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Shrug exercises combined with shoulder abduction improve scapular upward rotator activity and scapular alignment in subjects with scapular downward rotation impairment

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ABSTRACT

The aim of this research was to investigate which shoulder abduction angle (30°, 90°, 150°) during shrug exercise is superior for (1) activating the scapular upward rotators and (2) improving scapular and clavicular position in subjects with scapular downward rotation impairment. Twenty subjects performed shrug exercises at three different shoulder abduction angles (30°, 90°, 150°) which were obtained and maintained actively. Surface EMG data were collected from the levator scapulae (LS), upper trapezius (UT), lower trapezius (LT), and serratus anterior (SA) during shrug exercises. Scapular downward rotation index (SDRI) and clavicular tilt angle (CTA) were measured immediately after each shrug exercise. One-way repeated-measures analysis of variance was used to determine the significance. UT muscle activity was greater at 90° and 150° than at 30° of shoulder abduction. UT/LS muscle activity ratio was greater at 90° than at 30°. LT and LT/LS increased as shoulder abduction angle increased. SA was greater at 150° than at 30° or 90°. SA/LS was greater at 150° than at 30°. SDRI was lower at 90° and 150° than at 30°. CTA was greater at 90° and 150° than at 30°. In conclusion, shrug exercises at 90° or 150° of shoulder abduction angle may be advocated to activate scapular upward rotators, decrease SDRI, and increase CTA in patients with scapular downward rotation impairment.

1. Introduction

The scapula is anatomically and biomechanically critical for optimal functioning of the shoulder joint (Bunch and Siegel, 1993; DiVeta et al., 1990; Kibler and McMullen, 2003; Solem-Bertoft et al., 1993). Normal scapular alignment is described as the vertebral border of the scapula being parallel to the spine and positioned approximately three inches from the midline of the thorax (Sobush et al., 1996). Alterations in the normal position of the scapula are responsible for pathologies related to shoulder pain, resulting in interference with the scapulohumeral rhythm during arm movement (Azevedo et al., 2008; Hebert et al., 2002; Kibler and McMullen, 2003; Reinold et al., 2009). Impairment in scapular alignment has known causative factors including muscle imbalances, such as in the resting lengths of the muscles (Caldwell et al., 2007; Kibler and Sciascia, 2010; Sahrmann, 2002).

Scapular downward rotation syndrome is a common scapular alignment impairment (Sahrmann, 2002). Scapular downward rotation impairment occurs when the vertebral border is not parallel to the spine; instead, the inferior angle of the scapula is medial to the root of the spine of the scapula (Sahrmann, 2002). Muscle imbalance involved with scapular downward rotation impairment exists between the upward rotators and the downward rotators of the scapula (Sahrmann, 2002). Regarding the muscle length imbalance, scapular downward rotation impairment typically features shortened levator scapula (LS) and rhomboid, and lengthened upper trapezius (UT) and serratus anterior (SA) muscles (Sahrmann, 2002). Also, weakness of lower trapezius (LT) can play a substantial role in insufficient scapular upward rotation (Inman et al., 1944; Kendall et al., 1993; Reinold et al., 2009). Latency in recruitment of upward rotators during shoulder abduction has been demonstrated in subjects with decreased scapular upward rotation (Struyf et al., 2011; Wadsworth and Bullock-Saxton, 1997). Alterations in dominance among the scapular rotators can

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also compromise the muscle balance around the scapula, causing abnormalities in coordinated scapular rotation (Cools et al., 2003).

The shrug exercise has been used to strengthen trapezius muscle, especially UT, in shoulder rehabilitation programs (Fig. 1) (Burkhead and Rockwood, 1992; Ekstrom et al., 2003; Hintermeister et al., 1998; Pizzari et al., 2014). Yet, in the case of scapular downward rotation impairment, not only UT but also LT and SA are required to be activated during the exercise. It was also described that shrug exercise with the arms by the side may activate the LS rather than UT (Moseley et al., 1992; Smith et al., 2004). Thus, in order to elicit improved balance among the force couple in the movement of scapular upward rotation, modifying a shrug exercise may be attempted. There are three possible theoretical rationales for modifying the shrug exercise. First, instead of a standard shrug, completing shrug exercise in 30° of glenohumeral abduction facilitates initiation of upward rotation, resulting in increased UT muscle activity (Pizzari et al., 2014; Watson et al., 2009). Second, 90° of shoulder abduction during shrug exercise may provide maximal load to UT due to its maximal lever arm and moment arm in this arm position (Sigholm et al., 1984). Third, some authors have pointed out that the shrug should be performed with arms overhead because standard shrug may reinforce the activity of the shortened downward rotators in subject with scapular downward rotation impairment (Sahrmann, 2002). Overhead exercises have also been recommended to elicit higher trapezius muscle activity (McGarvey et al., 2013).

However, it remains unclear how the shoulder abduction angle during shrug exercises affects scapular muscle activities and kinematics of the scapula and clavicle in subjects with scapular downward rotation impairment. Therefore, the purpose of this study was to investigate which shoulder abduction angle (30°, 90°, 150°) during shrug exercise is superior for (1) activating the scapular upward rotators and (2) improving scapular and clavicular position. It was hypothesized that muscle activities of LS, UT, LT, and SA, muscle activity ratios of UT/LS, LT/LS, and SA/LS, SDRI, and CTA would differ with three different shoulder abduction angles during shrug exercises.

2. Methods

2.1. Subjects

In total, 20 subjects (12 males, 8 females) with scapular downward rotation impairment were recruited (age = 19.8 ± 1.6 years and body mass index = 20.2 ± 1.5 kg/m^2). Prior to beginning data collection, all subjects read the experimental protocol with sufficient explanation from the primary investigator and signed an informed consent form approved by the Yonsei University Wonju Institutional Review Board. A power analysis performed using the results of a pilot study with five subjects demonstrated that this study would require at least 11 subjects to satisfy α level of 0.05, power of 0.80, and effect size of 0.87 (G*power software 3.1.2; Franz Faul, University of Kiel, Kiel, Germany).

The inclusion criteria were: (1) downwardly rotated scapula determined if SDRI was over 10 (Choi et al., 2014). SDRI mean value and standard deviation was 16.9 ± 5.7 and (2) increased slope of the shoulder girdle and lower clavicular angle than normal, when clavicle was appeared to be horizontal by visual observation with palpation (Ha et al., 2011; Sahrmann, 2002). CTA mean value and standard deviation was 4.74 ± 4.37°. More downwardly rotated side (greater SDRI value) was chosen to collect the data (6 dominant and 14 non-dominant side). Exclusion criteria were: (1) not being able to perform at least 160° of shoulder abduction, (2) positive impingements test of Hawkins, Neer, and Jobe test, (3) positive apprehension test, (4) positive upper limb tension test, (5) positive Adam's forward bend test, and (6) a history of surgery or injury of the neck, shoulder, or back within 3 years.

2.2. Surface electromyography

Surface EMG was used to collect the LS, UT, LT, and SA muscle activities (TeleMyo DTS; Noraxon, Inc., Scottsdale, AZ, USA). Bipolar electrodes (Ag/AgCl) were adhered with a 2 cm inter-electrode distance after preparation of the area to reduce impedance by rubbing with alcohol, shaving the hair, and debriding the skin. The electrode placements were as follows (Criswell, 2010; Ludewig et al., 1996). LS: between the anterior margin of the upper trapezius and the posterior margin of the sternocleidomastoid muscle, UT: slightly lateral to and one-half the distance between the cervical spine at C-7 and the acromion, LT: 5 cm down from the scapular spine, next to the medial edge of scapula at a 55° oblique angle, SA: below the axillary area, at the level of inferior tip of scapula, and medial to the latissimus dorsi. EMG data were analyzed using the Noraxon MyoResearch 1.06 software. The EMG signals were amplified, band-pass filtered (20–450 Hz), and notch filtered (60 Hz). Then, the data were recorded at 1000 Hz and processed into root-mean-square with a window of 50 ms.

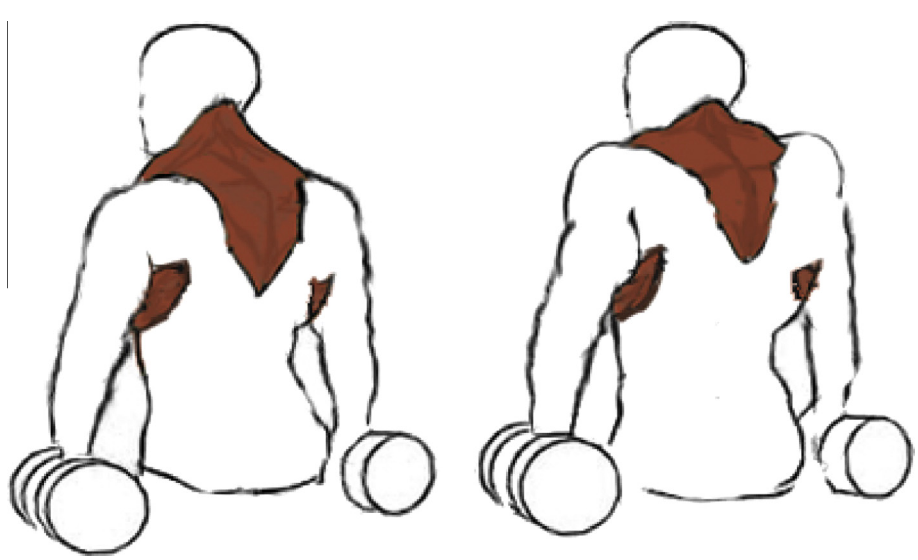

Fig. 1. Standard shrug exercise with dumbbell. Scapular upward rotators, trapezius and serratus anterior, are illustrated.

The maximal voluntary isometric contraction (MVIC) was used to normalize the EMG data of each tested muscle. To collect MVIC data, we used following positions (Kendall et al., 2005). LS: sitting, head side-bent and rotated to the test side, shoulder elevated against the resistance downwards, UT: sitting, neck posterolaterally extended and arm abducted at 90° against the resistance toward shoulder depression, LT: prone, arm in 150° of abduction and raised upwards against the resistance applied above the elbow downwards, SA: sitting, arm flexed to 90°, protract the scapula against the resistance applied over hand backwards. The mean value of middle three seconds of three trials in each muscle was taken as the MVIC. All EMG data were expressed as percentages of MVIC.

2.3. Procedures

Subjects underwent a familiarization session for the shrug exercise at each angle of shoulder abduction for 20 minutes to achieve a proper exercise performance capability. Shrug exercises with shoulder abduction (30°, 90°, 150°) were performed in a randomized order. The randomization scheme was generated using the web site "randomization.com" (http://www.randomization.com). SDRI and CTA were measured twice by the same examiner immediately after the shrug exercises. The examiner was blinded with the shoulder abduction angle during the shrug exercise.

2.3.1. Shrug exercise

To perform the shrug exercise, subject stood with shoulder abduction at the given angle. Two white plastic poles were placed in front of both wrists for palms to face front, maintaining the external rotation of shoulder. Three lines were marked at the two white plastic poles at 30°, 90°, and 150° shoulder abduction angle, customized for each subject, so as to achieve constant shoulder abduction during the shrug exercise. Each shoulder abduction angle during the shrug exercises was obtained and maintained actively. Two target bars were located on the level of the shoulder height that was determined as 90% of maximal height the subject could achieve during the shrug exercise. Five seconds of holding shrug exercise were performed ten times. A rest time was given for five seconds between trials and ten minutes between exercises at each angle to minimize muscle fatigue or pain and to prevent any order effect (Fig. 2). Muscle activities were collected from the middle three seconds of the last two trials during the shrug exercise at each angle of shoulder abduction.

2.3.2. Scapular downward rotation index

SDRI is defined as $(a - b) \div a \times 100$. This equation includes two lineal distances. One is the perpendicular distance from the root of the scapular spine to the thoracic mid-line (a), and the other is the perpendicular distance from the inferior angle of the scapula to the thoracic mid-line (b) (Choi et al., 2014). While the subject was asked to stand still, look directly ahead, and rest arms at the sides, the examiner attached 5-mm diameter paper tape along the spinous process, from the 1st to the 12th thoracic vertebrae. Next, the examiner palpated the subject's scapula and marked two landmarks with tiny round-shaped yellow stickers: the root of the scapular spine and the inferior angle. Then, the examiner measured the lengths of the two perpendiculars from the two landmarks to the paper-tape line (Choi et al., 2014) (Fig. 3).

2.3.3. Clavicular tilt angle

CTA was defined as the angle between the line bisecting the proximal portion of the clavicle and the horizontal line (Akel et al., 2008). While subject was asked to stand still, look directly ahead, and rest arms at the sides, examiner attached tiny round-shaped yellow stickers at two landmarks: the mid-point of end of medial side of clavicle and the mid-point of end of lateral side of clavicle (Ha et al., 2013). Then, a two-dimensional camera captured a photographic image two meter away from the subject's clavicle. The CTA was calculated using the ImageJ software (Fig. 4).

2.4. Statistical analysis

Test–retest reliability of EMG data was assessed by calculating intraclass correlation coefficient (ICC), 95% confidence interval (CI) based on the following criteria: <0.69 = poor, 0.70–0.79 = moderate, 0.80–0.89 = good, and 0.90–0.99 = excellent (T'Jonck et al., 1996). We used one-way repeated-measures analysis of variance with the shoulder abduction angle (30°, 90°, 150°) as a factor to assess the significance of differences using the following dependent variables: muscle activities of LS, UT, LT, and SA, the muscle activity ratios of UT/LS, LT/LS, and SA/LS, SDRI, and CTA. The level of significance was set at $\alpha = 0.05$. Also, the Bonferroni correction was used. Cohen's *d* was calculated to express effect size with the results. All statistical analyses were performed using Statistical Package for Social Science 21 (SPSS Inc., Chicago, IL, USA).

3. Results

The test–retest reliabilities of EMG data in three shrug exercises were excellent for LS [(30°: ICC(95%CI) = 0.93(0.79–0.97), 90°: 0.97(0.92–0.99), 150°: 0.93(0.79–0.98)], UT [30°: 0.94(0.82–0.98), 90°: 0.90(0.72–0.97), 150°: 0.93(0.79–0.97)], LT [30°: 0.93(0.80–0.98), 90°: 0.92(0.77–0.97), 150°: 0.91(0.75–0.97)], and SA [30°: 0.94(0.83–0.98), 90°: 0.93(0.80–0.98), 150°: 0.95(0.86–0.98)].

3.1. Muscle activity and muscle activity ratios

LS muscle activity was not significantly different among the shoulder abduction angles during the shrug exercises ($F_{(2,18)} = 2.169$, $p = .134$). UT ($F_{(2,18)} = 16.327$, $p < .001$), LT ($F_{(2,18)} = 32.895$, $p < .001$), and SA ($F_{(2,18)} = 9.940$, $p = .004$) muscle activity and UT/LS ($F_{(2,18)} = 6.949$, $p = .008$), LT/LS ($F_{(2,18)} = 19.982$, $p < .001$), and SA/LS ($F_{(2,18)} = 4.068$, $p = .035$) muscle activity did differ significantly among the shoulder abduction angles during shrug exercise.

UT muscle activity was significantly greater at 90° ($p < .001$, ES = 0.85) and 150° ($p < .001$, ES = 0.67) than at 30°of shoulder abduction. UT/LS muscle activity ratio was significantly greater at 90° than at 30°of shoulder abduction during the shrug exercise ($p < .001$, ES = 0.60). LT muscle activity increased significantly as shoulder abduction angle increased (all $p < .001$; ES = 1.08, 1.84, and 1.35, respectively). LT/LS muscle activity ratio increased significantly as shoulder abduction angle increased (all $p < .001$, ES = 0.99, 1.05, and 0.99, respectively). SA muscle activity was significantly greater at 150° than at 30° ($p < .001$, ES = 0.96) or 90° ($p < .001$, ES = 0.74) of shoulder abduction. SA/LS muscle activity ratio was significantly greater at 150° than at 30° of shoulder abduction ($p < .001$, ES = 0.79) (Fig. 5).

3.2. Scapular downward rotation index and clavicular tilt angle

The SDRI was 13.83 ± 5.77 after the shrug exercise at 30° of shoulder abduction, 9.52 ± 6.75 after the shrug exercise at 90° of shoulder abduction, and 7.14 ± 5.51 after the shrug exercise at 150° of shoulder abduction. SDRI after the shrug exercise differed significantly among shoulder abduction angles ($F_{(2,18)} = 20.905$, $p < .001$), being lower at 90° ($p = .013$, ES = 0.61) and 150° (ES = 1.07, $p < .001$) than at 30° of shoulder abduction (Fig. 6A). The CTA was 5.65 ± 4.3° after the shrug exercise at 30° of shoulder abduction, 7.59 ± 4.65° after the shrug exercise at 90° of shoulder

Fig. 2. Start and maintenance postures of the shrug exercise at each angle (30°, 90°, 150°).

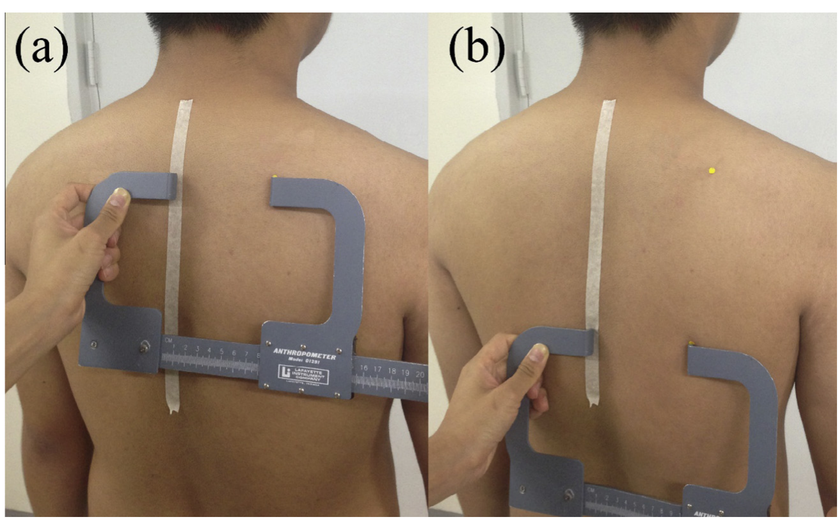

Fig. 3. Scapular downward rotation index, measuring (a) the perpendicular distance from the root of the scapular spine to the thoracic mid-line, and measuring (b) the perpendicular distance from the inferior angle of the scapula to the thoracic mid-line.

abduction, and 8.08 ± 3.87° after the shrug exercise at 150° of shoulder abduction. The CTA after shrug exercises differed significantly among shoulder abduction angles ($F_{(2,18)} = 8.654$, $p = .002$), being greater at 90° ($p < .001$, ES = 0.43) and 150° ($p < .001$, ES = 0.60) than at 30° of shoulder abduction (Fig. 6B).

4. Discussion

The first purpose of this study was to investigate the effects of shoulder abduction angle (30°, 90°, 150°) on activities of the LS, UT, LT, and SA muscles, and the UT/LS, LT/LS, and SA/LS muscle activity ratios during shrug exercises. The EMG data findings, with the exception of LS muscle activity, support our research hypothesis. While LS muscle activity showed no significant difference among the shoulder abduction angles, muscle activities of scapular upward rotators (UT, LT, and SA) exhibited significant differences among the shoulder abduction angles during shrug exercises. Also, muscle activity ratios, which are the value of scapular upward rotator (UT, LT, and SA) muscle activities divided by LS muscle activity, showed significant differences among the shoulder abduction angles during shrug exercises, showing a similar trend to the muscle activities.

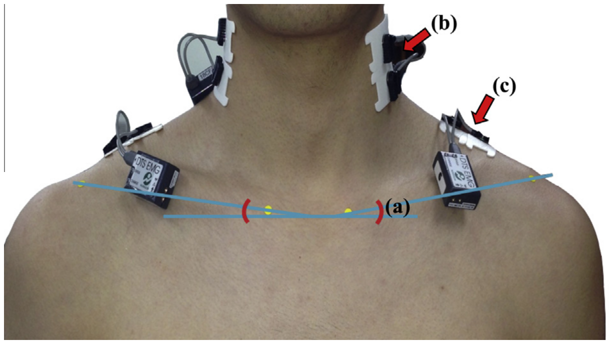

Fig. 4. Clavicular tilt angle (a), defined as the angle between a horizontal line and the line bisecting the medial and lateral end of the clavicle and measured by using software tool with the photographic image. The arrow (b) indicates the electrode placement for levator scapulae and (c) for upper trapezius.

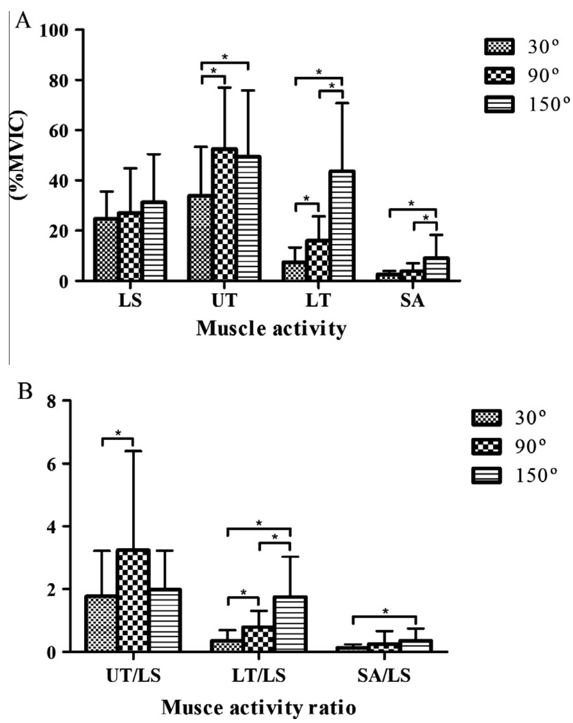

Fig. 5. (A) Muscle activities (%MVIC) in the levator scapulae (LS), upper trapezius (UT), lower trapezius (LT), and serratus anterior (SA) during shrug exercises with shoulder abductions of 30°, 90°, and 150°. (B) Muscle activity ratios of the upper trapezius (UT), lower trapezius (LT), and serratus anterior (SA) to that of the levator scapulae (LS) during shrug exercises with shoulder abductions of 30°, 90°, and 150° (* $p < .05$) (MVIC, maximal voluntary isometric contraction).

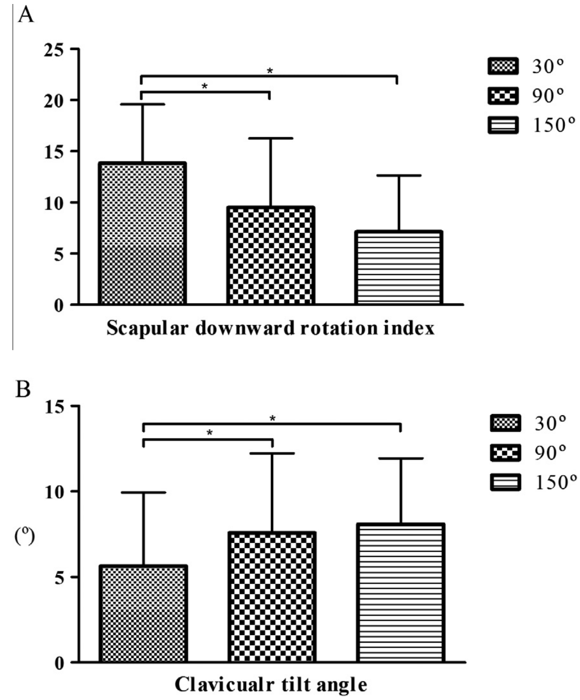

Fig. 6. (A) Scapular downward rotation indices after shrug exercises with shoulder abductions of 30°, 90°, and 150°. (B) Clavicular tilt angles after shrug exercises with shoulder abductions of 30°, 90°, and 150° (* $p < .05$).

UT muscle activity was greater at 90° (by 9.5%) and 150° (by 15.7%) than at 30° of shoulder abduction. The UT/LS muscle activity ratio was significantly greater at 90° (by 82.6%) than at 30° of shoulder abduction during the shrug exercise in the current study. Thus, 90° of shoulder abduction was found to be a favorable shoulder abduction angle for shrug exercises. The results of UT muscle activity and the UT/LS muscle activity ratio likewise showed that the UT had maximal muscle activity at 90° shoulder abduction during shoulder rehabilitation programs (Moseley et al., 1992). Higher UT activity might occur at 90° of shoulder abduction because not only the longest lever arm is produced at 90° of shoulder abduction but also 90° of shoulder abduction requires higher UT muscle force due to a longer external moment arm than at the higher shoulder abduction angle. Beyond 140° of shoulder abduction, the UT moment arm becomes shorter, while the LT and SA maintain long moment arms and continue to be activated (Kibler and McMullen, 2003). Also, the position of 90° of shoulder abduction during shrug exercises may provide maximal tension generation because at this angle of shoulder abduction, the UT is placed at a midrange length, in comparison with 30° or 150° of shoulder abduction. Additionally, the non-significant UT muscle activity difference between 90° and 150° of shoulder abduction suggests that a patient with shoulder impingement or difficulty in elevating arm further can still benefit from 90° of abduction during shrug exercises for UT muscle activation.

LT muscle activity and the LT/LS muscle activity ratio increased significantly during the shrug exercise as the shoulder abduction angle increased (greater at 90° than 30°, by 114.8%, and at 150° than 90°, by 171.3% for LT muscle activity, and greater at 90° than 30°, by 121.2%, and at 150° than 90°, by 121.9% for the LT/LS muscle activity ratio). The LT muscle participates in glenohumeral abduction minimally below 90° due to the role of LT as a stabilizer of the scapula (Ballantyne et al., 1993). According to reports that described the EMG activation pattern of the trapezius during shoulder abduction in the scapular plane (Bagg and Forrest, 1986; Neumann, 2013), the UT shows a significant rise during the initiation of shoulder abduction, then increases gradually throughout the remainder of shoulder abduction. However, LT has a trend to be activated particularly at the later range of scaption as shoulder abduction progresses beyond 90°. Bagg and Forrest (1986) explained the mechanical advantage that the LT would have during the latter half of arm elevation because of a location change in the instantaneous center of rotation of scapula from the area of the root of the scapular spine toward the acromioclavicular joint. Additionally, the significant difference in LT muscle activity may be described using anatomical principles. Pizzari et al. (2014) explained that the arrangement of the muscle fiber changed at different shoulder abduction angles, due to greater upward rotation of the scapula, rather than exhibiting a pure elevation movement. Previous researchers have reported that LT muscle activity may elicit greater muscle activity at shoulder abduction angles of 135–160° during shoulder exercise (Bagg and Forrest, 1986; Gaffney et al., 2014; Kibler and McMullen, 2003; Park and Yoo, 2013). Kibler and McMullen, 2003 introduced previous findings of force couples for scapular rotation, describing the LT as ideally placed to keep the scapular position and pull along its long axis at maximum arm elevation. Evidence was also provided by previous study of gradual increases in LT muscle activity with higher shoulder elevation angles during isometric pull-down exertions at 60°, 90°, and 150° of shoulder abduction (Park and Yoo, 2013).

SA muscle activity was significantly greater at 150° than at 30° (by 244.7%) and 90° (by 133.49%). SA/LS muscle activity ratio was also significantly greater at 150° than at 30° (by 170.5%). Hardwick et al. (2006) reported greater muscle activity of the SA during scaption and wall slide at 140° of humeral elevation than that at 90° or 120°, emphasizing the importance of exercise above 90° for optimal generation in SA muscle activity. SA muscle activity has been reported to increase gradually with arm abduction (Bagg and Forrest, 1986; Neumann, 2013).

The second aim of this study was to investigate the effects of shoulder abduction angle (30°, 90°, 150°) on SDRI and CTA immediately after shrug exercises. Our kinematic data support the research hypothesis in that there were differences among the shoulder abduction angles in the shrug exercises. SDRI is considered a reliable method of measuring scapular downward rotation (Choi et al., 2014). The higher the SDRI value, the more downwardly rotated the scapula is. SDRI immediately after shrug exercise was significantly lower at 90° (by 31.2%) and 150° (by 48.4%) than at 30° of shoulder abduction. This indicates that the more scapular upward rotation at 90° and 150° of shoulder abduction effectively maintained the position of the scapula. Reduction of scapular upward rotation at lower humeral elevation angles in symptomatic subjects was demonstrated previously (Borstad and Ludewig, 2002). Ha et al. (2011) reported that the passive correction of the downwardly rotated scapular position decreases neck pain and improves proprioception and active neck rotation in neck-pain patients with bilateral scapular downward rotation syndrome. Our results add to that previous study, in that scapular misalignment might be corrected immediately by active shrug exercises: 10 trials of 5-s holding, performed at 90° and 150° shoulder abduction in subjects with scapular downward rotation impairment.

CTA after shrug exercises was significantly greater at 90° (by 34.4%) and 150° (by 43.1%) than at 30° of shoulder abduction. Our data suggest that exercises at higher shoulder abduction angles have a more immediate effect than do shrug exercises at lower shoulder abduction in restoring clavicular alignment in subject with scapular downward rotation impairment. CTA was reported as $5.9 \pm 1°$ in neutral standing (Ludewig et al., 2009). McClure et al. (2004) reported that the CTA was about 4°, derived from an electromagnetic sensor. Increased CTA can reduce prolonged compressive loading of the posterior cervical structures as a result of the transfer of the weight of the extremities to the cervical region through the attachments of the cervicoscapular muscles (UT and LS) (Van Dillen et al., 2007). For these reasons, clavicular assessment is important in upper-extremity evaluations. We used a reliable method to measure CTA according to previous studies: two-dimensional photographic analysis provides information useful for the assessment of shoulder girdle kinematics and the outcome of treatment interventions, and is indicative of the CTA measured from plain-film radiographs (Ha et al., 2013).

For Cohen's *d*, effect sizes of 0.2, 0.5, and 0.8 are considered small, medium, and large effects, respectively. Although the kinematic data collected in the current study suggested an immediate effect, the Cohen's *d* of the significant differences in SDRI and CTA indicated a medium-to-large effect.

This study had several limitations. First, it was of a cross-sectional design, so evaluated only the immediate effects of shrug exercises. Thus, a longitudinal study of the long-term effects of shrug exercises on scapular muscle activities and kinematics is warranted. Second, although there were different instructions for applying surface electrodes on each muscle while collecting the surface EMG data from LS and UT, there might have been crosstalk because the two muscles partially overlap (Fig. 4). Finally, we did not investigate or exclude rhomboid muscle activity, which is a scapular downward rotator and could be variable among subjects. Further study is needed to exclude subjects with rhomboid dominance.

5. Conclusions

Based on our EMG data, it may be reasonable to select shrug exercises at 90° shoulder abduction if a patient needs to activate the UT, relative to the LS, and wishes to do so early in the rehabilitation process. If a patient has relatively weak LT or SA among the scapular upward rotators, shrug exercises at 150° shoulder abduction are recommended, to elicit greater LT and SA muscle activity, relative to the LS, in the patient. The present findings suggest that shrug exercises at 90° or 150° of shoulder abduction are more effective in terms of decreasing SDRI and increasing CTA in patients with scapular downward rotation impairment.

Conflict of interest

The authors declare that they have no conflict of interest.

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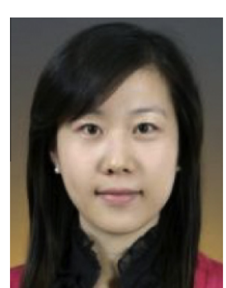

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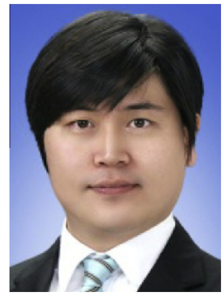

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