한국전문물리치료학회지 2017년 24권 4호 29-37
Phys Ther Korea 2017;24(4):29-37
ISSN (Print) 1225-8962, ISSN (Online) 2287-982X
https://doi.org/10.12674/ptk.2017.24.4.029

Comparison of Serratus Anterior Muscle Activity between Serratus Anterior Strengthening Exercises and Scapular Upward Rotation Exercise

Jun-hee Kim[1], BPT, PT, Ui-jae Hwang[1], PhD, PT Sung-hoon Jung[1], BPT, PT, Gyung-tae Gwak[1], BPT, PT, Oh-yun Kwon[2,3], PhD, PT

[1]Dept. of Physical Therapy, The Graduate School, Yonsei University
[2]Dept. of Physical Therapy, College of Health Science, Yonsei University
[3]Dept. of Ergonomic Therapy, The Graduate School of Health and Environment, Yonsei University

Abstract

Background: The serratus anterior (SA) muscle is one of the important muscles in the upward rotation of the scapula when the arm is raised. Insufficient muscle activity of the SA can cause deformation of the shoulder rhythm resulting in shoulder pathology.

Objects: This study intends to compare SA and upper trapezius (UT) activity during the conventional wall-slide and push-up plus exercises for SA muscle strengthening and the scapular upward rotation (SUR) exercise.

Methods: A total of 30 subjects participated in this study, and we measured the muscle activity of the SA and UT muscles during the wall-slide, push-up plus and SUR exercises. The one-way repeated ANOVA was used to compare SA and UT muscle activities during the 3 exercises.

Results: During the SUR exercise, SA muscle activity was 79.88% maximum voluntary isometric contraction (MVIC), which was significantly higher than its activity during the other 2 exercises. The UT muscle activity was 47.53 %MVIC during the SUR exercise, indicating a significantly higher UT muscle activity than during the other 2 exercises.

Conclusion: These findings suggest that the SUR exercise can maximize SA muscle activity to strengthen the SA while keeping UT muscle activity at an appropriate level.

Key Words: Push-up plus; Scapular upward rotation; Serratus anterior; Upward rotator strength; Wall slide.

Introduction

The serratus anterior (SA) muscle is one of the scapular upward rotation (SUR) muscles that is considered to be important in maintaining the scapulohumeral rhythm and optimal function of the shoulder complex when elevating the arm (Ekstrom et al, 2004; Inman and Abbott, 1996; Levangie and Norkin, 2011). While elevating the arm, the SA rotates the scapular bone upwards and prevents anterior tilting and winging of the scapular bone (Gregg et al, 1979; Watson and Schenkman, 1995). These functions of the SA allow the scapular bone to move in close contact with the thorax while the arm is moving (Gregg et al, 1979; Ludewig et al, 1996; Ludewig et al, 2004).

The scapulohumeral rhythm or alignment of the scapula can be deteriorated by various conditions, including muscle fatigue, alteration of muscle length, or insufficient activation of the SA muscle (McQuade et al, 1998; Sahrmann, 2002; Yoshizaki et al, 2009). Among these, decreased SA muscle activity causes deformation of the scapulothoracic rhythm, which causes the scapula to be winging, rotate downward, or tilt anteriorly (Sahrmann, 2002; Watson and Schenkman,

Corresponding author: Oh-yun Kwon kwonoy@yonsei.ac.kr

1995). Especially, decreased activity of the SA can break the balance of force couples among upward rotator muscles and cause shoulder pathology (Ekstrom et al, 2003; Ludewig et al, 2004; Sahrmann, 2002). The deformation of the shoulder blade position in a superior translation can also occur because other synergistic muscles are predominantly used to compensate for decreased activity of the SA during shoulder elevation (Lukasiewicz et al, 1999; Peat and Grahame, 1977). Ludewig and Cook (2000) found that patients who suffer from shoulder impingement syndrome display decreased muscle activity of the SA and imbalance of other synergistic muscles of upward rotator muscles.

To solve the deformation of the shoulder, numerous researches have investigated increasing the SUR muscles' activities respectively and restoring balance between the SUR muscles. To strengthen each SUR muscle, a shoulder shrug motion was used for maximum muscle activity of the upper trapezius (UT) (Ekstrom et al, 2003). The shoulder elevation motion above the head in the prone position showed the largest muscle activity of the lower trapezius (Ekstrom et al, 2003; Peterson-Kendall et al, 2005). Scapular protraction, like a forward punching motion, was used for selective muscle activity of the SA. To restore balance between the SUR muscles, the push-up plus (PUP) exercise, which protracts the shoulder blade and pushes the trunk toward the ceiling, was used for inducing isolated activity of the SA (Lehman et al, 2008; Ludewig et al, 2004). Also, the wall slide (WS) exercise was used to maximize the activity of the SA, among other SUR muscles (Hardwick et al, 2006).

Muscle activity transmitted through an EMG signal reflects the motor unit of the muscle or muscle group during muscle recruitment, and it has a higher muscle activity when it is given more load or the muscle generates more force (David et al, 2000). Therefore, the more a muscle exhibits high muscle activity during a specific movement, the more advantageous the movement is for obtaining muscle strength (David et al, 2000). To improve specific muscle strength, the minimum muscle activity can be achieved at 40 to 60 %MVIC (Andersen et al, 2006; Ayotte et al, 2007). Several researchers have recommended exercising with the arm at 90° or less of the humerus elevation in the early stage of rehabilitation in order to prevent excessive strain on the rotator cuff and shoulder ligament (Jobe et al, 1987; McCann et al, 1993; Pappas et al, 1985). However, most of these exercises for SA muscle strength did not reach or barely reached a minimum of muscle activity to gain strength. The traditional exercise methods for restoring strength of the SA, forward punch or shoulder protraction exercises, show a mean muscle activity of 31.4 to 47 %, which barely met the minimum muscle activity to obtain muscle strength. In the case of the push-up plus exercise used at a later stage of rehabilitation, the mean muscle activity was 35.1%, which did not reach the minimum muscle activity to obtain muscle strength (Decker et al, 1999; Hardwick et al, 2006).

However, in the case of workers or athletes requiring high-strength muscles, the exercise needs to achieve higher SA muscle activity. However, such exercises can cause excessive muscle activity of the UT and cause shoulder problems (Decker et al, 1999; Ekstrom et al, 2003). For this reason, we have devised a method of SUR exercise that maximizes SA muscle activity while maintaining appropriate UT muscle activity. Therefore, the purpose of this study was to compare 2 previously studied conventional exercise methods for selectively increasing SA muscle activity, the WS and PUP, with the SUR exercise method.

Methods

Subjects

A total of 30 healthy, right-handed men (age=23.9±3.3 years, height=174.0±4.7, mass=73.2±10.9) (Table 1) participated in this study. All the participants in the study were right-handed. Participants in the study completed a self-report to determine if there were any orthopedic or neurological problems in the upper extremities. Subjects were excluded from this study if they had (1) a history of dislocation or traumatic injuries of the tested shoulder complex or (2) a history of shoulder surgery within the previous 6 months. All subjects received an explanation of this study and agreed to participate in this study by signing a consent form. This study was approved by the Yonsei University Wonju Institutional Review Board (approval number: 1041849-201705-BM-045-01).

Surface electromyography (EMG)

The SA and UT muscle activities were measured using the TeleMyo 2400T (Noraxon Inc., Scottsdale, AZ, USA) and analyzed using MyoResearch software (XP Master Edition 1.07, Noraxon Inc., Scottsdale, AZ, USA). Before attaching EMG electrodes, the skin was shaved and gently rubbed with sandpaper to reduce skin impedance. One surface electrode was applied to the SA parallel to the muscle fibers, below the axilla, anterior to the latissimus dorsi, and posterior to the pectoralis major (Criswell, 2010). Correct electrode placement was verified through observation of the oscilloscope during resisted scapular protraction. In addition, resisted shoulder extension was observed to limit potential crosstalk from the latissimus dorsi. A second surface electrode was applied to the UT parallel to the muscle fibers, two-thirds of the way between the spinous process of the seventh cervical vertebrae and the acromion process (Criswell, 2010).

To normalize EMG data, maximal voluntary isometric contraction (MVIC) was used. All data were presented as percentages of MVIC. To collect the MVIC data, subjects performed MVIC of the SA and UT muscles based on the muscle manual testing position (Kendall et al, 2005). In order to examine the SA, the subjects sat on a chair with a backrest to fix the trunk and performed arm elevation in a position between 120° and 130° of flexion. Manual resistance was applied to the dorsal surface of the subject's arm, between the shoulder and elbow, downward in the direction of extension. To assess the UT, subjects sat on a chair and performed elevation of the acromial end of the clavicle and scapula. Manual resistance was applied to the subject's shoulder, in the direction of depression. Subjects repeated the MVIC 3 times with a 30 second rest between each trial to obtain the mean EMG value used as 100 %MVIC. Subjects maintained each trial for 5 seconds with a 30 min rest between each muscle contraction (Soderberg, 2000). The average value of the middle 3 seconds of the 5 second period was used for data analysis. For data analysis, the EMG signals were amplified and the sampling rate was 1000 Hz. A bandpass filter between 20 and 450 Hz was used and a notch filter at 60 Hz was applied. EMG data were processed into the root-mean-square (RMS) value, which was calculated from 50-ms data points of windows.

Table 1. General characteristics of the subjects (N=30)

Parameters	Mean±SD[a]
Age (year)	23.9±3.3
Height (㎝)	174.0±4.7
Weight (㎏)	73.2±10.9
Dominant hand	Right=30 / Light=0

[a]mean±standard deviations.

Experimental procedure

All subjects performed the 3 different exercises, and EMG activity in the SA and UT muscles was recorded during the exercises. The durations of the 3 exercises were controlled by a sound signal generated by a metronome. Each subject was given a 5 min practice time to acclimatize to the movement and speed. Participants performed 3 trials of each exercise in a randomized order, with a rest time of 3 min between exercises to minimize the order effect. In addition, 1 min of rest was given per trial to minimize the effects of muscle fatigue. During each trial, the average value of the middle 3 seconds of the 5 second period was recorded.

Scapular upward rotation (SUR)

For the SUR exercise, the subject sat on the chair. The subject then placed the palm of the hand on the crown of the head to rotate the scapula upwardly. The scapula was fixed with an orthopedic belt (Figure 1). To fix the scapula in the upward rotation direction using the orthopedic belt, the fixing device located under the chair and the scapula were connected to the orthopedic belt at an angle of 45°. At this time, the angle of the scapula was rotated 45° upward, so that the scapula was not elevated but resisted in the SUR direction (Figure 2).

Wall slide (WS)

The subject stood facing the wall, spreading his feet as wide as his shoulders, putting a foot on the wall and a foot behind. In the starting position, the medial side of the forearm was touching the wall, and the shoulder was flexed at 90° and horizontally abducted at 45° in the scapular plane. The elbow was flexed at 90°. Subjects were instructed to push their arms over the wall. When the shoulder flexion angle reached 145°, the sliding movement was ended. The subject was instructed to lift both arms until the elbow did not push the target bar but touched it slightly and to maintain the position of the arm for 5 seconds at the end position (Hardwick et al, 2006) (Figure 3).

Push-up plus (PUP)

The PUP exercise started from a standard push-up position, in which the both arms were opened to the shoulder width and the upper body was maintained in a straight line. PUP refers to the action of protracting the shoulder from the end of a normal push-up, with the elbow fully up. The subjects were kept in motion for 5 seconds at this plus phase. Something to note when carrying out this exercise is that the back should not be bent too much (Ludewig et al, 2004) (Figure 4).

Figure 1. Scapular with orthopaedic belt.

Figure 2. Scapular upward rotation (SUR).

Statistical analysis

Variables were normally distributed, as determined by Kolmogorov-Smirnov tests; thus, parametric statistics were used. Data of this study were expressed as mean±standard deviations. Statistical analyses were done with SPSS ver. 24.0 (SPSS Inc., Chicago, IL, USA). After half the data (n=15) was collected, a power analysis was done to calculate the number of subjects needed to determine a clinically meaningful difference between exercises. The number of subjects chosen was calculated using G*Power Software (University of Kiel, Berlin, Germany) and was based on an effect size of .25 standard deviation (SD) with an α level of .05 and power at .92. One-way repeated-measures analyses of variance with 1 with-

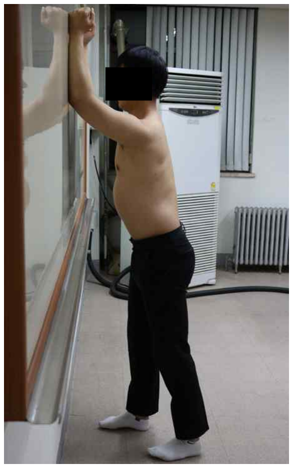

Figure 3. Wall slide (WS).

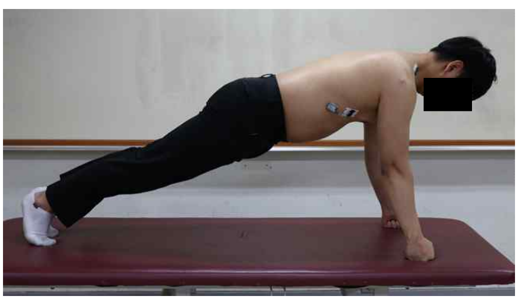

Figure 4. Push-up plus (PUP).

in-subject factor (exercise) were used to compare the muscle activity of the SA and UT muscles according to the 3 exercises.

Results

Serratus anterior muscle activation

The SA muscle activity was 49.77 %MVIC when the PUP exercise was performed. In the case of the WS exercise, the SA muscle activity showed 65.01 %MVIC. When the SUR exercise was performed, the muscle activity was 79.88 %MVIC. The SUR exercise showed significantly higher SA muscle activity than the WS exercise (p=.026) and the PUP exercise (p<.001). Additionally, the WS exercise showed significantly higher muscle activity than the PUP exercise (p=.025) (Table 2)(Figure 5A).

Upper trapezius muscle activation

The UT muscle activity was 7.86 %MVIC when the PUP exercise was performed. In the case of the WS exercise, the UT muscle activity showed 9.98 %MVIC, and when the SUR exercise was performed, the UT muscle activity was 47.53 %MVIC. The SUR exercise showed significantly higher UT muscle activity than the WS exercise (p<.001) and the PUP exercise (p<.001). However, there was no significant difference in UT muscle activity between the WS and PUP exercises (p=.396) (Table 2)(Figure 5B).

Discussion

The SUR is a motion caused by the synergistic contraction of the SA, the UT, and other muscles (Escamilla and Andrews, 2009; Johnson et al, 1994). However, imbalance between these muscles can lead to shoulder structural deformation (Ludewig and Cook, 2000; Lukasiewicz et al, 1999). Ludewig and Cook (2000) found that while the arm was elevated along the scapular plane, the average SA muscle activity of the normal group was between 30 and 50 %MVIC, while the UT muscle activity ranged from 15 to 20 %MVIC. Conversely, on average in the group with shoulder impingement, the SA showed muscle activity from less than 20 to 40 %MVIC, while the UT muscle activity ranged from 22 to 30

Table 2. Mean muscle activity for three exercises (Unit: %MVIC)

Exercises	Serratus anterior	Upper trapezius
SUR[a]	79.88±34.43[b]	47.53±35.36
WS[c]	65.01±30.98	9.98±7.92
PUP[d]	49.77±15.96	7.86±5.47

[a]scapular upward rotation, [b]mean±standard deviation, [c]wall slide, [d]push-up plus.

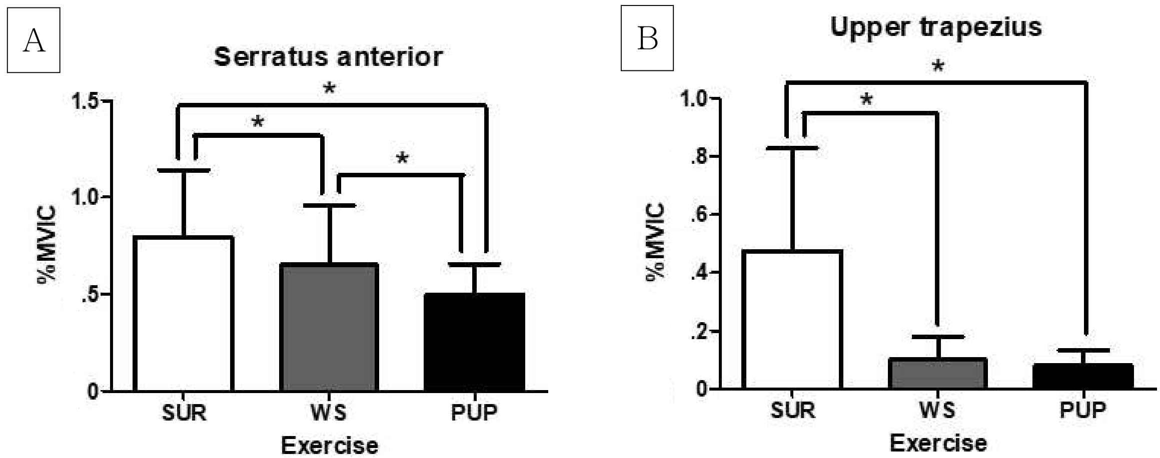

Figure 5. Comparison EMG activity during three exercises. *p<.05, (A) SA (B) UT (SA: serratus anterior, UT: upper trapezius, SUR: scapular upward rotation, WS: wall slide, PUP: push-up plus, MVIC: maximal voluntary isometric).

%MVIC. When the arms were raised with 4 to 6 ㎏ dumbbells, the normal group showed UT muscle activity from 53 to 64 %MVIC, whereas the group with shoulder impingement showed significantly higher UT muscle activity, from 56 to 78 %MVIC (Ludewig and Cook, 2000). Given the above results, the decreased SA muscle can cause compensatory hyperactivity of the UT muscle and cause shoulder lesions (Cram, 2003; Edgerton et al, 1996). For this reason, a great deal of research has been conducted on methods for maximizing muscle activity of the SA while maintaining moderate activity of the UT (Decker et al, 1999; Ekstrom et al, 2004; Hardwick et al, 2006; Ludewig et al, 2004).

We found that the SA muscle activity was the highest when performing the SUR exercise (79.88 %MVIC); when performing the WS exercise, it showed 65.01 %MVIC, and the lowest muscle activity occurred when the PUP exercise was performed (49.77 %MVIC). The UT showed higher muscle activity during the SUR exercise (47.53 %MVIC) than the WS exercise (9.98 %MVIC), and significantly higher muscle activity during the SUR exercise than the PUP exercise (7.86 %MVIC). However, there was no significant difference in the UT muscle activity when the WS and PUP exercises were compared.

In a previous study performed by Hardwick et al (2006), although the SA exhibited various levels of muscular activity according to the angle of the humerus, the maximum muscle activity exhibited during the WS exercise was 75.7 %MVIC. In addition, in the above study, the SA muscle activity was barely over 31.3 %MVIC when the PUP exercise was performed (Hardwick et al, 2006). One notable fact is that it showed the highest muscle activity when elevating the shoulder in the scapular plane. When the shoulder angle reached 140° in the scapular plane, SA muscle activity was up to 82.4 %MVIC (Hardwick et al, 2006). Other studies that measured SA muscle activity when performing various exercises showed that when the shoulder was flexed more than 125° or the shoulder was abducted more than 125° in the scapular plane, the SA muscle activity of the MVIC was 91 and 89%, respectively (Ekstrom et al, 2005). However, when performing the above actions, the UT muscle activity was 83 and 77 %MVIC, respectively, which was quite high (Ekstrom et al, 2005).

When interpreting the results of this study, the following explanations can be made. First, based on the results of the above studies, it seems necessary to elevate the arms more than 125° to elicit high muscle activity of the SA (Ekstrom et al, 2003; McCann et al, 1993). However, this motion has been shown to increase the UT muscle activity of the synergistic muscles of the SUR. Nevertheless, we could use the orthopedic belt to resist the upward rotation of the scapula and limit the elevation movement, which would result in higher muscle activity of the SA, with lower muscle activity of the UT than other exercises performed with an angle of the shoulder greater than 125°. Another reason for this was that the WS movement could be difficult to provide enough resistance with the wall against the arm-raising force (Hardwick et al, 2006). For this reason, previous studies dealing with the WS did not show a high SA muscle activity during the exercise (Hardwick et al, 2006). In addition, the PUP exercise had a strong resistance due to the direction of the force acting on the force and the direction of the gravity acting on the resistance in the opposite direction, but since it did not involve the elevation of the upper arm, it would be difficult to produce the maximum muscle activity of the SA (Lehman et al, 2008; Ludewig et al, 2004).

The results of our study show that the muscle activity of the SA was close to 80 %MVIC and the muscle activity of the UT was only about 50 %MVIC during the SUR exercise. Although the muscle activity of the UT during the SUR exercise was significantly higher than that of the other 2 exercises, previous studies have shown that the UT muscle activity must also be close to its maximum value in order to reach the maximum value of the SA muscle activity; therefore, it may be effective to increase muscle activity of the SA for strengthening of the SA (Decker et al, 1999; Ekstrom et al, 2005).

This study has some limitations. First, only young people of the same sex participated in the study. Thus, this result cannot be relied on for subjects of other sexes or elderly persons. In addition, since this study was conducted on healthy subjects, it is not known what type of muscle activity will occur in subjects who are suffering from shoulder disease, such as shoulder impingement syndrome or SLAP lesions.

Conclusion

The WS and PUP exercises can selectively activate the muscles, but they exhibit relatively low muscle activity of the SA compared to the MVIC. Maximal muscle activity of the SA can be achieved through the SUR exercise, which can also enhance SUR motion. The SUR exercise may involve UT muscle contraction with a relatively high MVIC, but it may drive the SA muscle to maximum muscle activity.

References

Andersen LL, Magnusson SP, Nielsen M, et al. Neuromuscular activation in conventional therapeutic exercises and heavy resistance exercises: Implications for rehabilitation. Phys Ther. 2006;86(5):683-697.

Ayotte NW, Stetts DM, Keenan G, et al. Electromyographical analysis of selected lower extremity muscles during 5 unilateral weight-bearing exercises. J Orthop Sports Phys Ther. 2007;37(2):48-55.

Cram JR. The history of surface electromyography. Appl Psychophysiol Biofeedback. 2003;28(2):81-91.

Criswell E. Cram's Introduction to Surface Electromyography. 2nd ed. Sudbury, Jones and Bartlett Publishers, 2010:289-299.

David G, Magarey M, Jones M, et al. Emg and strength correlates of selected shoulder muscles during rotations of the glenohumeral joint. Clin Biomech (Bistol, Avon). 2000;15(2):95-102.

Decker MJ, Hintermeister RA, Faber KJ, et al. Serratus anterior muscle activity during selected rehabilitation exercises. Am J Sports Med. 1999;27(6):784-791.

Edgerton VR, Wolf SL, Levendowski DJ, et al. Theoretical basis for patterning emg amplitudes to assess muscle dysfunction. Med Sci Sports Exer. 1996;28(6):744-751.

Ekstrom RA, Bifulco KM, Lopau CJ, et al. Comparing the function of the upper and lower parts of the serratus anterior muscle using surface electromyography. J Orthop Sports Phy Ther. 2004;34(5):235-243.

Ekstrom RA, Donatelli RA, Soderberg GL. Surface electromyographic analysis of exercises for the trapezius and serratus anterior muscles. J Orthop Sports Phy Ther. 2003;33(5):247-258.

Ekstrom RA, Soderberg GL, Donatelli RA. Normalization procedures using maximum voluntary isometric contractions for the serratus anterior and trapezius muscles during surface emg analysis. J Electromyogr Kinesiol. 2005;15(4):418-428.

Escamilla RF, Andrews JR. Shoulder muscle recruitment patterns and related biomechanics during upper extremity sports. Sports Med. 2009;39(7):569-590. https://doi.org/10.2165/00007256-200939070-00004.

Gregg JR, Labosky D, Harty M, et al. Serratus anterior paralysis in the young athlete. J Bone Joint Surg Am. 1979;61(6):825-832.

Hardwick DH, Beebe JA, McDonnell MK, et al. A comparison of serratus anterior muscle activation during a wall slide exercise and other traditional exercises. J Orthop Sports Phy Ther. 2006;36(12):903-910.

Inman VT, Abbott LC. Observations of the function of the shoulder joint. Clin Orthop Reat Res. 1996;330:3-12.

Jobe FW, Moynes D, Brewster C. Rehabilitation of shoulder joint instabilities. Orthop Clin North Am. 1987;18(3):473-482.

Johnson G, Bogduk N, Nowitzke A, et al. Anatomy and actions of the trapezius muscle. Clin Biomech (Bristol, Avon). 1994;9(1):44-50. https://doi.org/10.1016/0268-0033(94)90057-4

Lehman GJ, Gilas D, Patel U. An unstable support surface does not increase scapulothoracic stabilizing muscle activity during push up and push up plus exercises. Man Ther. 2008;13(6):500-506.

Levangie PK, Norkin CC. Joint Structure and Function: A comprehensive analysis. 4th ed. Philadelphia, PA, FA Davis, 2005:258-265.

Ludewig PM, Cook TM. Alterations in shoulder kinematics and associated muscle activity in people with symptoms of shoulder impingement. Phys Ther. 2000;80(3):276-291.

Ludewig PM, Cook TM, Nawoczenski DA. Three-dimensional scapular orientation and muscle activity at selected positions of humeral elevation. J Orthop Sports Phy Ther. 1996;24(2):57-65.

Ludewig PM, Hoff MS, Osowski EE, et al. Relative balance of serratus anterior and upper trapezius muscle activity during push-up exercises. Am J Sports Med. 2004;32(2):484-493.

Lukasiewicz AC, McClure P, Michener L, et al. Comparison of 3-dimensional scapular position and orientation between subjects with and without shoulder impingement. J Orthop Sports Phy Ther. 1999;29(10):574-583.

McCann PD, Wootten ME, Kadaba MP, et al. A kinematic and electromyographic study of shoulder rehabilitation exercises. Clin Orthop Relat res. 1993;288:179-188.

McQuade KJ, Dawson J, Smidt GL. Scapulothoracic muscle fatigue associated with alterations in scapulohumeral rhythm kinematics during maximum resistive shoulder elevation 1. J Orthop Sports Phy Ther. 1998;28(2):74-80.

Pappas AM, Zawacki RM, Mccarthy CF. Rehabilitation of the pitching shoulder. Am J Sports Med. 1985;13(4):223-235.

Peat M, Grahame RE. Electromyographic analysis of soft tissue lesions affecting shoulder function. Am J Phys Med. 1977;56(5):223-240.

Peterson-Kendall F, Kendall-McCreary E, Geise-Provance P, et al. Muscles Testing and Function With Posture and Pain. 5th ed. Baltimore: MD, Lippincott Williams and Wilkins, 2005:330-332.

Sahrmann S. Diagnosis and Treatment of Movement Impairment Syndromes. 1st ed. St. Louis, Mosby, 2002:228-255.

Soderberg GL, Knutson LM. A. guide for use and interpretation of kinesiologic electromyographic data. Phys Ther. 2000;80(5):485-498.

Watson CJ, Schenkman M. Physical therapy management of isolated serratus anterior muscle paralysis. Phys Ther. 1995;75:194-194.

Yoshizaki K, Hamada J, Tamai K, et al. Analysis of the scapulohumeral rhythm and electromyography of the shoulder muscles during elevation and lowering: Comparison of dominant and nondominant shoulders. J Shoulder Elbow Surg. 2009;18(5):756-763. https://doi.org/10.1016/j.jse.2009.02.021

This article was received September 29, 2017, was reviewed September 29, 2017, and was accepted November 1, 2017.