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Comparison of Upper Trapezius, Anterior Deltoid, and Serratus Anterior Muscle Activity during Push-up plus Exercise on Slings and a Stable Surface

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Abstract. [Purpose] The purpose of this study was to identify effects of push-up plus exercise on different support surfaces on upper extremity muscular activity. [Subjects] The subjects were 28 students (10 males, 18 females) at B University. [Methods] The subjects performed push-up plus exercises either on slings or on a fixed support. [Results] Push-up plus exercises on slings showed significant increases in the muscle activity of the trapezius (upper fiber), deltoid (anterior fiber), and serratus anterior muscles compared with stabilization exercises on a fixed support. [Conclusion] Based on these results, it is considered that performance of the push-up plus exercise on slings will increase scapular muscle activity.

Key words: Push-up plus exercise, Sling, Muscle activity

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INTRODUCTION

Decreases in serratus anterior (SA) muscle activity in patients with shoulder pain and shoulder instability are associated with abnormal scapular movements[1)]. A weakened SA induces excessive trapezius (upper fiber) (TU) muscle activity due to the TU's compensatory action[2, 3)], leading to subacromial collisions through abnormal upward rotations of the scapula[1)]. Those who have shoulder instability showed 15% to 20% higher rotator cuff muscle activity along with 8% to 10% lower deltoid (anterior fiber) (DA) muscle activity compared with healthy persons[4–6)].

Sling exercises (considered closed kinetic chain [CKC] exercises) can impose gradually increasing loads and improve muscle strength and proprioception[7)]. CKC exercises were developed for application to patients with musculoskeletal system disorders and increase muscle activity on an unstable surface, since they are performed with part of the body hanging on slings[8)]. Sling exercises are used to prevent functional disorders in shoulder joints and as part of shoulder joint exercise programs. The balance of the scapular stabilizers is important for sling exercises, and thus a CKC is mainly used[9)]. This CKC is an intervention method that can stimulate proprioception around joints because axial loads are imposed on the joints and improve coordinated contraction of muscles, posture maintenance and dynamic stability[10)]. Push-up plus exercises are performed in push-up postures while maintaining scapular protraction; they have been reported as CKC exercises that are more effective than push-ups[11)].

Some previous studies reported that using an unstable surface in rehabilitation exercises and muscle strength exercises could increase muscle activity, apply very difficult exercise levels, and improve joint proprioception[12)]. Another previous study reported that rehabilitation treatments using unstable surfaces in patients with shoulder instability led to improvement in the patients' joint proprioceptive balance[13)]. Some conflicting evidence has also been published. In another study, when muscle activity was compared between exercises performed on Swiss balls (which are unstable surfaces) and exercises performed on benches (stable surfaces), the effects of differences in surface were small. The researchers argued that, as limb muscle strength plays a role in joint stability during balance training on unstable surfaces, limb muscle strength should be improved on stable surfaces[14)].

Therefore, controversies existed over differences in muscle activity related to differences in surfaces in previous studies, and few studies implemented push-up plus exercises on an unstable surface using slings. Therefore, the purpose of this study was to implement push-up plus exercises using slings and push-up plus exercises on stable surfaces in order to compare the scapular muscle activity.

SUBJECTS AND METHODS

Subjects

This study was conducted with 28 students (10 males, 18 females) attending B University in Cheonan, South Ko-

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rea. The subjects' mean age was 23.67 ± 2.67 years, mean height was 166.28 ± 7.47 cm, and mean weight was 60.46 ± 13.10 kg. Those who had shoulder pain during the last six months and those who had any congenital malformation or serious medical, surgical, or neurologic disease were excluded from subject selection. The subjects received explanations about the study, voluntarily participated, and signed written consent forms, and the study was approved by the Health Ethics Research Board of Bronco Memorial Hospital.

Methods

The subjects performed push-up plus exercises either on slings or on stable surfaces.

In the case of the push-up plus exercises using slings, the suspension point was located 30 cm above the ground. As a starting posture, the subjects placed their hands and feet apart at shoulder width, aligned the capitate bone of the middle finger with the acromion to achieve scapular protraction, and took a push-up posture. Then, the subjects raised one leg, placed their head, trunk, and hip in a straight line, and maintained this posture for five seconds. The subjects repeated the motion three times.

The push-up plus exercise on a stable surface was performed in the same posture on a surface that was 30 cm from the ground.

Muscle activity was measured using surface electromyography after removing body hair and keratin and disinfecting the skin using alcohol to reduce skin resistance. Electromyography was performed using 1-cm diameter round Ag/AgCl electrodes, the distance between the two electrodes was maintained at 2 cm. Electrodes were attached to the TU (muscle belly at the midpoint between the C7 spinous process and the right acromioclavicular joint, which is the region of insertion of the trapezius)[15], the DA (close to the anterior acromion, one-fifth of the way from the anterior acromion to the lateral epicondyle)[16], and the SA (the muscle belly on the midaxillary line of the right fifth rib)[15]. The sampling rate was set to 2000 Hz, and the bandwidth was set between 400 and 500 Hz. During the stabilization exercises, the maximal voluntary isometric contraction (MVIC) of each muscle was measured for 5 sec to normalize the EMG signals from individual muscles. To yield the MVIC, root-mean-square (RMS) values were obtained for the 3 sec in the middle excluding 1 sec at the beginning and end; of the 5 measurements obtained for the RMS value, the average of the middle 3 values (excluding the largest and smallest values) was used to calculate the MVIC. The muscle activities of the TU, DA, and SA muscles measured in individual subjects were normalized against the MVIC to measure %MVIC.

Statistical analysis was conducted using SPSS for Windows (ver 18.0). The data are indicated as means ± standard deviations. Paired sample t-tests were used to analyze the data in order to compare differences in the activity of the TU, DA, and SA muscles according to the type of push-up plus exercise. The statistical significance level was set to 0.05.

Table 1. Comparison of muscle activity between supports (N=28)

	Sling	Stable surface
Upper trapezius	43.28 ± 19.86*	29.13 ± 17.05
Anterior deltoid	42.72 ± 39.36*	9.80 ± 8.04
Serratus anterior	55.94 ± 36.21*	29.73 ± 20.00

Unit: %MVIC. *p<0.05. Mean ± SD

RESULTS

In the muscle activity comparison, the %MVIC of the TU was shown to be 43.28% on the sling and 29.13% on the stable surface; for the DA, the values were 42.72% and 9.80%, respectively, and for the SA, they were 55.94% and 29.73%, respectively. The differences between the types of bearing surfaces were significant (p<0.05) (Table 1).

DISCUSSION

In this study, push-up plus exercises on slings showed significant increases in the muscle activity of the TU, the DA, and the SA compared with push-up plus exercises on stable surfaces.

Low TU/SA ratios mean high SA activity and low TU activity. In the case of patients with shoulder instability, shrug motions occur when the arm is raised above the head due to excessive muscle activity of the TU, and the imbalance of TU/SA ratios during flexion leads to more cases of winging of the scapula than during abduction because of insufficient scapular control and TU compensation for the weakened SA[17]; it also results in reduced muscle activity of the deltoid[4].

A previous study that compared muscle activity between different surfaces reported that muscle activity was higher on unstable surfaces than on stable surfaces[12]. Drake et al.[18] announced that when trunk extension exercises were implemented on different surfaces, average peak values decreased or did not change; Lehman et al.[15] advised that differences in muscle activity of the TU, the trapezius lower fiber, and the SA between different surfaces were not significant and that the muscle activity of the SA varied according to changes in the height of the feet. Uhl et al.[16] reported that during push-ups, the DA showed a %MVIC increase of 31% and that the pectoralis major (PM) muscle showed a %MVIC increase of 33%; during one-handed push-ups, the DA and the PM showed 46% and 44% increases, respectively, and the differences between the two muscles were not significant. De Oliveria et al.[19] reported that during push-ups on stable surfaces, the muscle activity of the SA was similar to that of the PM and that that of the SA was higher than that of the DA or the TU. During push-ups on balls, the muscle activities of the DA and SA were higher than that of the TU, and only the DA showed significant differences when the different surfaces were compared. However, Lehman et al.[15] indicated that muscle activity sufficiently increased only with the posture in which one leg was raised regardless of the types of surfaces, and Jung et al.[20] advised that, because the distal part of the lower

limbs can only move stably when elevated if the proximal part is in a stabilized posture, muscle activity increases before the height of the lower limbs increases because of pre-contraction of the shoulder muscles.

Eom et al.[21] suggested that exercises on slings provide dynamic environments so that the number of myofibrils increases, leading to increases of contraction. Santos and Aruin[22] advised that more muscle contractions occurred in order to maintain the center of gravity in a reduced base of support. Kang et al.[8] reported that bridge exercises using slings increased muscle activity by more than bridge exercises using balls because the use of local muscles among trunk muscles increased more. In this study, when the activities of the upper limb muscles were compared, the TU showed a %MVIC of 43.3% on slings compared with a %MVIC of and 29.1% on stable surfaces; the DA showed a %MVIC of 42.72% on slings compared with a %MVIC of 9.80% on stable surfaces; and the SA showed a %MVIC of 55.9% on slings compared with a %MVIC of 29.7% on stable surfaces. The reason why performing the exercise on slings showed higher muscle activity is thought to be that the muscle activity of muscles around the shoulder increased during push-up plus exercises on shaking slings in order to maintain the balance and alignment of the upper limbs and trunk.

Therefore, based on the results of this study, push-up plus exercises on slings are considered more effective for improvement of the muscle activity of the scapular muscles, and these exercises may be recommended for muscle re-education and muscle function improvement. Limitations of this study include that the subjects were males and females in their 20, which means that the results cannot be generalized to all age groups; that the height of the slings was set uniformly; and that patients with disorders in shoulder joint function were not included. In future studies, the effects of the application of exercises for lengthy periods of time and the activity of diverse muscles around the shoulder should be compared in more subjects.

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