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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.
muscles and the lower region of the SA muscle with a 2 cm
Ambu, Denmark) were placed over the UT and the LT
artifacts. Bipolar surface electrodes (Blue Sensor P-00-S,
tact. When necessary, the skin was shaved to reduce skin
surface electrodes, the skin was cleaned with alcohol on
UT, LT and SA muscle were measured. Before placing the
of the Faculty of Health Sciences, Hokkaido University (ID:
This study was approved by the institutional review board
in each exercise. All participants read and signed an in -
age; 21.9 years ± 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 in-
formed 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 con-
tact. 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 SENIAM\(^\text{13}\), and the electrode
placement for the SA followed the descriptions of previous
studies\(^\text{13, 16}\). The reference electrode was placed over the
seventh cervical vertebra. All of the electrodes were con-
ected to a MyoSystem 1,200 electromyographic receiver
(Noraxon USA Inc., Scottsdale, AZ, USA). Unit specifica-
tions include a differential input impedance of greater than
10 MΩ, 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 volun-
tary isometric contraction (MVIC) tests specified for each
muscle of interest as described by SENIAM and previous

studies\(^\text{13, 16}\). During the MVIC tasks, subjects performed
and held each posture for 5 seconds against manual resis-
tance 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 sec-
onds 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 ro-
tation (SideEr) (Fig. 1a–d). In addition, shoulder flexion
with glenohumeral horizontal abduction load (FlexBand)
and horizontal adduction load (FlexBall) in standing posi-
ture (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.,\(^\text{13}\) all exercises, except
for those performed in the side-lying posture, were per-
formed 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 partici-
pants had 30 seconds rest, and between exercises, they took
a 1 minute rest to avoid muscle fatigue. During the exercis-
eses, 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 ra-
tio 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, Chi-
ago, IL, USA). The α level for the analysis of variance was
chosen as 0.05. In addition, following the study of Cools et
al.,\(^\text{13}\), 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 (cat-
-egory 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% lim-
ts (category 3); and exercises with at least 1 of the 3 phases

Fig. 1. Scapular muscle exercises
a: prone extension (ProExt); b: prone horizontal abduc-
tion (ProHAbd); c: forward flexion in the side-lying posi-
tion (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)
such as sitting and standing. In our study, when the intra-scapular muscle activity in anti-gravity postures had induced balanced scapular muscle activity. To the best of our knowledge, this is the first study to have investigated a strategy that induces anti-gravity posture. To the best of our knowledge, this is the first study to have investigated a strategy that induces anti-gravity posture. UT/LT ratio and the UT/SA ratio among commonly used muscular and intermuscular activity ratios of the exercises belonged to category four. According to the described above classification, the UT/SA ratio of the FlexBall exercise belonged to category one. Therefore, we recommend that the FlexBand exercise be used to enhance balanced muscle activity between the UT and LT muscles.

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\(^{13}\). 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 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.

### REFERENCES


