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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

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 dysfunction1–5). 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 function7, 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.
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 to avoid the effects of muscle fatigue. As in the previous study by Cools et al., 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 the 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., 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
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 abduction or horizontal abduction 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 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 activity. Our present results indicate that the ProHAbd exercise elicited a significantly greater UT/SA ratio than the other exercises in all 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 FlexBand 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.

**REFERENCES**


2) Merolla G, De Santis E, Campi F, et al.: Supraspinatus and infraspinatus weakness in overhead athletes with scapular dyskinetic strength assessment before and after restoration of scapular muscle balance. Muscu-

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

<table>
<thead>
<tr>
<th></th>
<th>ProExt</th>
<th>ProHAbd</th>
<th>SideFlex</th>
<th>SideEr</th>
<th>FlexLoop</th>
<th>FlexBall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentric</td>
<td>55.2±50.8%</td>
<td>42.4±36.7%</td>
<td>82.8±494.7%</td>
<td>38.9±52.6%</td>
<td>112.0±58.2%</td>
<td>299.5±259.5%</td>
</tr>
<tr>
<td>Isometric</td>
<td>45.3±75.2%</td>
<td>59.5±29.3%</td>
<td>20.8±17.9%</td>
<td>32.4±41.8%</td>
<td>93.8±59.9%</td>
<td>259.5±502.9%</td>
</tr>
<tr>
<td>Eccentric</td>
<td>74.8±64.1%</td>
<td>66.6±30.3%</td>
<td>28.9±50.7%</td>
<td>39.9±50.69%</td>
<td>118.7±76.9%</td>
<td>353.0±272.2%</td>
</tr>
</tbody>
</table>

*: Significantly greater than the other exercises

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

<table>
<thead>
<tr>
<th></th>
<th>ProExt</th>
<th>ProHAbd</th>
<th>SideFlex</th>
<th>SideEr</th>
<th>FlexLoop</th>
<th>FlexBall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentric</td>
<td>265.8±313.1%</td>
<td>714.3±596.0%</td>
<td>244.1±644.9%</td>
<td>431.9±660.9%</td>
<td>81.8±55.6%</td>
<td>46.1±32.7%</td>
</tr>
<tr>
<td>Isometric</td>
<td>380.8±534.5%</td>
<td>1,355.7±1,038.9%</td>
<td>93.6±103.1%</td>
<td>358.7±532.9%</td>
<td>67.4±41.7%</td>
<td>56.1±29.5%</td>
</tr>
<tr>
<td>Eccentric</td>
<td>338.3±436.4%</td>
<td>1,100.2±939.1%</td>
<td>134.4±121.3%</td>
<td>372.6±567.3%</td>
<td>103.7±76.4%</td>
<td>49.6±30.2%</td>
</tr>
</tbody>
</table>

*: Significant differences between all exercises except the FlexBall exercise
**: Significant differences between all exercises
**: Significant differences between all exercises except 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 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**


