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Rehabilitation Exercises to Induce Balanced Scapular Muscle Activity in an Anti-gravity Posture

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Abstract. [Purpose] The purpose of this study was to compare the intramuscular balance ratios of the upper trapezius muscle (UT) and the lower trapezius muscle (LT), and the intermuscular balance ratios of the UT and the serratus anterior muscle (SA) among prone extension (ProExt), prone horizontal abduction with external rotation (ProHAbd), forward flexion in the side-lying position (SideFlex), side-lying external rotation (SideEr), shoulder flexion with glenohumeral horizontal abduction load (FlexBand), and shoulder flexion with glenohumeral horizontal adduction load (FlexBall) in the standing posture. [Methods] The electromyographic (EMG) activities of the UT, LT and SA were measured during the tasks. The percentage of maximum voluntary isometric contraction (%MVIC) was calculated for each muscle, and the UT/LT ratios and the UT/SA ratios were compared among the tasks. [Results] The UT/LT ratio with the FlexBand was not significantly different from those of the four exercises in the side-lying and prone postures. The UT/SA ratio with the FlexBall demonstrated appropriate balanced activity. [Conclusion] In an anti-gravity posture, we recommend the FlexBand and the FlexBall for inducing balanced UT/LT and UT/SA ratios, respectively.

Key words: Scapular muscle exercise, Balanced scapular muscle activity, Electromyography

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INTRODUCTION

Recently, scapula movement has begun to attract attention. Previous studies have reported relationships between the resting position and the dynamic motion (dyskinesis) of the scapula and shoulder pain and dysfunction^{1–5)}. Decreased activation of the lower trapezius (LT) muscle and the serratus anterior (SA) muscle together with simultaneous excessive activation of the upper trapezius (UT) muscle have been reported to be related to scapula dyskinesis⁶⁾. Some previous studies have reported that scapular muscle exercises positively affect not only shoulder pain but also shoulder function^{7, 8)}. Restoration of balanced scapular muscle activity is one of the aims of scapular muscle exercises, and of decreased activation of the LT and the SA and increased activation of the UT indicate the importance of the intramuscular balance ratio (UT/LT) and intermuscular balance ratio (UT/SA)^{6, 9–12)}. Cools et al. concluded

that four exercises were able to facilitate LT activity with minimal activation of the UT, from the point of view of the scapular muscle balance (Fig. 1a–d)¹³⁾. A previous study reported that the scapular muscle rehabilitation exercises performed by athletes with impingement syndrome improved their pain and function¹⁴⁾. All of the exercises are carried out in side-lying or prone postures, even though upper extremity activities of daily living frequently occur in anti-gravity postures such as sitting or standing. To the best of our knowledge, few studies have examined scapular muscle exercises in sitting or standing postures which aim to elicit balanced scapular muscle activity. A high level of maximum voluntary isometric contraction in the LT muscle was reported for exercises including scapular retraction motion¹⁵⁾. SA muscle activity has been induced not only with shoulder horizontal adduction¹⁶⁾, but also with shoulder horizontal abduction in an anti-gravity posture¹⁷⁾. Taking these previous studies into account, we hypothesized that if glenohumeral flexion with horizontal abduction directional load or with horizontal adduction directional load, both of which induce scapular retractor activity, were performed, balanced scapular intramuscular and also intermuscular activation would be induced in an anti-gravity posture. Thus, the purpose of the current study was to compare the intramuscular and intermuscular scapular muscle ratios (UT/LT, UT/SA) among commonly used scapular muscle exercises

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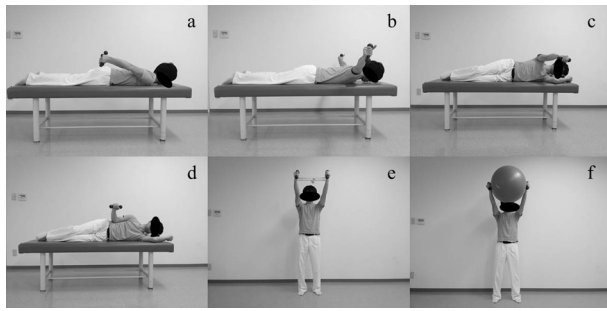


Fig. 1. Scapular muscle exercises

a: prone extension (ProExt); b: prone horizontal abduction (ProHAbd); c: forward flexion in the side-lying position (SideFlex); d: side-lying external rotation (SideEr); e: shoulder flexion with glenohumeral horizontal abduction load (FlexBand); f: shoulder flexion with glenohumeral horizontal adduction load (FlexBall)

carried out in the side-lying and prone postures and flexion with glenohumeral horizontal adduction load or horizontal abduction load in an anti-gravity posture, such as sitting or standing.

SUBJECTS AND METHODS

Sixteen healthy males volunteered for this study (mean age; 21.9 years $\pm$ 0.83 years). Exclusion criteria included shoulder pain and an orthopedic and/or a neurological history of the shoulder. All participants read and signed an informed consent form prior to their inclusion in this study. This study was approved by the institutional review board of the Faculty of Health Sciences, Hokkaido University (ID: 13-76).

Surface electromyographic (EMG) activities of the UT, LT and SA muscle were measured. Before placing the surface electrodes, the skin was cleaned with alcohol on a cotton swab in order to get a good electrode-skin contact. When necessary, the skin was shaved to reduce skin artifacts. Bipolar surface electrodes (Blue Sensor P-00-S, Ambu, Denmark) were placed over the UT and the LT muscles and the lower region of the SA muscle with a 2 cm inter-electrode distance. Placement of the electrodes for the UT and the LT followed SENIAM¹⁸⁾, and the electrode placement for the SA followed the descriptions of previous studies^{13, 16)}. The reference electrode was placed over the seventh cervical vertebra. All of the electrodes were connected to a MyoSystem 1,200 electromyographic receiver (Noraxon USA Inc., Scottsdale, AZ, USA). Unit specifications include a differential input impedance of greater than 10 M Ω , a gain of 1000, and a common mode rejection ratio of greater than 100 dB at 60 Hz. The sampling rate was set at 1,000 Hz. Baseline noise was filtered with a band-pass filter of 10–500 Hz.

Before performing the series of the scapular muscle activation tasks, the EMG signal quality was verified for each muscle during the performance of the maximal voluntary isometric contraction (MVIC) tests specified for each muscle of interest as described by SENIAM and previous

studies^{13, 16)}. During the MVIC tasks, subjects performed and held each posture for 5 seconds against manual resistance and each trial was repeated three times. After signal filtering with a sixth order Butterworth 6 Hz low-pass filter, EMG value of the middle one-second window of the 5 seconds was averaged for each trial. The mean of the trials was calculated and used as the normalization value.

Each participant performed the four exercises, which were selected as exercises representative of those used for promoting balanced scapular muscle activity. They were prone extension (ProExt), prone horizontal abduction with external rotation (ProHAbd), forward flexion in the side-lying position (SideFlex), and side-lying with external rotation (SideEr) (Fig. 1a–d). In addition, shoulder flexion with glenohumeral horizontal abduction load (FlexBand) and horizontal adduction load (FlexBall) in standing posture (Fig. 1e, f) were also performed. The order of the tasks was randomized to avoid the effects of muscle fatigue. As in the previous study by Cools et al.¹³⁾, all exercises, except for those performed in the side-lying posture, were performed bilaterally. Before data collection, the participants performed the exercises without resistance to familiarize themselves with their execution. Each exercise was divided into concentric, isometric and eccentric phases. Each phase was performed for 5 seconds regulated by a metronome beat. The subjects held 1 kg dumbbells in both hands, and completed 3 trials of each task. Between trials, the participants had 30 seconds rest, and between exercises, they took a 1 minute rest to avoid muscle fatigue. During the exercises, when necessary, performance correction was verbally given to the subjects by the examiner (M. H).

All raw EMG signals were transferred to a Windows computer through a USB analog/digital (A/D) converter at 1,000 Hz and a 16 bit A/D board. They were full-wave rectified and filtered with a 6th order Butterworth 6 Hz low-pass filter. For each phase, the data were averaged across the middle 3 seconds of the 5 seconds. Then, the data of each trial were averaged within the same exercise. The results were normalized to the MVIC data. The mean EMG data, expressed as a %MVIC, were used to assess the activities of the UT, LT and SA muscle in each exercise.

In order to assess intermuscle and intramuscle balance of the scapular muscle, the UT/LT ratio and the UT/SA ratio were calculated. One-way repeated analysis of variance (ANOVA), and the Tukey HSD test as a post hoc test, were conducted for the comparison of data across the exercises in each phase. The statistical analysis was performed using the IBM SPSS Statistics 18 software program (IBM, Chicago, IL, USA). The α level for the analysis of variance was chosen as 0.05. In addition, following the study of Cools et al.¹³⁾, the exercises were divided into 3 subgroups based on the ratios of 100 to 80% (moderate), 80 to 60% (good), and <60% (excellent), and categorized as follows: exercises in which the ratio was smaller than 60% in each phase (category 1); exercises in which the ratio was smaller than 80% in each phase, with at least 1 phase having a ratio between 60 to 80% (category 2); exercises with a ratio much smaller than 100%, with at least 1 phase between the 60 to 80% limits (category 3); and exercises with at least 1 of the 3 phases

Table 1. The UT/LT ratios of all the exercises

	ProExt	ProHAbd	SideFlex	SideEr	FlexLoop	FlexBall	
Concentric	55.2±50.8%	42.4±36.7%	82.8±494.7%	38.9±52.6%	112.0±58.2%	299.5±259.5%	*
Isometric	85.3±75.2%	59.5±29.3%	20.8±17.9%	32.4±41.8%	93.8±59.9%	539.5±502.9%	*
Eccentric	74.8±64.1%	66.6±30.3%	28.9±50.7%	39.9±50.69%	118.7±76.9%	353.0±272.2%	*

*: Significantly greater than the other exercises

Table 2. The UT/SA ratios of all the exercises

	ProExt	ProHAbd		SideFlex	SideEr	FlexLoop	FlexBall	
Concentric	265.8±313.1%	714.3±596.0%	*	244.1±644.9%	431.9±660.9%	81.8±55.6%	46.1±32.7%	***
Isometric	380.8±534.5%	1,335.7±1,038.9%	**	93.6±103.1%	358.7±532.9%	67.4±41.7%	56.1±29.5%	
Eccentric	338.3±436.4%	1,100.2±939.1%	**	134.4±121.3%	372.6±567.3%	103.7±76.4%	49.6±30.2%	

*: Significant differences between all exercises except the FlexBall exercise

**: Significant differences between all exercises

***: Significant difference from the prone horizontal abduction exercise

much higher than 100% (category 4).

RESULTS

The results of one-way repeated ANOVA for the UT/LT ratio are summarized in Table 1. As the result of the ANOVA, there were significant differences in each phase ($p < 0.001$). There were no significant differences between FlexBand exercise and the other exercises ($p > 0.05$ among all exercises), whereas the FlexBall exercise demonstrated a significantly greater UT/LT ratio than those of the all other exercises in the concentric, isometric and eccentric phases ($p < 0.05$, respectively).

As the result of the ANOVA, Significant differences were found in the UT/SA ratio (Table 2) in each phase ($p < 0.001$). The ProHAbd exercise demonstrated a significantly greater UT/SA ratio than the other exercises in each phase ($p < 0.001$). The SideEr exercise demonstrated a significantly greater UT/SA ratio than the other exercises in all phases ($p < 0.05$), except the FlexBall exercise in the concentric phase. The UT/SA ratio of the FlexBall exercise was significantly smaller than those of the ProHAbd and the SideEr exercises in the concentric phase ($p < 0.05$).

According to the described above classification, the UT/SA ratio of the FlexBall exercise belonged to category one, whereas the UT/LT ratio of the FlexBand and the FlexBall exercises belonged to category four.

DISCUSSION

The purpose of the present study was to compare the UT/LT ratio and the UT/SA ratio among commonly used scapular muscle exercises which are carried out in side-lying and prone postures and flexion with glenohumeral horizontal abduction or horizontal adduction load in an anti-gravity posture. To the best of our knowledge, this is the first study to have investigated a strategy that induces balanced scapular muscle activity in anti-gravity postures such as sitting and standing. In our study, when the intramuscular and intermuscular activity ratios of the exercises

in an anti-gravity posture were significantly lower than or similar to the exercises in the side-lying and prone postures, we concluded that the exercises in the anti-gravity posture had induced balanced scapular muscle activity.

Our study revealed that the UT/LT ratio of the FlexBand exercise was not significantly different from those of the four exercises performed in the side-lying and prone postures in each phase. Because horizontal abduction load elicits its lower trapezius muscle activity in the FlexBand exercise, the FlexBand exercise induced balanced intra-scapular muscle activity. However, the FlexBall exercise elicited a significantly greater UT/LT ratio than the other exercises in each phase. Based on these results, we recommend that the FlexBand exercise be used to enhance balanced muscle activity between the UT and LT muscles.

A previous study by Cools et al. reported that the ProExt, ProHAbd, SideFlex, and SideEr exercises were not suitable for inducing balanced UT/SA activity¹³⁾. Our present results indicate that the ProHAbd exercise elicited a significantly greater UT/SA ratio than the other exercises in all the phases, while the FlexBall exercise demonstrated a significantly smaller UT/SA ratio than the ProHAbd exercise in the concentric phase. However, under the classification criteria, the FlexBall exercise belonged to category one. Therefore, we propose that the FlexBall exercise might induce balanced UT/SA activity in an anti-gravity posture.

This study has some limitations. First, during the FlexBall exercise, the participants held a ball and dumbbells, and this might have changed muscle activity. Second, UT/SA ratio varied widely among subjects. We should consider these limitations when conducting the exercises with patients.

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