Correlation between Scapular Asymmetry and Differences in Left and Right Side Activity of Muscles Adjacent to the Scapula

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Objectives: The aim of this study was to analyze the correlation between scapular asymmetry in young female adults and differences in left and right side activity of muscles adjacent to the scapula.

Methods: This study included 60 female students from U university in Korea. In order to examine scapular asymmetry, the lateral scapular slide test (LSST) was used. The LSST was performed in 3 different postures (LSST-1, LSST-2, and LSST-3; i.e., 0°, 45°, and 90° of upper limb abduction, respectively). Muscle activity was measured during external and internal rotation of the shoulder joints. Muscle activity was measured at the upper, middle, and lower trapezius, and the serratus anterior.

Results: In external shoulder rotation, there was a significant correlation (R = 0.450) between LSST-2 and the middle trapezius. In internal shoulder rotation, there was a significant correlation (R = 0.472) between LSST-2 and the upper trapezius, and between LSST-3 and the lower trapezius (R = 0.657); these results demonstrated a moderate positive linear correlation.

Conclusion: There was a positive correlation between left and right scapular asymmetry and the difference in left and right muscle activity of the trapezius in female adults. Problems in the trapezius may lead to scapular asymmetry.

Key Words: scapula, shoulder joint, anthropometry, electromyography

INTRODUCTION

The shoulder joint has a greater range of motion than other joints in the human body and can move in various directions. This is possible because of its anatomical structure, the characteristics of an articular surface between the humeral head and a concave joint, and the relatively high instability of the articular surface [1]. Because the joint is unstable, the shoulder has a greater risk of injury. However, muscles adjacent to the shoulder joint aid in reducing this instability [2]. Hence, these muscles may be more important than those surrounding other joints with regard to their contribution to stability.

The increase in smartphone usage means that more people spend longer periods in abnormal postures. Although the human body normally distributes loads to each muscle evenly, the fatigue of muscles supporting a posture increases when the posture is maintained for a prolonged duration [3]. If a posture is held repeatedly, the muscle length increases and endurance is lessened, causing a vicious cycle and abnormal body alignment [4]. In particular, the role of the muscles in stabilizing the shoulder joint puts them under greater stress.
The rotator cuff muscles provide stability between the humerus and scapula in the shoulder joint and the significance of these muscles is clinically recognized [5]. However, the stability between the scapula and body is no less significant than in the shoulder joint. Considering that the scapulothoracic joint is not directly connected to the vertebrae, and its location or alignment is determined by muscle(s), dependence on the muscles for stability is high [6].

Studies have attempted to predict abnormal alignment of the shoulder joint or muscles using the posture of the scapula, e.g., in winged scapula, if the stability of the scapulothoracic joint decreases. The lateral scapular slide test (LSST) has been used in these studies. Kibler [7] reported that decreased stability and abnormal alignment could be observed by measuring the distance between the thoracic spine and scapula.

Scapular asymmetry, as assessed by the LSST, reflects decreased stability of the scapula, and can lead to functional deterioration of most of the muscles contributing to this stability. The correlation between scapular asymmetry and muscle activity can be analyzed by objectively measuring muscle activity and movement.

Therefore, this study aimed to analyze the correlation between asymmetry of the scapula in young female adults and the differences in left and right side activity of muscles adjacent to the scapula. Accordingly, the activity of these muscles was measured during external and internal rotation of the shoulder, and the left and right side muscles were compared. Moreover, the correlation with scapular asymmetry was analyzed.

### MATERIALS AND METHODS

1. Participants

This study included 60 female students from Uiduk University in Gyeongju, Korea (mean ± standard deviation of age, 20.5 ± 0.5 years; height, 158.6 ± 2.3 cm; weight, 53.5 ± 9.3 kg) (Table 1). The inclusion criteria were as follows: absence of specific diseases that could affect the study outcomes, no visible or auditory impairment, no problems in the nervous system or vestibular organs, and the ability to understand the study instructions. The purposes and procedures of this study were explained to all participants prior to the experiment, and written informed consent was obtained.

2. Ethics

According to the Declaration of Helsinki, information about the study was provided and the individuals gave written consent to participate. The study was approved by the Korea National Institute for Bioethics Policy (P01-201611-23-001).

3. Study protocol

After left and right scapular asymmetry was measured using the LSST, the activity of the muscles adjacent to the scapula was measured. The trunk was stabilized in the sitting position, and muscle activity was measured during external and internal rotation of the shoulder with the elbows flexed at 90°. The difference in left and right muscle activity measurements was determined. All measurements were performed three times, and the results were expressed as mean ± standard deviation.

4. Lateral scapular slide test

The LSST was used to measure scapular asymmetry [7]. Asymmetry was verified using the difference in the left and right values, after the distance between the inferior angle of the scapula and the spinous process of thoracic vertebra 7 was measured. Measurement was performed with 0°, 45°, and 90° of upper limb abduction (LSST-1, LSST-2, and LSST-3, respectively).

5. Electromyography (EMG)

To verify the activity of muscles adjacent to the scapula, a wireless device (FreeEMG 1000; BTS Bioengineering, Milano, Italy) and Ag-Ag/Cl electrodes were used.

Eight electrodes were attached (four areas each on the left and right) at the upper, middle, and lower trapezius muscles, and on the serratus anterior. The middle trapezius and rhomboid muscles were measured simultaneously, as they are difficult to measure separately due to the characteristics of surface EMG [8].

The EMG signal was obtained at a standard sampling rate of 1,000 Hz and processed by electric wave rectification. For data storage, interval filtering was conducted using software (BTS EMG-Analyzer; BTS Bioengineering) at 30 to 500 Hz, and the signals were processed via a notch filter at 60 Hz for noise removal. In order to standardize the values for each muscle, the measured data were converted to effective values, and muscle activity was analyzed by obtaining the mean of three measurements. In addition, the maximal voluntary isotonic contraction was measured for each muscle; using this value as a reference,
muscle activity was standardized.

6. Statistical analysis

IBM SPSS Statistics ver. 22.0 for Windows (IBM Co., Armonk, NY, USA) was used for data analysis. In order to investigate the correlation between LSST and the differences in activity in the muscles adjacent to the scapula (left and right: upper, middle, and lower trapezius, and serratus anterior), Pearson’s coefficient was used. Statistical significance was indicated by \( \alpha = 0.05 \).

RESULTS

In external shoulder rotation, there was a significant moderate positive linear correlation between LSST-2 and middle trapezius activity (\( R = 0.450 \) (\( p < 0.05 \)) (Table 2).

In internal shoulder rotation, there was a significant moderate positive linear correlation between LSST-2 and the upper trapezius (\( R = 0.472 \) (\( p < 0.05 \)). In addition, there was a significant moderate positive linear correlation between LSST-3 and lower trapezius (\( R = 0.657 \) activity (\( p < 0.05 \), Table 3).

DISCUSSION

This study used LSST to evaluate asymmetry between the left and right scapula in young female adults. A large difference was observed between left and right muscle activity, based on LSST results, suggesting high asymmetry once the distance between the scapula and thoracic vertebrae was measured. Moreover, this is a readily usable tool with high reliability \([7,9]\).

During motion of the humerus in the shoulder, the location of the scapula can change or remain stable due to the motion of muscles adjacent to the scapula. Balanced strength between various muscles attached to the scapula is necessary for this motion \([10]\).

When the strength of adjacent muscles is unbalanced, muscle stability decreases and scapular instability increases \([11]\). Kibler \([7]\) reported that scapular asymmetry increased as instability increased.

This study hypothesized that if asymmetry of the scapula was caused by muscle instability, then muscle activity of adjacent muscles would also be asymmetric. In order to verify this, the activity of muscles adjacent to the scapula was measured using EMG, and the correlation between left and right asymmetry and measured muscle activity was analyzed. Thus, the activities of the trapezius and serratus anterior, the adjacent muscles that stabilize

| Table 2. Correlations between LSST and activity of adjacent muscles of the scapula in external shoulder rotation |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| LSST            | UT (%MVIC)      | MT (%MVIC)      | LT (%MVIC)      | SA (%MVIC)      |
|                 | (17.3 ± 11.2)   | (17.6 ± 9.3)    | (10.0 ± 9.9)    | (15.7 ± 11.7)   |
| LSST-1 (6.6 ± 5.5 mm) | −0.244         | −0.135          | −0.184          | −0.383          |
| LSST-2 (8.1 ± 5.8 mm) | −0.319         | 0.450*          | −0.056          | 0.046           |
| LSST-3 (5.3 ± 4.9 mm) | 0.197          | 0.419           | 0.077           | −0.019          |

Values are presented as mean ± standard deviation.
LSST, lateral scapular slide test; LSST-1, LSST with shoulder abduction at 0°; LSST-2, LSST with shoulder abduction at 45°; LSST-3, LSST with shoulder abduction at 90°; MVIC, maximum voluntary isometric contraction; UT, upper trapezius; MT, middle trapezius; LT, lower trapezius; SA, serratus anterior.

| Table 3. Correlations between LSST and activity of adjacent muscles of the scapula in internal shoulder rotation |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| LSST            | UT (%MVIC)      | MT (%MVIC)      | LT (%MVIC)      | SA (%MVIC)      |
|                 | (8.3 ± 8.2)     | (4.2 ± 2.9)     | (6.3 ± 5.3)     | (18.4 ± 10.3)   |
| LSST-1 (6.6 ± 5.5 mm) | 0.026          | −0.138          | −0.023          | 0.141           |
| LSST-2 (8.1 ± 5.8 mm) | 0.472**         | −0.295          | −0.090          | −0.102          |
| LSST-3 (5.3 ± 4.9 mm) | −0.164         | 0.078           | 0.657**         | 0.007           |

Values are presented as mean ± standard deviation.
LSST, lateral scapular slide test; LSST-1, LSST with shoulder abduction at 0°; LSST-2, LSST with shoulder abduction at 45°; LSST-3, LSST with shoulder abduction at 90°; MVIC, maximum voluntary isometric contraction; UT, upper trapezius; MT, middle trapezius; LT, lower trapezius; SA, serratus anterior.

** \( p < 0.01 \).
the scapula were measured.

External rotation of the shoulder in this study showed a moderate correlation between LSST-2 and middle trapezius activity. There was also a moderate correlation between LSST-3 and middle trapezius activity. This result indicates that the difference between left and right muscle activity of the middle trapezius increases during external rotation as the asymmetry between the left and right scapula becomes greater with upper limb abduction.

In addition, in this study, there was no correlation between scapular asymmetry in upper limb abduction and the difference in muscle activity of the lower trapezius during external rotation. This finding is supported by previous studies [6–14].

In a study by Ekstrom et al. [12], the activity of the middle trapezius was observed to be greater than that of the lower trapezius during external rotation with increased shoulder abduction. This finding was corroborated by Escamilla et al. [14]. Although the experiment was performed while the subjects lay face down, it is interesting that muscle activity in both the lower and middle trapezius was increased during increased shoulder abduction.

Cools et al. [13] reported that the middle trapezius but not the lower trapezius was activated during external shoulder rotation. They also reported that an injury to the shoulder joint led to middle trapezius weakness on the injured side during external rotation and imbalance on the opposite side. Consequently, the results of these previous studies support the result of the present study.

In this study, internal shoulder rotation showed a moderate positive linear correlation between LSST-2 posture and upper trapezius activity, suggesting that the difference in activity between the left and right upper trapezius muscles increases during internal shoulder rotation, as asymmetry between the left and right scapula increases with 45° upper limb abduction.

The LSST was conducted during upward rotation of the scapula. A previous study reported that the trapezius played a significant role in stabilizing the scapula by maintaining length during upward rotation [6]. Left and right asymmetry in this posture indicates a difference in left and right trapezius muscle activity during stabilization of the scapula.

Moreover, another study reported that the upper trapezius caused upward rotation of the scapula as well as inner rotation of shoulder [11]. Because the difference between left and right muscle activity becomes large during internal rotation, it was thought that the result of this study would be replicated by the development of asymmetry in the upper trapezius.

A moderate positive linear correlation was observed between LSST-3 and the lower trapezius with internal shoulder rotation. This may imply that the difference between left and right lower trapezius activity increases during internal shoulder rotation as the asymmetry between the left and right scapula increases with upper limb abduction at 90°.

A previous study reported that the lower trapezius resists outward movement, which results from the pulling strength of the serratus anterior during upward rotation of the scapula; this was particularly increased at 90° [6]. If this role of the lower trapezius is diminished, the scapula is protracted as it is pulled toward the serratus anterior. Smith et al. reported that the protraction of the scapula could weaken the muscle power of internal shoulder rotation [15], indicating that the lower trapezius is important for internal shoulder rotation; this finding agrees with our results.

The results of the present study should be helpful for treating scapular asymmetry using normal posture as a baseline. A limitation of this study is that muscle activity was examined only during internal and external rotation of shoulders. In addition, the study comprised only female subjects and there could have been differences between female and male subjects, given the unique attributes of the female body. Further studies examining other motions are warranted.

There was a positive correlation between left and right scapular asymmetry and differences in muscle activity between the left and right trapezius muscles in female adults. The asymmetry in the left and right scapula resulted from a functional problem in the trapezius muscle when stabilizing the scapula. A posture with a small open angle (LSST-2, 45° open) was correlated with upper and middle trapezius muscle activity, and a posture with a large open angle (LSST-3, 90° open) was correlated with middle and lower trapezius muscle activity.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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