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Comparative Effect of Modified Shrug Exercises With and Without Trunk Stabilization Exercise on Scapular Upward Rotator EMG and Thickness in Subjects With Scapular Downward Rotation Syndrome

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Abstract

Background: Scapular downward rotation syndrome (SDRS) is a common scapular alignment impairment that causes insufficient upward rotation and muscle imbalance, shortened levator scapulae (LS) and rhomboid, and lengthened serratus anterior (SA) and trapezius. A modified shrug exercise (MSE), performing a shrug exercise with the shoulders at 150° abduction, is known as an effective exercise to increase scapular stabilizer muscle activation. Previous studies revealed that scapular exercise are more effective when combined with trunk stabilization exercises in decreasing scapular winging and increasing scapular stabilizer muscle activation.

Objects: The purpose of our study was to clarify the effect of MSE with or without trunk stabilization exercises in subjects with SDRS.

Methods: Eighteen volunteer subjects (male=10, female=8) with SDRS were recruited for this experiment. All subjects performed MSE under 3 different conditions: (1) MSE, (2) MSE with an abdominal draw-in maneuver (ADIM), and (3) MSE with an abdominal expansion maneuver (AEM). The muscle thickness of the lower trapezius (LT) and the SA were measured using an ultrasonography in each condition. Electromyography (EMG) data were collected from the LT, LS, SA, and upper trapezius (UT) muscle activities. Data were statistically analysed using one-way repeated analysis of variance at a significance level of .05.

Results: The muscle thickness of the LT and the SA were the significant different in the MSE, MSE with ADIM (MSE+ADIM) and MSE with AEM (MSE+AEM) conditions ($p<.05$) In both LT and SA, the order of thick muscle thickness was MSE+AEM, MSE+ADIM, and MSE alone. No significant differences were found in the EMG activities of the SA, UT, LS, and LT in all condition.

Conclusion: In conclusion, MSE is more beneficial to people with SDRS when combined with trunk stabilization exercises by increased thickness of scapular stabilizer muscles.

Key Words: Abdominal draw-in maneuver; Abdominal expansion maneuver; Scapular downward rotation syndrome; Shoulder rehabilitation; Shrug exercise.

Introduction

In typical scapular alignment, the vertebral border of the scapular and the vertebral spine are parallel, and the average distance between the vertebral border of the scapular and the midline of the thoracic spine is about three inches (Sahrmann, 2002). Excessive downward rotation, elevated, depressed, abducted, adducted, or winged scapulae are the frequently observed scapular alignment impairments (Kendall et al,

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1983). Scapular downward rotation syndrome (SDRS) describes an atypical alignment of the scapula in which the inferior border of the scapular is positioned more centrally than the superior border of the scapula, thus positioning the shoulder lower with a downward slope at the acromial end (Caldwell et al, 2006). Persons with SDRS tend to demonstrate insufficient upward rotation, shortened levator scapulae (LS) and rhomboids, weak and lengthened serratus anterior (SA) and trapezius, and a muscle imbalance between the scapular upward and downward rotators (Sahrmann, 2002).

The shrug exercise, the most common therapeutic exercise used for SDRS, is targeted to strengthen the trapezius muscles (Burkhead and Rockwood , 1992; Ekstrom et al, 2003; Hintermeister et al, 1998; Pizzari et al, 2014). However, it has been reported that performing the shrug exercise in the traditional way (with the arms at the side of the trunk) strengthens the LS rather than the trapezius muscles, especially the upper trapezius (UT) (Moseley et al, 1992; Smith et al, 2004). Choi et al (2015) examined the effects of the shrug exercise while subjects with SDRS performed shrug exercises at three different shoulder abduction positions. They measured the scapular downward rotation index (SDRI) and electromyography (EMG) activation of the UT, LS, SA, and lower trapezius (LT) muscles and found that the shrug exercise at 150° of shoulder abduction was effective for eliciting greater SA and LT muscle activity, decreased SDRI, and improved muscle balance among the UT, LS, SA, and LT compared with 30° and 90° shoulder abduction conditions. Additionally, Choi et al (2015) recommended performing shrug exercises at 150° of shoulder abduction for people with relatively weak scapular upward rotators, especially SA and LT.

The abdominal draw-in maneuver (ADIM) has been widely used in clinics to increase lumbo-pelvic stability through selective activation of the transverse abdominis and internal oblique muscles (Macedo et al, 2009). The ADIM is also commonly performed during arm and leg exercises to increase the stability of the lumbopelvic area. A prior study reported that the effects of scapular stabilizer (UT, SA, and LT) activities were significantly greater when the scapular exercise was superimposed onto the ADIM than when performing the scapular exercise alone (Kim et al, 2017). As activation of the abdominal muscles might affect the scapular muscle activity through the myofascial connections in the trunk, the abdominal expansion maneuver (AEM) was used to increase the stability of the deep trunk muscle and the lumbopelvic posture (Myers, 2009; Kim et al, 2012). Subjects were requested to hold their navel anteriorly and downwardly while expanding the lower abdomen but not the thoracic cage (Yoon et al, 2015). More recently, many studies have revealed a positive effect of AEM, indicating that AEM facilitates the co-contraction of the diaphragm and the deep spinal stabilizer muscles and increases the intra-abdominal pressure (Lee and Kim, 2015; Yoon et al, 2015).

However, no previous studies have compared ADIM and AEM with the shrug exercise in subjects with SDRS. Based on the findings of Choi et al (2015)'s experiment, we perform the shrug exercise at 150° of shoulder abduction, which we name the modified shrug exercise (MSE). The purpose of our study is to clarify the effect of MSE with and without trunk stabilization exercises (ADIM or AEM) in subjects with SDRS. More specifically, we aim to determine which trunk stabilization exercise is more effective at enhancing and normalizing scapular muscle activation during the MSE.

Methods

Subjects

Eighteen (10 males and 8 females) subjects with SDRS were recruited from community and university populations. The mean age of the subjects was 22.8 years (20-26 years). Prior to this study, we examined 70 people to select subjects with SDRS. Based

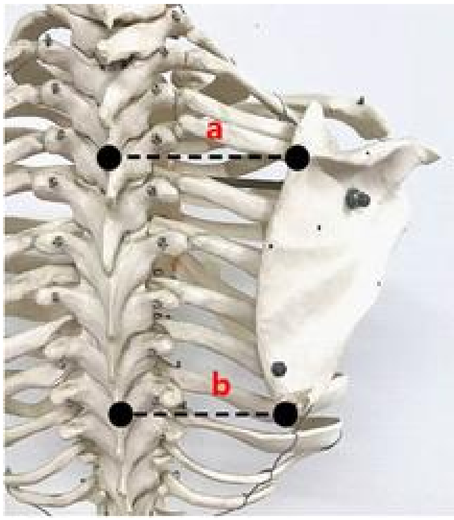

Figure 1. Scapular downward rotation index (a): distance between root of the scapular spine and spinous process in same level of the scapular spine, (b): distance between inferior angle of scapula and spinous process in same level of the inferior angle.

on previous studies, we use the following inclusion criteria: (1) medial border of scapula is not parallel to thoracic spine, (2) a scapula abduction angle less than 60° during full shoulder abduction, (3) distance from the thoracic spine to medial boarder of the scapula is less than three inches, and (4) SDRI is greater than 10 (Figure 1.) (Lee et al, 2016). The exclusion criteria were (1) subjects with downward rotation syndrome due to a neurological problem; (2) a history of injury or surgery of the shoulder, trunk, and neck; (3) a positive result for the apprehension test; and (4) a positive result for the upper limb tension test. All subjects read an explanation about the experimental procedures and signed an informed consent form approved by the Yonsei University Wonju Institutional Review Board (approval number: 1041849-201705-BM-053-02).

Instrumentation

Surface electromyography (EMG)

Noraxon TeleMyo 2400T (Noraxon Inc., Scottlsdale, AZ, USA) was used to collect EMG signals from the UT, LS, SA, and LT muscles. The skin area was shaved and cleaned using rubbing alcohol. Bipolar surface electrodes (Ag/AgCl) were adhered at a 2 ㎝ inter-electrode distance. Electrodes for the UT were placed slightly laterally to and one-half the distance between the cervical spine at C-7 and the acromion. Electrodes for the SA were determined by palpation while the patient flexed the arm against resistance; they were placed just anterior to the border of the latissimus dorsi muscle at the level of the inferior tip of the scapula. The LT EMG electrode site was determined by palpating the inter-scapular region while the subjects flexed the arm to at least 90° of scapular retraction and depression. Electrodes were placed at an oblique angle, approximately 5㎝ down from the scapular spine. Electrodes of the LS were placed between the anterior margin of the UT and the posterior margin of the sternocleidomastoid (Criswell, 2010; Ludewig et al, 1996). EMG data were analyzed using Noraxon MyoResearch 1.06 software. The sampling rate was 1000 ㎐. A bandpass filter between 20 and 450 ㎐ was used. EMG data were processed into the root- mean-square with a window of 50 ㎳.

Subjects were asked to perform maximum voluntary isometric contraction (MVIC) for 5 s for each muscle to normalize the EMG data of each muscle in individual. MVIC was repeated three times with intervals of 5 s between trials. The average value of three attempts was used for each subject's final MVIC. A specific test position for the MVIC was selected based on Kendall et al (1983).

Ultrasonography measurement

Ultrasonography (Mysono U6, Medison, Seoul, Korea) was used to capture the linear depth of the LT and SA in each MSE condition. Before conducting the measurement, we identified the target muscles and placed the ultrasound (US) transducer at the scapular inferior angle at the same level as the vertebrae spine (O'sullivan et al, 2007). The thickness of the SA was measured between the pectoralis major and latissimus dorsi on a rib angle at the same level as the scapular inferior angle (Basmajian, 1983; Cuadros et al, 1995; Day and Uh, 2013). A 5-12㎒ linear transducer was placed transversely to measure the LT and vertically along the SA area. Screen calipers, which come with mysono U6, were used to measure the muscle thickness. The LT muscle thickness measurement was determined by the thickness value of a part 2 ㎝ away from the spinous process on the same level (O'sullivan et al, 2007). The SA thickness was measured from the superior border of the rib to the inside portion of the muscle border. The distance of the five parts, spanning the width of the rib, was measured and the average value was obtained and analyzed (Day and Uh, 2013).

Experimental procedure

In this study, the subjects performed the MSE under three different conditions in a random order. After receiving a verbal explanation of the experimental procedures, the subjects familiarized themselves with the MSE and the MSE combined with trunk stabilization exercises (ADIM and AEM).

First at all, the subjects were asked to perform the MSE by elevating their shoulders to an abduction of 150° in sitting position on a backless chair and then shrug their shoulders as hard as they could. In the way of doing MSE with ADIM (MSE+ADIM), prior to initiating the MSE, the subjects were asked to pull their navel toward the spine and shrug their shoulders as hard as they could. The subjects maintained the shoulder muscle contraction for 5 seconds while maintaining the ADIM. In MSE with AEM (MSE+AEM) condition, they expanded the lower abdomen and pushed their navel in an anterior-inferior direction (toward the symphysis pubis) without lateral expansion of the rib cage. This method allowed the subject to achieve co-contraction of the diaphragm and deep spinal stabilizer muscles and increase the intra-abdominal pressure (Yoon et al, 2015). No chest movements were allowed during the AEM. They performed the MSE while maintaining the AEM.

These process were repeated three times in each conditions with a rest of 5 seconds between the trials. To confirm the contraction of the TrA muscle in all conditions, the examiner palpated the subject's abdominal wall and utilized a visual bio-feedback using the US. While subjects conducted the exercises, the examiner measured the SA and LT muscle thicknesses and the UT, LS, SA, and LT activities to record any changes in muscle activation and thickness. EMG data were collected during the middle 3 seconds period while the subjects maintained the MSE for 5 seconds.

Table 1. Muscle thickness

Muscle	Exercise conditions	muscle thickness (Mean±SD[a])
Serratus anterior	MSE[b]	.68±.26
	MSE+ADIM[c]	.8±.33
	MSE+AEM[d]	.88±.26
Lower trapezius	MSE	.39±.19
	MSE+ADIM	.42±.22
	MSE+AEM	.57±.22

[a]modified shrug exercise, [b]modified shrug exercise with abdominal draw-in maneuver, [c]modified shrug exercise with abdominal expansion maneuver, [d]standard deviation.

Statistical analysis

The data were analyzed using Windows SPSS version 24.0 (SPSS Inc., Chicago, IL, USA). A one-way repeated analysis of variance (ANOVA) was used to compare the muscle thickness and muscle activities in the three conditions. The Bonferroni test was used for the post-hoc analysis, and the significance level was set at .05.

Results

First, the muscle thickness of the LT and SA were found to be significantly different across the conditions ($p<.05$) (Figure 2)(Table 1). The thickness of the SA was greatest in the MSE+AEM condition and decreased toward the MSE+ADIM and MSE conditions ($p<.05$). The post-hoc analysis revealed that the SA muscle thicknesses were significantly

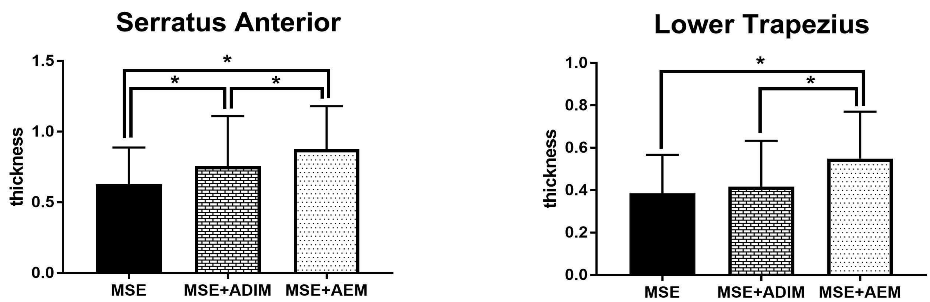

Figure 2. muscle thickness of serratus anterior and lower trapezius (MSE: modified shrug exercise, MSE+ADIM: modified shrug exercise with abdominal draw-in maneuver, MSE+AEM: modified shrug exercise with abdominal expansion maneuver).

different in all paired comparisons (p<.05). The Thickness of the LT was also greatest in the MSE+AEM condition and decreased toward the MSE+ADIM and MSE conditions. However, the post-hoc analysis revealed that the LT muscle thickness in the MSE+ADIM was not statistically greater than that in the MSE condition (p<.05).

EMG amplitudes of the scapular upward rotators (UT, SA, and LT) were greater when the MSE was combined with the trunk muscle stabilization exercise than when the MSE was performed alone. However, for the LS, the downward rotator, the muscle activity was greatest when the MSE was performed without the trunk muscle exercise. Nevertheless, amplitudes of the EMG activities of all measured muscles were not statistically different among the three conditions (p<.05) (Figure 3)(Table 2).

Discussion

The purpose of this study was to clarify the effect of the MSE with and without trunk stabilization exercises (ADIM and AEM) in subjects with SDRS. To our knowledge, this study is the first to evaluate the muscle thickness and activity of the UT, LS, SA, and LT muscles during the MSE with and without trunk stabilization exercises for subjects with SDRS. The main findings of this study indicate that, combining the MSE with trunk stabilization exercises

Table 2. Surface EMG amplitude (Unit: %MVIC)

Muscle	Exercise conditions	%MVIC[a] (Mean±SD[b])
Upper trapezius	MSE[c]	49.84±52.47
	MSE+ADIM[d]	54.57±47.63
	MSE+AEM[e]	62.92±37.29
Levator scapulae	MSE	45.02±57.14
	MSE+ADIM	38.42±29.09
	MSE+AEM	39.9±37.16
Serratus antreior	MSE	45.03±25.5
	MSE+ADIM	53.33±59.3
	MSE+AEM	54.59±36.12
Lower trapezius	MSE	19.68±24.21
	MSE+ADIM	39.88±24.83
	MSE+AEM	46.31±42.15

[a]maximal voluntary isometric contraction, [b]mean±standard deviation, [c]modified shrug exercise, [d]modified shrug exercise with abdominal draw-in maneuver, [e]modified shrug exercise with abdominal expansion maneuver.

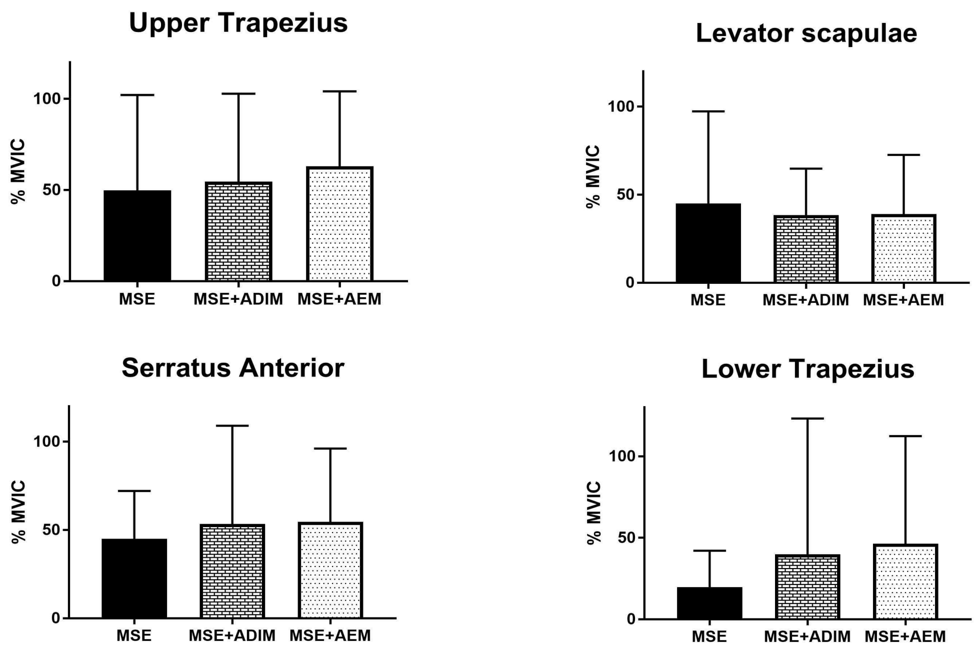

Figure 3. muscle activation of upper trapezius, levator scapulae, serratus anterior and lower trapezius. (MSE: modified shrug exercise, MSE+ADIM: modified shrug exercise with abdominal draw-in maneuver, MSE+AEM: modified shrug exercise with abdominal expansion maneuver, MVIC: maximal voluntary isometric contraction)

tends to increase the muscle activities and thicknesses of the scapular upward rotators (UT, SA, and LT) and decrease the muscle activity of the scapular downward rotator (LS). In terms of changes in muscle thicknesses of the SA and LT during the MSE, the MSE+AEM condition was most effective, followed by the MSE+ADIM condition and MSE alone.

The tendency to increase the scapular upward rotator EMG activities and the statistical increase of muscle thickness in SA and LT during the MSE combined with trunk stabilization exercises were the main findings of this study. We are unable to reveal any significant differences in the EMG activities among the MSE conditions, which was likely because of the small number of subjects and relatively large variability within the EMG data. However, the results of this study are consistent with previous findings by Kim et al (2017), ADIM greatly increased the activation of SA during push-ups plus exercise. It can be partially explained by the synergistic relationship between core stabilizers and scapular stabilizer muscles via thoracolumbar fascia. Thoracolumbar fascia, which consists of anterior, middle, and posterior layers, has an important biomechanical function in transferring the energy and load between the upper and lower extremities, between the right and left sides of the body, and between the abdominal wall and lumbo-pelvic area (Vleeming et al, 2014). The posterior layer of the thoracolumbar fascia consists of deep and superficial lamina. The superficial lamina is comprised of a fascia cover that includes muscles such as the rhomboids, pectoralis major and minor, trapezius, SA, latissimus dorsi, and gluteus maximus (Willard et al, 2012). Therefore, a synergetic relationship exists between the core stabilizers, originating from the deep lamina, and the scapular stabilizers, originating from the superficial lamina (Kanik et al, 2017). For these reasons, the SA and LT thicknesses might increase more when performing the MSE with trunk stabilization exercises than when performing MSE alone.

A previous study by Choi et al (2015) stated that the SA and LT of subjects with SDRS were most facilitated during the shrug exercise at 150° of shoulder abduction. Based on their recommendation, we conducted this experiment to increase the involvement of SA and LT during the shrug exercise. We named the shrug exercise at 150° of shoulder abduction the MSE. Because the UT is shortened in length at 150° of shoulder abduction, the MSE is mechanically less advantageous for the UT in generating power compared to at 90° of shoulder abduction. The maximal muscle activity of the UT is achieved at 90° of shoulder abduction because both the lever arm of the UT and the external moment arm were longest at 90° of shoulder abduction (Moseley JR et al, 1992). However, the level of the UT increased by performing the MSE and the trunk muscle activation simultaneously. Therefore, adding trunk muscle stabilization exercises to the MSE considerably enhances the use of all measured upward rotators.

Conclusion

MSE for people with SDRS at 150° of shoulder abduction more effectively facilitates the use of the upward rotator thickness when combined with trunk stabilization exercises. Therefore, training the trunk stabilizer muscles and performing the shrug exercise is recommended in shoulder rehabilitation. Future studies should investigate why the AEM is more effective than the ADIM.

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