Research Report

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Effects of Shoulder Horizontal Abduction with Thoracic Extension on Electromyography of Trapezius Muscles

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Background Shoulder horizontal abduction exercise is a common exercise for promoting lower trapezius muscle activity. However, studies on the effectiveness of shoulder horizontal abduction exercises performed in various positions are lacking.

Purpose This study aimed to verify the effect of shoulder horizontal abduction exercise with thoracic extension performed in the prone and sitting positions on upper and lower trapezius muscle activity.

Study design Case series study

Methods A total of 12 healthy adults without shoulder pain performed prone shoulder horizontal abduction, prone shoulder horizontal abduction with thoracic extension, and sitting shoulder horizontal abduction with thoracic extension. Upper and lower trapezius muscle activity during each shoulder horizontal abduction exercise was measured using surface electromyography.

Results Upper trapezius muscle activity was lowest during sitting shoulder horizontal abduction with thoracic extension compared to prone shoulder horizontal abduction with and without thoracic extension, whereas lower trapezius muscle activity was highest during prone shoulder horizontal abduction with thoracic extension compared to prone shoulder horizontal abduction and sitting shoulder horizontal abduction with thoracic extension. The upper trapezius/lower trapezius muscle activity ratio did not differ between exercises.

Conclusions The findings indicate that considering various exercise positions based on the purpose of the shoulder horizontal abduction exercise is necessary.

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INTRODUCTION

Weakness of the lower trapezius (LT) is associated with various shoulder diseases and incorrect shoulder alignment.[1] The LT plays an important role in scapular stability and movements, including scapular adduction, depression, and posterior tilt.[2] Insufficient scapular posterior tilt due to LT weakness can cause shoulder diseases, such as subacromial impingement syndrome.[3,4] Additionally, because round shoulder posture, a typical incorrect shoulder alignment, is accompanied by scapular abduction and anterior tilt,[5] LT weakness may be a contributing factor to round shoulder posture.[6,7]

The LT is the back muscle connecting the spinous processes of the 6th to 12th thoracic vertebrae[2,8] and assists in thoracic extension. Therefore, previous studies have used thoracic or trunk extension movements to promote LT activity.[9,10] Recently, the effects of adding scapula posterior tilt and trunk extension during shoulder horizontal abduction exercise have been investigated.[11] The results showed that adding scapula posterior tilt and trunk extension significantly increased LT activity.[11] Additionally, this study showed that this addition increased not only LT muscle activity but also upper trapezius (UT) muscle activity.[11]

Cocontraction of the UT and LT contributes to normal scapular upward rotation through a force couple.[2] However, excessive UT muscle activity can break the balance of force couple for normal scapular upward rotation.[1,12] An unbalanced force couple (i.e., incresed UT muscle activity and decreased LT muscle activity) is one of the main characteristics in patients with shoulder diseases.[3,4] Thus, selective muscle contraction of the LT relative to the UT is important for the treatment and prevention of shoulder diseases.[9,11]

In previous studies, thoracic or trunk extension movements were applied only in the prone position to facilitate LT muscle activity.[9-11] In general, the sitting position has the advantage of being easier and more convenient to use in daily life settings than the prone position. In addition, the sitting position with the trunk tilted forward induces thoracic extension against gravity; however, no study has verified the effect of shoulder horizontal abduction exercise with thoracic extension in the sitting position. Therefore, this study aimed to investigate the effect of adding thoracic extension movement on UT and LT muscle activity during shoulder horizontal abduction exercises performed in the prone and sitting positions. We hypothesized that shoulder horizontal abduction in combination with thoracic extension performed in the sitting and prone positions would improve selective activation of the LT compared to conventional prone shoulder horizontal abduction (PSHA).

METHODS

Participants

A total of active 12 males with a mean age of 22.67 ± 0.98 years, a mean height of 174.42 ± 7.20 cm, and a mean weight of 73.75 ± 5.61 kg who had no shoulder pain were included in this study.[11] Individuals with a history of shoulder diseases were excluded from the study.[11] Sample size was calculated using power analysis based on a previous study.[13] This study was approved by the Institutional Review Board of the Catholic University of Pusan. Written informed consent was obtained from all participants.

Measurements of muscle activity

UT and LT muscle activity was measured using a surface electromyography (EMG) system (Noraxon Ultium EMG system; Noraxon Inc., Scottsdale, USA) to assess the effects of shoulder horizontal abduction with thoracic extension. Data were collected using a sampling rate of 2,000 Hz and bandwidth of 10–450 Hz and converted to root mean square. The examiner placed EMG sensors on the UT and LT landmarks on the side of the dominant arm.[14] The EMG sensors for UT (the midpoint between C7 and acromion) and LT (approximately 5 cm below from scapular spine) were attached parallel to the direction of each muscle fiber.[14] All sensors were placed The participants performed each shoulder horizontal abduction exercise for 5 s, and the mean EMG activity of the UT and LT during the middle 3 s was recorded. The participants repeated each exercise three times, and the mean value of the three trials was calculated for data analysis. All EMG data obtained during the exercises were normalized to the mean value of two trials of maximum voluntary isometric contraction of each muscle.[11]

Shoulder horizontal abduction exercises

The participants performed PSHA, prone shoulder horizontal abduction with thoracic extension (PSHATE), and sitting shoulder horizontal abduction with thoracic extension (SSHATE). The three exercises were performed in random order, and each exercise was repeated three times with a 1 min rest period between repetitive exercises and a 5 min rest period between exercise conditions.

For PSHA, the participants performed shoulder abduction of 145° with elbow extension and shoulder external rotation in the prone position. The participants were asked to perform shoulder horizontal abduction (Figure 1A).[11,15] For PSHATE, the participants assumed the same position as PSHA. The participants extended the upper trunk as much as possible while maintaining the xiphoid process on the table and then performed shoulder horizontal abduction (Figure 1B). For SSHATE, the participants assumed a slumped posture (i.e., natural flexion of thoracic and lumbar spines) and actively extended their upper trunk as much as possible.[16] The examiner monitored compensatory lumbar extension during upper trunk extension. After active upper trunk extension, the participants performed shoulder horizontal abduction with shoulder abduction of 145°, elbow extension, and shoulder external rotation (Figure 1C).

The participants performed shoulder horizontal abduction on the side of the dominant arm and maintained the shoulder horizontal abduction position for 5 s during all exercises.

Statistical analysis

Data analysis was performed using IBM SPSS Statistics ver. 29.0 (IBM Corp., Armonk, NY, USA). Normal distribution was demonstrated using Shapiro-Wilk test. Differences in UT and LT muscle activity and the UT/LT muscle activity

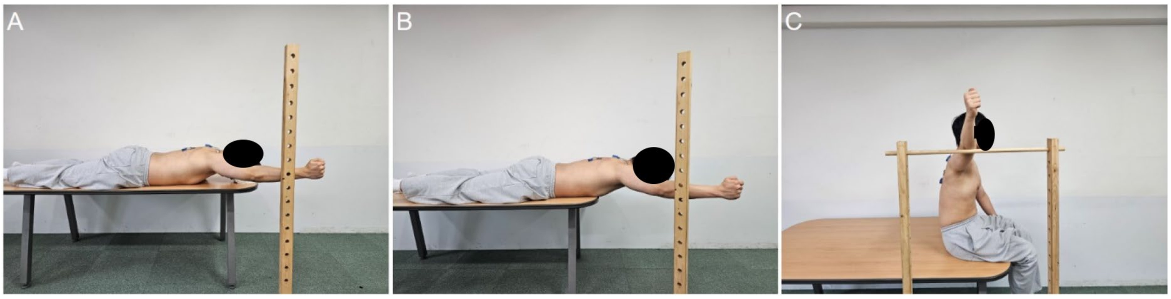

Figure 1. Shoulder horizontal abduction exercises. (A) Prone shoulder horizontal abduction (PSHA), (B) Prone shoulder horizontal abduction with thoracic extension (PSHATE), (C) Sitting shoulder horizontal abduction with thoracic extension (SSHATE).

ratio during the three shoulder horizontal abduction exercises were assessed using one-way repeated measures analysis of variance. Bonferroni correction with an α-level of 0.05 was used for post hoc analysis.

RESULTS

All variables were normally distributed ($p<0.05$). Significant differences in EMG activity of the UT ($p=0.003$) and LT ($p=0.001$) were observed among the shoulder horizontal abduction exercises. However, no significant difference in the UT/LT muscle activity ratio was observed ($p=0.352$) (Table 1).

The post hoc analysis revealed that the EMG activity of the UT was significantly decreased during SSHATE compared with PSHA ($p=0.033$) and PSHATE ($p=0.018$). However, no significant difference in the EMG activity of the UT was observed between PSHA and PSHATE ($p=1.000$) (Table 2).

The EMG activity of the LT was significantly increased during PSHATE compared with PSHA ($p=0.010$) and SSHATE ($p=0.005$). However, no significant difference in the EMG activity of the LT was observed between PSHA and SSHATE ($p=1.000$) (Table 2).

DISCUSSION

This study showed that, among shoulder horizontal abduction exercises, SSHATE decreased UT muscle activity, whereas PSHATE was most effective in increasing LT muscle activity. Additionally, a significant decrease in UT muscle activity was observed during SSHATE compared with PSHA ($p=0.033$) and PSHATE ($p=0.018$), indicating that the sitting position is more effective than the prone position in minimizing UT muscle activity during shoulder horizontal abduction. The UT muscle connects the cervical spine to the lateral portion of the clavicle. Contraction of the UT muscle can cause clavicular retraction due to the direction of the muscle fibers.[2,17] Clavicular retraction is a movement accompanying shoulder horizontal abduction. Therefore, PSHA and PSHATE (performing shoulder horizontal abduction against gravity) require greater activation of the clavicular retractors than SSHATE. Previous findings of increased UT muscle activity during shoulder external rotation in a 90° shoulder abduction position compared to a 0° shoulder abduction position in standing support the hypothesis that

Table 1. Muscle activities during various shoulder horizontal abduction exercises

Measures	PSHA	PSHATE	SSHATE	*P* value
UT (%MVIC)	35.05±9.75	35.81±10.02	30.55±10.08	0.003*
LT (%MVIC)	67.87±7.93	75.87±8.42	65.40±11.15	0.001*
UT/LT (Ratio)	0.52±0.15	0.47±0.12	0.48±0.15	0.352

Values aer mean±standard deviation.
*Significant difference among shoulder horizontal abduction exercises, $p < 0.05$.
Abbreviations: LT, lower trapezius; MVIC, maximal voluntary isometric contraction; PSHA, prone shoulder horizontal abduction; PSHATE, prone shoulder horizontal abduction with thoracic extension; SSHATE, sitting shoulder horizontal abduction with thoracic extension; UT, upper trapezius.

Table 2. Pairwise comparisons of muscle activities during various shoulder horizontal abduction exercises.

Measures	PSHA vs. PSHATE	PSHA vs. SSHATE	PSHATE vs. SSHATE
UT	1.000 (0.077)	0.033 (0.454)*	0.018 (0.523)*
LT	0.010 (0.977)*	1.000 (0.249)	0.005 (1.040)*
UT/LT	0.384 (0.364)	0.919 (0.267)	1.000 (0.073)

Values aer *P*-value (effect size).

*Significant difference between shoulder horizontal abduction exercises, $p < 0.05$.

Abbreviations: LT, lower trapezius; MVIC, maximal voluntary isometric contraction; PSHA, prone shoulder horizontal abduction; PSHATE, prone shoulder horizontal abduction with thoracic extension; SSHATE, sitting shoulder horizontal abduction with thoracic extension; UT, upper trapezius.

shoulder movement against gravity increases UT muscle activity.[18] Thus, because of the effects of exercise positions, UT muscle activity was significantly decreased during SSHATE compared with PSHA and PSHATE. A previous study showed that adding thoracic extension increased UT muscle activity during shoulder horizontal abduction.[11] However, in this study, no significant difference in UT muscle activity was observed between PSHA and PSHATE (p=1.000). These contradictory results may be due to differences in the experimental methods. In the previous study, not only the thoracic extension but also the scapular posterior tilt motion was added during shoulder horizontal abduction.[11] Since scapular posterior tilt can induce clavicular retraction through the acromioclavicular joint, the results of the previous study[11] are believed to be the result of applying scapular posterior tilt rather than thoracic extension.

This study showed that LT muscle activity was significantly increased during PSHATE compared with PSHA (p=0.010) and SSHATE (p=0.005). In this study, PSHA was performed with the whole trunk supported on a table, whereas PSHATE was performed without the upper trunk above the xiphoid process being supported on the table. Therefore, a higher level of back muscle activity is required to maintain upper trunk alignment against gravity.[19] For this reason, LT muscle activity was higher during PSHATE than during PSHA. Similar to our study, a previous study comparing PSHA to PSHA with upper trunk extension and scapular posterior tilt found that LT muscle activity was significantly increased in the PSHA with upper trunk extension and scapular posterior tilt condition.[11] Taken together, our findings and those of previous studies suggest that thoracic extension can have a significant effect on increasing LT muscle activity. Although the thoracic extension movement during SSHATE was performed in a direction against gravity, the shoulder horizontal abduction movement was performed in the horizontal plane. Therefore, the resistance applied during shoulder horizontal abduction would have been greater in the prone position than in the sitting position. For this reason, LT muscle activity was significantly increased during PSHATE compared with SSHATE.

This study showed a significant difference in UT (p=0.003) and LT (p=0.001) muscle activity between the three shoulder horizontal abduction exercise conditions. However, no significant difference in the UT/LT muscle activity ratio was observed (p=0.352). Therefore, the three shoulder horizontal abduction exercises performed in this study may be useful when planning exercise methods to change the activity of a specific trapezius muscle rather than to promote selective activation of the LT. In other words, if the purpose is to increase LT muscle activity, PSHATE may be an effective exercise, and if the purpose is to minimize UT muscle activity during LT strengthening exercises, SSHATE can be an effective exercise. However, considering that the sitting is an easily applicable position in daily life settings, future studies should consider a modified SSHATE that may enhance selective activation of LT muscle by increasing LT muscle activity.

This study has some limitations. First, this study included only subjects without shoulder pain, which may limit the generalizability of the results to subjects with shoulder pain or LT muscle weakness. Thus, future studies need to verify the long-term effects of prone or sitting shoulder horizontal abduction exercises in patients with shoulder pain. Second, this study included only 12 male participants, which may limit the generalizability of the results to all populations. Future studies need to include large samples of both males and females. Lastly, future studies should compare the effects of sitting shoulder horizontal abduction with and without thoracic extension in order to verify the effectiveness of thoracic extension in sitting.

CONCLUSIONS

This study showed that the prone position was more effective than the sitting position in promoting LT muscle activity during shoulder horizontal abduction exercise with thoracic extension. However, shoulder horizontal abduction exercise with thoracic extension performed in the sitting position was most effective in minimizing UT muscle activity. These results suggest that when performing shoulder horizontal abduction with thoracic extension exercises, it is necessary to consider a sitting position to decrease UT muscle activity and a prone position to increase LT muscle activity.

Key Points

Question Does trapezius muscle activity change based on the position during shoulder horizontal abduction exercise?

Findings Upper trapezius muscle activity is lowest during shoulder horizontal abduction with thoracic extension in the sitting position compared to shoulder horizontal abduction with and without thoracic extension in the prone position, whereas lower trapezius muscle activity was highest during prone shoulder horizontal abduction with thoracic extension compared to that without thoracic extension and sitting shoulder horizontal abduction with thoracic extension.

Meaning Exercise positions should reflect the intended purpose of the shoulder horizontal abduction exercise.

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