessment of the scapular position, trapezius muscle activity during shoulder flexion and abduction, and the UQYBT, which is a measure of upper extremity function.

Outcome measures

Participants were asked to lie comfortably in the supine position on the treatment table. At this time, the evaluator measured the distance between the posterior border of the scapular acromion of the dominant arm and the table using a digital caliper (Mitutoyo 150 mm Digital Caliper, Mitutoyo, Kawasaki, Japan) with a scale of 0.01 mm [21]. The mean value of three repeated measurements was used for the analysis.

sEMG (OQUS100, Zero WIRE EMG, Italy, 2009) was used to measure the trapezius muscle activity of the dominant arm during shoulder flexion and abduction. To capture the muscle's electrical signal, disposable bipolar Ag/AgCl surface electrodes (1.0 cm diameter) were placed parallel to the muscle fibers, with an inter-electrode distance of 2.0 cm. Prior to electrode placement, the skin surface was shaved and cleansed with alcohol to minimize impedance. The electrode positions [32] are as follows (Figure 1): For

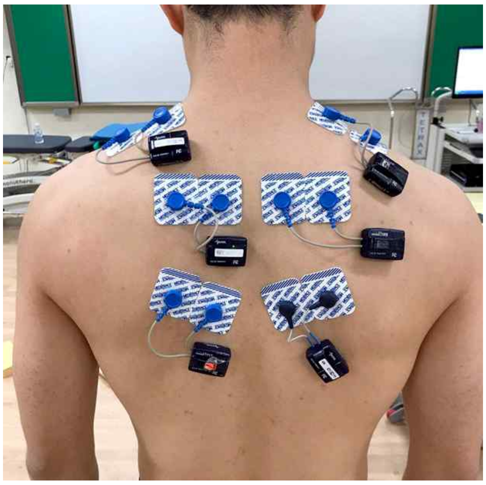

Figure 1. Electrode placements for electromyography

the upper trapezius (UT), the electrode was positioned at 50% on the line from the scapular acromion to the 7th cervical vertebra, with the shoulder in 90° abduction. The electrode for the middle trapezius (MT) was placed at 50% between the medial border of the scapula and the spine of the 3rd thoracic vertebra. For the lower trapezius (LT), the electrode was placed at 2/3 on the line from the spine root of the scapula to the 8th thoracic vertebra in the shoulder in 90° flexion. During muscle activity measurements (shoulder flexion and abduction), participants were instructed to maintain shoulder flexion and abduction at 180° for 3 seconds, using a metronome for timing. Measures were taken three times for each condition. To normalize the recorded muscle activity during movement, maximum voluntary isometric contractions (MVIC) of each muscle were measured. For the MVIC assessment, participants performed a maximum voluntary isometric contraction for 5 seconds, guided by a metronome, with three repetitions for each muscle. A 30-second rest was provided between measures. MVIC of the UT was measured in a seated position with the shoulder in 90° abduction and the thumb facing upward, while the examiner applied downward resistance at the elbow. For the MT and LT, MVIC measurements were performed in the prone position, with the shoulder in 90° and 135° abduction respectively, and the thumb facing upward. Similarly, the examiner applied downward resistance at the elbow. There was a 90-second rest period between measurements of each muscle. The sEMG signal was processed with a band-pass filter set to 20-500 Hz, and muscle activity was quantified using the root mean square (RMS) method. The mean amplitude, derived from three measurements and converted to RMS, was normalized to the MVIC percentage (% MVIC). The normalized %MVIC values were then used to calculate the relative ratio of each muscle (UT + MT + LT = 100%) during the movements.

The UQYBT was conducted according to the procedures of the previous study [31] using a kit (Perform Better, West Warwick, RI, USA) consisting of a platform with three arms arranged in a Y-shape: medial, superior-lateral, and inferior-lateral (Figure 2). The angles between the medial and inferior-lateral bars and between the inferior-lateral and superior-lateral

Figure 2. Upper quarter Y-balance test. (A) medial, (B) superior-lateral, and (C) inferior-lateral directions.

bars were 135° and 90°, respectively. Measurements were recorded in 1.0 cm increments. Prior to the test, participants were instructed on the procedure through a video, and their arm length was measured. The test was performed in a push-up position, with the participant's dominant hand on the center of the platform and feet shoulder-width apart. Then, using the opposite hand, extend it as far as possible in three directions. After two practice trials, three test trials were conducted with a 30-second rest between each trial. The mean reach distances of three trials in each direction were normalized as a percentage of the arm length (% arm length). Arm length was determined from the spinous process of the 7th cervical vertebra to the tip of the 3rd finger in the shoulder abducted to 90° and fingers extended. Participants were reassessed in the following cases: 1) inability to maintain posture on the platform or if the hand touched the floor; 2) failure to maintain the hand on the platform in the indicated direction during movement; 3) use of the hand on the platform for support; 4) inability to return to the starting position after reaching the maximum distance; or 5) lifting the feet off the floor.

Statistical analysis

The normality test of the data was conducted using the Shapiro–Wilk test. The two-tailed Pearson product-moment correlation coefficients (r) were used to examine the relationships between (1) acromion-table distance and trapezius muscle (UT, MT, LT) activity and (2) acromion-table distance and UQYBT. In addition, a correlation was analyzed between UT, MT, and LT muscle activity during shoulder flexion and abduction. Pearson correlation coefficients (r) were interpreted as weak (0.00-0.40), moderate (0.41-0.69), and strong (0.70-1.00) [33]. The statistical significance level was set as p-values < 0.05. All statistical data were analyzed using the SPSS 22.0 software (SPSS, IBM Corp., Armonk, New York, USA).

Results

General characteristics of participants are shown in Table 1. The data obtained for acromion–table distance, UQYBT, and trapezius muscle activity during shoulder flexion and abduction are presented in Table 2.

Table 3 indicates the correlation of acromion-table distance with UQYBT and trapezius muscle activity. A significant negative correlation was observed between the acromion-table distance and the inferior-lateral direction reach distance of UQYBT ($r = -0.499$ and $p = 0.007$). However, the acromion-table distance did not significantly correlate with other directions of UQYBT and trapezius muscle activity ($p > 0.05$).

There were moderate and strong negative correlations between UT and LT during shoulder flexion ($r = -0.901$, $p < 0.001$) and abduction ($r = -0.661$, $p < 0.001$), respectively (Table 4). There was also a moderate negative correlation between UT and MT during shoulder abduction ($r = -0.466$, $p = 0.012$) (Table 4).

Table 1. General characteristics of participants

Variables	N = 28 (male)
Age (years)	23.46 ± 2.57
Height (cm)	174.21 ± 5.60
Body mass (kg)	73.57 ± 8.98
Dominant arm	Left = 3, Right = 25
Arm length (cm)	89.04 ± 3.95

Data are presented as mean ± standard deviation

Table 2. Mean and standard deviation for acromion–table distance, upper quarter Y balance test, and trapezius muscle activity during shoulder flexion and abduction

Variables		Values
Acromion-table distance (cm)		4.35 ± 1.15
Upper quarter Y balance test (% arm length)		
Medial direction		100.22 ± 10.06
Superior-lateral direction		74.45 ± 8.80
Inferior-lateral direction		93.21 ± 13.43
Muscle activity relative ratio (% MVIC)		
Shoulder flexion	Upper trapezius	52.40 ± 16.25
	Middle trapezius	17.86 ± 7.15
	Lower trapezius	29.74 ± 15.87
Shoulder abduction	Upper trapezius	46.17 ± 10.85
	Middle trapezius	35.71 ± 8.72
	Lower trapezius	18.12 ± 10.27

Data are presented as mean ± standard deviation
MVIC: maximal voluntary isometric contraction

Table 3. Correlation of acromion-table distance with upper quarter Y-balance test and trapezius muscle activity

Variables		Acromion-table distance	
		coefficients (r)	***p* value**
Upper quarter Y balance test			
Medial direction		-0.124	0.531
Superior-lateral direction		-0.308	0.110
Inferior-lateral direction		**-0.499**	**0.007**
Muscle activity relative ratio			
Shoulder flexion	Upper trapezius	-0.097	0.624
	Middle trapezius	0.281	0.148
	Lower trapezius	-0.027	0.890
Shoulder abduction	Upper trapezius	0.011	0.957
	Middle trapezius	-0.058	0.771
	Lower trapezius	0.037	0.850

Significant correlations ($p < 0.05$) are presented in bold

Table 4. Correlation between upper, middle, and lower trapezius muscle activity during shoulder flexion and abduction

Shoulder flexion	Middle trapezius		Lower trapezius	
	coefficients (r)	***p* value**	**coefficients (r)**	***p* value**
Upper trapezius	-0.273	0.160	**-0.901**	**< 0.001**
Middle trapezius	-	-	-0.171	0.385
Shoulder abduction	**Middle trapezius**		**Lower trapezius**	
	coefficients (r)	***p* value**	**coefficients (r)**	***p* value**
Upper trapezius	**-0.466**	**0.012**	**-0.661**	**< 0.001**
Middle trapezius	-	-	-0.356	0.063

Significant correlations ($p < 0.05$) are presented in bold

Discussion

Our study aimed to investigate the relationship between (1) acromion-table distance and trapezius muscle activity during shoulder flexion and abduction and (2) acromion-table distance and UQYBT. In addition, a correlation was identified between UT, MT, and LT muscle activity during shoulder flexion and abduction. According to the results, the scapular position estimated by the acromion-table distance was found to have a negative relationship with UQYBT, an upper extremity function evaluation tool. Additionally, muscle activation of UT during shoulder movement showed a negative relationship with LT and MT muscle activities.

The results of this study suggest the possibility that increased acromion-table distance may be a factor in reducing UQYBT reach distance. Individuals with forward shoulder postures were reported to have significantly reduced UQYBT reach distance [34] as well as decreased horizontal adduction [35]. The greater the acromion-table distance, the more forward the scapula was tilted, which suggested the possibility of shoulder pain or decreased subacromial space [28]. Accordingly, this study predicted a significant relationship between acromion-table distance and UQYBT. Furthermore, in the previous studies, the measurement of the acromion-table distance was used as an indicator for the forward shoulder posture and the length of the pectoralis minor [20–22]. If the acromion-table distance exceeds 2.54 cm, it indicates shortening of the pectoralis minor muscle [36]. The acromion-table distance of the participants in this study was 4.35±1.15, which predicts the shortening of the pectoralis minor muscle. This is presumed to be because, although the data was not obtained, all the participants were university students who spent a lot of time sitting down to study or work. Consequentially, the increased acromion-table distance in our study participants has the potential to reflect pectoralis minor muscle shortening and anterior shoulder posture. These participant characteristics may have contributed to the decrease in horizontal shoulder adduction. In other words, for this reason, the results of this study appear to show a negative relationship between the acromion-table distance and the reach distance in the inferior-lateral direction of UQYBT. Although there was no statistical significance, there was also a negative relationship ($r=-0.308$, $p=0.110$) between acromion-table distance and superior-lateral direction reach. The inferior-lateral and superior-lateral directions of UQYBT require horizontal shoulder adduction movements. Therefore, the position of the scapula and the shortening of the pectoralis minor muscle estimated by the acromion-table distance may influence the evaluation of upper limb function.

There are some cautions in interpreting the relationship between the UQYBT used as an assessment of upper limb function in the current study and the acromion-table distance. Similar to the functional movement screen, the YBT is primarily used by exercise professionals in sports settings rather than clinical settings [37, 38]. Thus, it should be noted that the results of this study, which show that scapular position assessed by acromion-table distance is related to UQYBT, should be extended with caution to clinical interpretation. Moreover, the participants in this study were healthy adults with no clinical limitations in the range of motion of the shoulder. That is, it may be appropriate to consider the findings of this study as data that may supplement clinical assessment. Nonetheless, it is noteworthy that scapular position, assessed visually using a caliper, has a significant relationship with UQYBT reach distance. This suggests that the scapular position should be considered when using UQYBT.

Huang et al. [24] reported that scapular muscle activity and kinematics are altered depending on the pattern of scapular dyskinesia. Accordingly, we hypothesized that the muscle activity pattern of the trapezius muscles during shoulder flexion and abduction would be related to the acromion-table distance. However, according to our results, there was no correlation between trapezius muscle activity patterns during shoulder movements and the acromion-table distance. This may be due to a methodological failure to sufficiently trapezius muscle activity. In a previous study, Reed et al. [39] assessed scapular muscle activation during shoulder abduction in the scapular and coronal planes using 50% of the maximum load. Another study by Reed et al. [40] showed that muscle activation around the shoulder increased with loads of 25%, 50%, and 75%, demonstrating a strong correlation between activation and load. In the current study, muscle activity was measured in the absence of any load. In other words, it was limited to determining the relationship between muscle activity in a non-load state and acromion-table distance. It should also be noted that the participants in this study were young healthy adults. Lopes et al. [25] divided participants with subacromial impingement syndrome into a scapular dyskinesis group and a normal scapular movement group, and then compared trapezius muscle activation during shoulder flexion. They observed a higher activation pattern of the UT muscle in patients with shoulder dyskinesia. Therefore, there may not have been a significant relationship between muscle activation pattern and acromion-table distance in participants who were not individuals with a specific abnormal muscle activation pattern.

Further analysis of this study found an inverse relationship between UT and LT during shoulder flexion and abduction. In particular, an inverse relationship also existed between UT and MT during shoulder abduction. It is a well-known pattern that as the UT activity increases, the activation of MT and LT decreases [41]. In particular, excessive activity of the UT and lack of LT activity were observed in patients with scapular dyskinesia [25, 42]. Therefore, the functions of MT and LT are often important targets in shoulder rehabilitation [26]. Our results seem to partially support these previous studies.

This study has several limitations. First, the participants in this study were limited to males. Considering differences in muscle contraction characteristics between sexes, further studies should also investigate differences between sexes. Second, as previously mentioned, the study participants were healthy adults. Therefore, it is difficult to generalize to individuals with shoulder-related diseases. Third, although many studies have investigated the Y-balance test of the lower extremities, relatively little has been done on the UQYBT, making the interpretation of the results difficult. Finally, since it was analyzed only for correlation, it is limited in identifying the causal relationship between variables.

Conclusion

This study confirmed that the acromion-table distance is related to the inferior-medial direction reach distance of the UQYBT, an upper limb function assessment tool. Anterior tilt of the scapula and limited range of motion of the shoulder may occur as the acromion-table distance increases. In addition, the acromion-table distance reflects the shortening of the pectoralis minor muscle, suggesting that the scapula position or the shortening of the pectoralis minor muscle may affect the upper limb function. Therefore, these factors should be considered when assessing upper limb function using the UQYBT. The findings of this study may be used as a basic reference for the evaluation and treatment of patients with upper limb dysfunction in clinical settings. In addition to the acromion-table distance, many methods exist to assess scapular position and kinematics. Thus, further study should be conducted on the relationship different measurement tools have with upper limb function.

References

1. Echalier C, Uhring J, Ritter J, Rey P, Jardin E, Rochet S, et al. Variability of shoulder girdle proprioception in 44 healthy volunteers. Orthop Traumatol Surg Res. 2019;105(5):825-9.
2. Lubiatowski P, Ogrodowicz P, Wojtaszek M, Kaniewski R, Stefaniak J, Dudziński W, et al. Measurement of active shoulder proprioception: dedicated system and device. Eur J Orthop Surg Traumatol. 2013;23:177-83.
3. Lugo R, Kung P, Ma CB. Shoulder biomechanics. Eur J Radiol. 2008;68(1):16-24.
4. Easwaran PG, Sharma U, Palekar TJ. Comparison of Scapular Muscles Activation with Shoulder Retraction and Shoulder Elevations in Individuals with Scapular Dyskinesia. Int J Sci Res Sci Technol. 2019;6(2):658-64.
5. Hsu Y, Chen W, Lin H, Wang WT, Shih Y. The effects of taping on scapular kinematics and muscle performance in baseball players with shoulder impingement syndrome. J Electromyogr Kinesiol. 2009;19(6):1092-9.

6. Burkhart SS, Morgan CD, Kibler WB. The disabled throwing shoulder: spectrum of pathology Part III: The SICK scapula, scapular dyskinesis, the kinetic chain, and rehabilitation. Arthrosc. 2003;19(6):641-61.
7. Paletta Jr GA, Warner JJ, Warren RF, Deutsch A, Altchek DW. Shoulder kinematics with two-plane x-ray evaluation in patients with anterior instability or rotator cuff tearing. J Shoulder Elbow Surg. 1997;6(6):516-27.
8. Warner JJ, Micheli LJ, Arslanian LE, Kennedy J, Kennedy R. Scapulothoracic Motion in Normal Shoulders and Shoulders With Glenohumeral Instability and Impingement Syndrome A Study Using Moire Topographic Analysis. Clin Orthop Relat Res (1976-2007). 1992;285:191-9.
9. Ludewig PM, Reynolds JF. The association of scapular kinematics and glenohumeral joint pathologies. J Orthop Sports Phys Ther. 2009;39(2):90-104.
10. Kibler BW, Sciascia A, Wilkes T. Scapular dyskinesis and its relation to shoulder injury. J Am Acad Orthop Surg. 2012;20(6):364-72.
11. Timmons MK, Thigpen CA, Seitz AL, Karduna AR, Arnold BL, Michener LA. Scapular kinematics and subacromial-impingement syndrome: a meta-analysis. J Sport Rehab. 2012;21(4):354-70.
12. Struyf F, Nijs J, Baeyens J, Mottram S, Meeusen R. Scapular positioning and movement in unimpaired shoulders, shoulder impingement syndrome, and glenohumeral instability. Scand J Med Sci Sports. 2011;21(3):352-8.
13. Spanhove V, Van Daele M, Van den Abeele A, Rombaut L, Castelein B, Calders P, et al. Muscle activity and scapular kinematics in individuals with multidirectional shoulder instability: a systematic review. Ann Phys Rehabil Med. 2021;64(1):101457.
14. Tsai N, McClure PW, Karduna AR. Effects of muscle fatigue on 3-dimensional scapular kinematics. Arch Phys Med Rehabil. 2003;84(7):1000-5.
15. Seitz AL, McClure PW, Lynch SS, Ketchum JM, Michener LA. Effects of scapular dyskinesis and scapular assistance test on subacromial space during static arm elevation. J Shoulder Elb Arthroplast. 2012;21(5):631-40.
16. Atalar H, Yilmaz C, Polat O, Selek H, Uras I, Yanik B. Restricted scapular mobility during arm abduction: implications for impingement syndrome. Acta Orthop Belg. 2009;75(1):19.
17. Silva RT, Hartmann LG, de Souza Laurino CF, Biló JR. Clinical and ultrasonographic correlation between scapular dyskinesia and subacromial space measurement among junior elite tennis players. Br J Sports Med. 2010;44(6):407-10.
18. Kibler WB, Sciascia A, Dome D. Evaluation of apparent and absolute supraspinatus strength in patients with shoulder injury using the scapular retraction test. Am J Sports Med. 2006;34(10):1643-7.
19. Mihata T, McGarry MH, Kinoshita M, Lee TQ. Excessive glenohumeral horizontal abduction as occurs during the late cocking phase of the throwing motion can be critical for internal impingement. Am J Sports Med. 2010;38(2):369-74.
20. Larsen CM, Søgaard K, Eshoj H, Ingwersen K, Juul-Kristensen B. Clinical assessment methods for scapular position and function. An inter-rater reliability study. Physiother Theory Pract. 2020;36(12):1-22.
21. Temprom V, Sangnon C, Boontham P, Viriyatharakij N. Clarifying acromial distance: Standardisation and association between supine and sitting positions. Phys Ther Sport. 2019;36:51-4.
22. Struyf F, Nijs J, De Coninck K, Giunta M, Mottram S, Meeusen R. Clinical assessment of scapular positioning in musicians: an intertester reliability study. J Athl Train. 2009;44(5):519-26.
23. Komati MA, Korkie FE, Becker P. Pectoralis minor length measurements in three different scapula positions. S Afr J Physiother. 2020;76(1):1487.
24. Huang T, Ou H, Huang C, Lin J. Specific kinematics and associated muscle activation in individuals with scapular dyskinesis. J Shoulder Elbow Surg. 2015;24(8):1227-34.
25. Lopes AD, Timmons MK, Grover M, Ciconelli RM, Michener LA. Visual scapular dyskinesis: kinematics and muscle activity alterations in patients with subacromial impingement syndrome. Arch Phys Med Rehabil. 2015;96(2):298-306.
26. Kinney E, Wusthoff J, Zyck A, Hatzel B, Vaughn D, Strickler T, et al. Activation of the trapezius muscle during varied forms of Kendall exercises. Phys Ther Sport. 2008;9(1):3-8.
27. Camargo PR, Neumann DA. Kinesiologic considerations for targeting activation of scapulothoracic

muscles–part 2: trapezius. Braz J Phys Ther. 2019;23(6):467–75.
28. Borstad JD, Ludewig PM. The effect of long versus short pectoralis minor resting length on scapular kinematics in healthy individuals. J Orthop Sports Phys Ther. 2005;35(4):227-38.
29. Yamamoto A, Takagishi K, Kobayashi T, Shitara H, Ichinose T, Takasawa E, et al. The impact of faulty posture on rotator cuff tears with and without symptoms. J Shoulder Elbow Surg. 2015;24(3):446-52.
30. Land H, Gordon S, Watt K. Clinical assessment of subacromial shoulder impingement–which factors differ from the asymptomatic population? Musculoskelet Sci Pract. 2017;27:49-56.
31. Gorman PP, Butler RJ, Plisky PJ, Kiesel KB. Upper Quarter Y Balance Test: reliability and performance comparison between genders in active adults. J Strength Cond Res. 2012;26(11):3043-8.
32. Hermens HJ, Freriks B, Disselhorst-Klug C, Rau G. Development of recommendations for SEMG sensors and sensor placement procedures. J Electromyogr Kinesiol. 2000;10(5):361-74.
33. Dancey CP, Reidy J. Statistics without maths for psychology. 5th ed. New Jersey: Prentice Hall; 2011.
34. Beyranvand R, Mirnasouri R, Mollahoseini S, Mostofi S. The functional stability of the upper limbs in healthy and rounded shoulder gymnasts. Sci. Gymnast. J. 2017;9(3):279-90.
35. Chen P, Cheng S, Chiu P. A Bilateral Comparison of Shoulder Horizontal Adduction Range of Motion Deficit and Its Correlation with Scapular Position in Collegiate Baseball Pitchers. KACEP Annual Meeting. 2012:44.
36. Sahrmann, S. Treatment of movement impairment syndromes. St. Louis, Mo: Mosby; 2002.
37. Beckham SG, Harper M. Functional training: fad or here to stay? ACSM's Health Fit J. 2010;14(6):24-30.
38. Girard J, Quigley M, Helfst F. Does the functional movement screen correlate with athletic performance? A systematic review. Phys Ther Rev. 2016;21(2):83-90.
39. Reed D, Cathers I, Halaki M, Ginn KA. Does changing the plane of abduction influence shoulder muscle recruitment patterns in healthy individuals? Man Ther. 2016;21:63-8.
40. Reed D, Cathers I, Halaki M, Ginn KA. Does load influence shoulder muscle recruitment patterns during scapular plane abduction? J Sci Med Sport. 2016;19(9):755-60.
41. Kara D, Harput G, Duzgun I. Shoulder-abduction angle and trapezius muscle activity during scapular-retraction exercise. J Athl Train. 2021;56(12):1327-33.
42. Chester R, Smith TO, Hooper L, Dixon J. The impact of subacromial impingement syndrome on muscle activity patterns of the shoulder complex: a systematic review of electromyographic studies. BMC Musculoskelet Disord. 2010;11:1-12.