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Influence of Pre-Emptive Scapular Posterior Tilt on Scapular Muscle Activation and Scapulohumeral Movements during Shoulder Horizontal Abduction in the Prone Position

Background: Shoulder horizontal abduction in the prone position (SHAP) has been reported as an effective exercise to strengthen the lower trapezius. However, the effects of pre-emptive scapular posterior tilt on scapular muscle activity and scapulohumeral movements during SHAP have not been examined.
Objectives: To examine the effect of the addition of scapular posterior tilt on muscle activity of the trapezius and posterior deltoid, and scapular posterior tilt and shoulder horizontal abduction, during SHAP.
Design: Cross-sectional study.
Methods: Fifteen healthy male subjects performed two types of SHAP: general and modified SHAP (SHAP combined with pre-emptive scapular posterior tilt). To perform modified SHAP, pre-emptive scapular posterior tilt training was performed prior to the modified SHAP. Muscle activity of the middle and lower trapezius and posterior deltoid, and the amount of scapular posterior tilt and shoulder horizontal abduction, were measured during two types of SHAP.
Results: Muscle activity of the lower trapezius and scapular posterior tilt was significantly increased during the modified SHAP, while muscle activity of the posterior deltoid and the amount of shoulder horizontal abduction were significantly decreased. However, the middle trapezius muscle activity did not change during the modified SHAP.
Conclusion: The SHAP with pre-emptive scapular posterior tilt can be useful to strengthen the lower trapezius.

Keywords: *Electromyography; Lower trapezius; Shoulder horizontal abduction*

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INTRODUCTION

The trapezius muscle is important for appropriate movements of the shoulder complex.[1-3] The trapezius is divided into (upper, middle, and lower sections, and the actions of each part of the trapezius muscle differ based on the anatomical attachments.[4,5] The upper trapezius, attached to the lateral portion of the clavicle, contributes to scapular movements through the acromioclavicular joint.[4-6] The middle and lower trapezius attach to the acromion and scapular spine, respectively, and contribute to scapular stabilization as well as movements of the shoulder complex.[4-6] To improve scapular stabilization, therapeutic exercises increasing middle and lower trapezius muscle activation have been emphasized in the clinical setting.

Shoulder horizontal abduction in the prone position (SHAP) can facilitate activation of the middle and lower trapezius.[7-9] SHAP can easily be performed in the clinical setting, because resistance is applied using the force of gravity. Previous studies demonstrated that SHAP increases electromyography (EMG) activity of the middle and lower trapezius.[7-12]

Despite the clinical advantages of SHAP, it can induce an increase in activation not only of the trapezius muscle, but also the posterior scapulohumeral muscles, because the arm is lifted against the force of gravity when performing SHAP.[4,5] The posterior deltoid, one of the posterior scapulohumeral muscles, is attached from the scapular spine to the deltoid tuberosity; therefore, contraction of this muscle contributes to arm-lifting against gravity during

SHAP.[4,5,13] However, excessive activation of the posterior deltoid leads to anterior translation of the humeral head, which can result in abnormal arthrokinematics of the glenohumeral joint.[14,15] Thus, many researchers emphasize that excessive and unnecessary muscle activation of the posterior deltoid should be minimized during shoulder exercises.[16-18]

A previous study suggested that a modified SHAP could be used to strengthen the lower trapezius.[19] In that study, SHAP combined with pre-emptive scapular posterior tilt increased muscle activation of the lower trapezius compared to an arm lifting exercise performed in a quadruped position. However, the study only examined the influence of pre-emptive scapular posterior tilt on middle and lower trapezius muscle activation during SHAP, and not how this exercise influences EMG activity of the posterior deltoid. Thus, the aim of our study was to demonstrate the effects of modified SHAP (i.e., SHAP combined with pre-emptive scapular posterior tilt) on EMG activity of the trapezius and posterior deltoid, and scapulohumeral kinematics. The findings of present study would be useful for physical therapists to plan lower trapezius strengthening exercise. In addition, our findings would be helpful to understand the importance of scapular motion on the lower trapezius muscle activation.

SUBJECTS AND METHODS

Subjects

A group of 15 healthy males (mean age: 24.33±1.91 years, height: 174.47±4.93 cm, body weight: 74.60±8.56 kg) participated in this study. No subject had current shoulder pain. Subjects were excluded if they had adhesive capsulitis or shoulder impingement. All subjects provided informed consent to participate in this study. The Institutional Research Review Committee of Inje University approved this study (IRB No. 2019-07-014-001).

Outcome Measures

Electromyography

To identify muscle activation patterns of the middle and lower trapezius, and the posterior deltoid on the tested arm side during SHAP, the TeleMyo Mini DTS surface EMG system (Noraxon Inc., Scottsdale, AZ, USA) was used. The sampling rate of the EMG signal was 1,500 Hz, and the signal was filtered with a bandwidth of 10-450 Hz. The middle trapezius electrodes were placed on the line between the root of the scapular spine and the thoracic spinous process on the same level.[19] The lower trapezius electrodes were placed on the line between the root of the scapular spine and the 7th thoracic spinous process.[19] The posterior deltoid electrodes were placed 2 cm below the lateral scapular spine.[16] All electrodes were attached on the dominant arm side along each muscle section.

The EMG signal was collected over 5 s of isometric contraction during the SHAP. For analysis purposes, the middle 3 s of the EMG signal was normalized by determined maximal voluntary isometric contraction (MVIC) value of each muscle. To determine MVIC value for each muscle, two MVIC trials using manual muscle testing maneuvers were performed.[20] Then, mean value of two MVIC trials were used to determine MVIC value for EMG normalization.[19]

Kinematics of Scapulohumeral Movements

In this study, the scapular posterior tilt angle and shoulder horizontal abduction angle were measured to identify scapulohumeral movements during SHAP. For scapular posterior angle measurements, a custom-made smartphone support was used, based on a previous study.[21] The two feet of the support were placed on the root of the scapular spine and the inferior angle of the scapula, respectively, and the smartphone was then placed on the support. Following this, the scapular posterior tilt angle was measured using a smartphone inclinometer application (Clinometer level and slope finder; Plaincode Software Solutions, Stephanskirchen, Germany).

To measure the shoulder horizontal abduction angle, the smartphone was placed on the posterior aspect of the humerus during the SHAP. The shoulder horizontal abduction angle was recorded using the same Clinometer level and slope finder, which was calibrated at 0° when the smartphone was placed parallel to the table.

Scapular posterior tilt angle and shoulder horizontal angle were measured during both the isometric general SHAP and modified SHAP. The mean value of three trials was used for data analysis.

Pre-Emptive Scapular Posterior Tilt Training

This study was cross-sectional study to identify the effects of scapular posterior tilt during SHAP between before and after pre-emptive scapular posterior tilt training.

Pre-emptive scapular posterior tilt training was performed for the modified SHAP. In the seated position, subjects were asked to pull back the acromion as if making a semicircle, to induce scapular posterior tilt. If necessary, an examiner guided the scapular posterior tilt movement using both hands. Once subjects could perform active scapular posterior tilt while seated, they were instructed to practice the movement in the prone position with 125° of shoulder abduction and shoulder external rotation. If subjects could perform scapular posterior tilt without excessive scapular adduction and external rotation, they were asked to perform modified SHAP. However, if subjects had a difficulty in performing correct scapular posterior tilt, they were trained with an examiner for 10 min.

Shoulder Horizontal Abduction in the Prone Position

Before pre-emptive scapular posterior tilt training, subjects performed general SHAP. Subjects were placed in the prone position, and the tested shoulder was positioned with 125° of shoulder abduction and external rotation (Figure 1).[10,22] Subjects were asked to extend the tested arm towards the ceiling as far as possible without trunk rotation. Subjects held this for 5 s and repeated the movement three times, with a 1-min rest period between each movement.

After pre-emptive scapular posterior tilt training, subjects performed modified SHAP. Subjects were asked to perform the pre-emptive scapular posterior tilt movement and then raise the tested arm towards the ceiling, as with the general SHAP. During arm raising, subjects were asked to maintain pre-emptive scapular posterior tilt as much as possible.[19] Subjects held this position for 5 s and repeated the movement three times, with a 1-min rest period between each movement.

Figure 1. Shoulder horizontal abduction in the prone position

Data and Statistical Analysis

To identify differences between the general SHAP and modified SHAP in terms of EMG activity of the middle trapezius, lower trapezius, and posterior deltoid, and the angle of the scapular posterior tilt and shoulder horizontal abduction, paired t-tests were performed using PASW Statistics 18 (SPSS Inc., Chicago, IL, USA). An α-value of 0.05 was considered significant.

RESULTS

Muscle activity of the lower trapezius was significantly higher, while EMG activity of the posterior deltoid was significantly lower, during the modified SHAP compared to the general SHAP ($P<.05$) (Table 1). Muscle activity of the middle trapezius was not

Table 1. Statistical data for the outcome variables of the SHAPs

	General SHAP	Modified SHAP	*P*
Middle trapezius (% MVIC)	50.57 ± 14.86	48.96 ± 13.35	.360
Lower trapezius (% MVIC)	58.20 ± 15.70	68.71 ± 15.70	<.001*
Posterior deltoid (% MVIC)	41.90 ± 10.29	37.66 ± 9.80	<.001*
Scapular posterior tilt (°)	19.13 ± 5.43	22.15 ± 6.14	.039*
Shoulder horizontal abduction (°)	−5.87 ± 8.05	−8.31 ± 8.68	.033*

*$P<.05$
MVIC: Maximal voluntary isometric contraction, SHAP: Shoulder horizontal abduction in prone

significantly different between the two SHAPs (P=.360) (Table 1).

There was significantly more scapular posterior tilt, and significantly less shoulder horizontal abduction, during the modified SHAP compared to the general SHAP (P<.05) (Table 1).

DISCUSSION

This study examined the influence of pre-emptive scapular posterior tilt training on the activity of the trapezius and posterior deltoid muscles, and on scapular posterior tilt and shoulder horizontal abduction, during SHAP. Pre-emptive scapular posterior tilt increased lower trapezius muscle activity and scapular posterior tilt angle, and decreased posterior deltoid muscle activity and shoulder horizontal abduction, during SHAP.

Scapular posterior tilt is a crucial action of the lower trapezius.[23] Therefore, it is reasonable to expect increased scapular posterior tilt to facilitate lower trapezius muscle activation during the modified SHAP. In this study, the amount of scapular posterior tilt significantly increased during the modified SHAP. This supports our finding that the EMG activity of the lower trapezius increased during the modified SHAP. A previous study showed greater muscle activity of the lower trapezius during the modified SHAP compared to an arm lifting exercise performed in the quadruped position.[19] Because arm lifting in the quadruped position has been reported to be effective for increasing lower trapezius muscle activity, the modified SHAP, which promotes greater lower trapezius muscle activity than arm lifting performed in the quadruped position, can be useful for strengthening the lower trapezius in the clinical setting. While the previous study did not include a general SHAP when comparing lower trapezius muscle activity among lower trapezius strengthening exercises[19], our study compared lower trapezius muscle activity between general and modified SHAPs, and showed that scapular posterior tilt can lead to greater muscle activation of the lower trapezius during SHAP. However, in this study, middle trapezius muscle activity did not change significantly during the modified SHAP. The middle trapezius provides scapular stabilization by limiting excessive scapular internal rotation and abduction.[6] In the modified SHAP, only scapular posterior tilt was added; thus, it is reasonable that middle trapezius muscle activity did not change significantly due to scapular movement related to the action of the lower trapezius during the modified SHAP.

In this study, the EMG activity of the posterior deltoid and amount of shoulder horizontal abduction were decreased during the modified SHAP. Decreased shoulder horizontal abduction may result from a decrease in muscle activation of the posterior deltoid, because posterior deltoid muscle activation contributes to shoulder horizontal abduction and external rotation.[4,5] When the purpose of the SHAP is to strengthen the lower trapezius, it is important to promote lower trapezius muscle activity and minimize the activation of synergistic muscles, as this can lead to instability of the glenohumeral joint during exercise. The modified SHAP increased lower trapezius muscle activity while minimizing anterior translation of the humeral head caused by excessive activation of the posterior deltoid. Thus, the modified SHAP can be useful to selectively strengthen the lower trapezius.

There were some limitations to this study. First, only healthy males were recruited. A future study should examine how the modified SHAP influences trapezius muscles in subjects with scapular dyskinesia. Second, only scapular posterior tilt was measured. A future study should measure scapular movements three-dimensionally to fully demonstrate the effects of modified SHAP. Lastly, we did not address the artifacts caused by electrocardiography during EMG recording.

CONCLUSION

This study demonstrated that pre-emptive scapular posterior tilt promotes lower trapezius muscle activity, while minimizing posterior deltoid muscle activity, during the SHAP exercise. The findings suggest that pre-emptive scapular posterior tilt should be considered for strengthening the lower trapezius in the clinical setting.

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