

Activation and Ratio of the Upper Trapezius and Serratus Anterior Muscles during Dynamic and Isometric Exercises on Various Support Surfaces

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Abstract. [Purpose] This study compared the activations of the upper trapezius (UT) and serratus anterior (SA) muscles and the SA/UT activation ratio during dynamic and isometric exercises on various support surfaces. [Subjects] We recruited 12 male subjects, all right-side dominant and with no congenital deformities in the upper extremities and no orthopedic or neurological disorders. [Methods] Push-ups and push-ups plus position maintenance exercises were performed on three different base surfaces: a wobble board, dual wobble boards, and a one-sided wobble board. Electromyography activities of the SA and UT muscles were recorded. [Results] The SA/UT ratio was significantly higher when dynamic exercises were performed using the one-sided wobble board than when they were performed on a normal wobble board or with dual wobble boards. The SA/UT ratio was significantly higher when isometric exercises were performed using a wobble board than when they were performed with a one-sided wobble board. [Conclusion] For clinical applications with a goal of selected SA muscle strengthening, greater benefit is achieved with isometric exercises performed on an unstable support surface and dynamic exercises performed on a stable support surface, as measured by the SA/UT ratio.

Key words: Electromyography, SA/UT ratio, Wobble board

(This article was submitted Jan. 27, 2010, and was accepted Mar. 2, 2010)

INTRODUCTION

Scapulothoracic dysfunction causes shoulder problems that include frozen shoulder, rotator cuff syndrome, superior labral lesions, shoulder instability and cervicobrachial pathologies¹⁻³⁾. Scapulothoracic muscle weakness is a cause of scapular instability and contributes to secondary subacromial impingement syndrome^{1,4,5)}. In athletes or workers who perform repeated overhead movements, shoulder muscle fatigue may result from shoulder pathologies^{6,7)}, and muscle

imbalance caused by acute muscle fatigue may impede normal muscular activation^{8,9)}.

Several studies have revealed the importance of scapular muscle strength, neuromuscular control and scapular stability for normal shoulder functioning^{4,10,11)}. Shoulder stability exercises include push-ups, scapular setting training, single arm rows, bicep curls, and wall wash, push-pull and isometric ball exercises¹²⁾. In early rehabilitation phases, other exercises commonly include joint repositioning tasks^{13,14)} and axial loading exercises such as closed kinetic chain techniques. Static

scapular setting exercises with a medicine ball are optimal for reinstating proprioception¹⁰⁾. Lephart et al.¹³⁾ and Paudua et al.¹⁵⁾ recommended an unstable surface for effective stability training.

Performing exercises on different types of support surfaces and with different joint positions affects muscle recruitment levels¹⁶⁾. The use of unstable support surfaces such as exercise balls, wobble boards, or foam padding provides an alternative to traditional exercises, under the hypothesis that an increase in the neuromuscular activation of the involved muscles will result from the variation¹⁶⁾. Therefore, exercise balls, wobble boards and other labile surfaces are often used in place of stable surfaces for resistance training exercises, both for injury management and for performance improvement^{17,18)}. The alleged benefits of unstable surface support training include improvements in joint proprioception and requirement of greater muscle activation^{16,19)}. However, the best supports for each exercise type are uncertain. Thus, the use of different support surfaces for different scapular setting exercises must be studied. Therefore, we measured the activations of the upper trapezius (UT) and serratus anterior (SA) muscles and calculated the SA/UT activation ratios during dynamic and isometric exercises performed on various support surfaces.

SUBJECTS AND METHODS

The subjects were 12 males, aged 23.1 ± 1.9 years (mean \pm SD), height 174.7 ± 4.5 cm, and body weight 69.7 ± 8.4 kg, who consented to participate in this study. All subjects were right-side dominant, and none had congenital deformities of the upper extremities or orthopedic or neurological disorders. Ethical approval was obtained from the Human Ethics Committee of the Faculty of Health Sciences at Yonsei University.

Muscle activities of the SA and UT muscles were recorded with an electromyography (EMG) system (Biopac Systems, Santa Barbara, CA, USA), using disposable surface EMG bipolar electrodes with a 20 mm diameter. All EMG signals were amplified, bandpass- (20 Hz to 500 Hz) and notch-filtered (60 Hz), and sampled at 1,000 Hz using Acknowledge 3.9.1 software (Biopac Systems, Santa Barbara, CA, USA). The root-mean-square values of the raw data were calculated, and the maximal EMG data were used to normalize the EMG signals acquired

during each maximum voluntary contraction (MVC) maneuver. The mean value of the EMG data for all tasks was expressed as a percentage relative to the MVC. Skin impedance to electrical signals was reduced by shaving body hair and cleaning the skin with 70% isopropyl alcohol prior to electrode placement. SA electrode positionings and MVC procedures were on the muscle belly at the midaxillary line of the right side over the fifth rib. With the subjects in the supine position, the scapula was protracted at 90 degrees of shoulder flexion as resistance was applied over the hand and at the elbow. UT electrodes were placed on the muscle belly midway between the C7 spinous process and the trapezius insertion, on the right acromioclavicular joint. With the subject sitting in an erect posture without back support, the shoulder was abducted to 90 degrees with the neck bent to the same side, rotated to the opposite side, and then extended as resistance was applied at the head and above the elbow¹⁶⁾. Each trial was performed for 5 seconds, and EMG data was averaged from the medial 3 seconds.

Before testing, a primary investigator explained the experimental conditions to all the subjects, who practiced for ten minutes to become familiar with the surfaces. Exercises were performed on three different base surfaces, a wobble board, a dual wobble board, and a one-sided wobble board. The wobble board was a type commonly used as a stability exercise tool, a wooden balance board, 16 inches in diameter and 3 inches high (Fitter International Inc., Canada). The dual wobble board and the one-sided wobble board were developed for this study. They are portable and can be used to create various exercise conditions. They were constructed from two small wooden wobble boards, 6 inches in diameter and 3 inches high and one square wooden box 6 inches long, 6 inches wide, and 3 inches high. Dual wobble board exercises were performed with small wooden wobble boards on both the right and left sides. One-sided wobble board exercises were performed with a square wooden box on the left side, and a small wooden wobble board on the right for selective application of the unstable support surface on the right side (Fig. 1).

In the prone position, the subject's arms were positioned shoulder-width apart and directly underneath the shoulders when in the upright position. The exercise began on the instruction

“start”, and two types of exercises were performed for 3 seconds each. Subjects performed two exercises, a dynamic push-up exercise, and an isometric plank exercise. Speed was controlled with a metronome at 60 beats per minute, and the investigator initiated and stopped the EMG program at the start and end of the phase. SA and UT muscle EMG activities were recorded. All exercises were performed three times, with a 3-minute rest between trials. All experimental procedures were performed by the same investigator to reduce variability in marker and electrode placements. The order in which the base surfaces were used and in which the exercises were performed were selected randomly.

The SPSS 12.0 statistical package (SPSS, Chicago, IL, USA) was used for statistical analysis. Differences in SA, UT and SA/UT ratio during push-ups and plank exercises using the wobble board, dual wobble board, or one-sided wobble board were tested by repeated one-way ANOVA. The major effects were determined using Bonferroni's correction, and significance was defined as $p < 0.05$.

RESULTS

The SA/UT ratio of normalized EMG data for the dynamic exercise was significantly different among the three support surfaces. The SA/UT ratio for the dynamic exercise performed using a one-sided wobble board was significantly higher than when the standard wobble board or dual wobble boards were used ($p < 0.05$). The UT and SA muscle activities during the dynamic exercise were not significantly affected by support surfaces (Table 1). The SA/UT ratio of normalized EMG data for the isometric exercise differed significantly with support surface. The SA/UT ratio for the isometric exercise performed using a wobble board was significantly higher than when performed with a one-sided wobble board ($p < 0.05$). The UT and SA data were not significantly different for isometric exercises on different supports (Table 2).

DISCUSSION

The training of scapulothoracic muscles, especially the SA and lower trapezius, are considered critical for rehabilitation of shoulder injuries^{10,20}. Scapular elevation and lateral rotation create synergy in the SA, UT and lower trapezius.

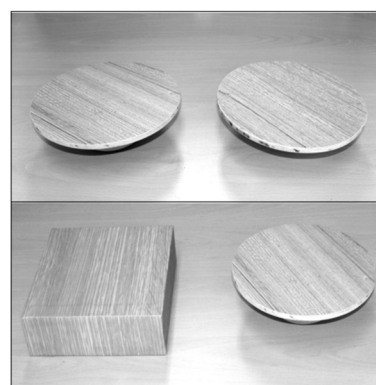


Fig. 1. Dual wobble boards (top), and a one-sided wobble board (bottom).

Table 1. Normalized EMG data for UT, SA and SA/UT ratio for dynamic exercise

	Dynamic Exercise (% Mean \pm SD)		
	Wobble board	Dual wobble boards	One-sided wobble boards
UT	47.7 \pm 19.2	45.2 \pm 15.2	40.5 \pm 19.8
SA	29.2 \pm 14.7	28.6 \pm 14.0	28.2 \pm 12.7
SA/UT ratio	0.4 \pm 0.2	0.7 \pm 0.3	1.1 \pm 0.4*

* $p < 0.05$

These muscles also support the scapular motions required during overhead motion²¹). Lin et al.²² found that patients with shoulder problems had muscle imbalance, specifically an overactive UT and an inhibited SA, along with scapular elevation and anterior tilt. According to Ludewig et al.²³, SA is an important component in rehabilitation, since selective SA strengthening reduces imbalance in the serratus and trapezius force-couple seen in patients with shoulder girdle complaints. Therefore, in patients with shoulder girdle complaints, the SA/UT ratio could be an important rehabilitation component^{22,23}). This study investigated the activations of the UT and SA muscles and the SA/UT activation ratios during dynamic and isometric exercises on various support surfaces, specifically a wobble board with one unstable support axis, a dual wobble board with two unstable support axes, and a one-side wobble board with one stable support axis and one unstable support axis.

For the isometric exercise using a wobble board, the SA/UT ratio was significantly higher than that for the one-sided wobble board. We conclude from

Table 2. Normalized EMG data for UT, SA and SA/UT ratio for isometric exercise

	Isometric Exercise (% Mean \pm SD)		
	Wobble board	Dual wobble boards	One-sided wobble boards
UT	17.9 \pm 16.0	21.1 \pm 19.0	18.2 \pm 15.1
SA	75.2 \pm 24.9	66.8 \pm 14.8	61.7 \pm 14.0
SA/UT ratio	8.3 \pm 5.3*	6.4 \pm 3.8	6.3 \pm 3.7

* $p < 0.05$

the SA/UT ratio that the isometric exercise was more beneficial when performed on the unstable support surface than when performed on the stable support surface. Therefore, when selectively strengthening SA using isometric exercises, greater benefit might be achieved using an unstable support surface. For dynamic exercise, the SA/UT ratio with a one-sided wobble board was significantly higher than with either the wobble board or the dual wobble board. We conclude from the SA/UT ratio that dynamic exercises might give greater benefit using stable support surfaces, rather than unstable support surfaces. Therefore, for selective strengthening of SA using a dynamic exercise, a stable support surface should be used. Specifically, the one-sided wobble board should be used for dynamic exercises for the selected strengthening of either the right or left SA muscle (by switching stable wooden box and unstable small wobble board) in clinical shoulder rehabilitation.

This study had several limitations. EMG data were obtained from only muscles on the right, dominant side of all participants. We examined only the short-term effects of the exercises, our sample size was small, and only male subjects were measured. Future studies should assess synchronously obtained three-dimensional motion analysis, collect EMG data for both right and left shoulder muscles, compare males and females, and investigate long term changes.

ACKNOWLEDGEMENTS

This research was supported by Basic Science Research Program Through the National Research Foundation of Korea(NRF) funded by the Ministry of Education, Science and Technology (No. 2009-0072055).

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