



Original Article

The effect of the push-up plus on shoulder muscle activation while using a sling with a pulley

KIM TAE HO, PhD, PT¹⁾, KONG KWAN WOO, MSc, PT^{1)*}

¹⁾ Department of Physical Therapy, College of Rehabilitation Science, Daegu University:
201 Daegudae-ro, Jillyang, Gyeongbuk, Republic of Korea

Abstract. [Purpose] This study was conducted to investigate the effects of the push-up plus while using a balance ball, a sling, and a sling with a pulley in a creeping position on an unstable floor. [Subjects and Methods] The subjects were divided into three groups of 15 members each who performed the different three type methods of push-up plus (with scapulae protruding) in a random order while in a creeping posture. The muscle activity of each group in the push-up plus posture was measured using electromyography, and the measurement values were compared among the groups using one-way analysis of variance (ANOVA). [Results] The intergroup comparison revealed that the activation of the pectoralis major muscle of the balance ball exercise group was significantly decreased. In this comparison, the activity ratio for the pectoralis major muscles of the balance ball exercise group significantly decreased, and the activity ratio of their serratus anterior muscles significantly increased. From the post analysis, the differences in the activity ratios of the pectoralis major and serratus anterior muscles for the balance ball exercise group were significant when compared with those of the other groups. [Conclusion] Among the three different exercise methods in unstable situations presented in this study, the push-up plus exercise in a creeping posture using the balance ball can be recommended for the selective strengthening of the serratus anterior muscle.

Key words: Push-up plus, Serratus anterior, Sling with a pulley

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INTRODUCTION

A motion that plays an important role in shoulder pain is the upward rotation of the scapula. Insufficient upward rotation of the scapula while raising the arm causes various pathological conditions, such as instability, rotator cuff tear, and the impingement syndrome¹⁾. Among the many muscles involved in the function and motion of the scapulae, recent studies have emphasized the role of the serratus anterior (SA) muscle²⁻⁴⁾. Furthermore, coupling of the SA muscle with the upper and lower trapezius is required for the upward rotation of the scapula. These muscles provide stabilization for the shoulder and chest joints, maintain the proper position of the scapula, and provide dynamic stability while the arm is moving⁴⁾. The scapular muscles become unbalanced when the upper and lower trapezius muscles are activated abnormally. In particular, the upper trapezius (UT) can become excessively activated whereas the SA muscle is less frequently activated. This situation causes various problems to the shoulder. First, the subacromial space is decreased because shoulder rotation is reduced when the arm is raised. A decrease of subacromial space triggers various pathological conditions, including the impingement syndrome and rotator cuff tear, causing pain and dysfunction⁵⁾.

To address this problem, various exercise methods for the upward rotation of the shoulder are being introduced⁶⁾. Among them, the push-up plus has been researched as an exercise to strengthen the SA muscle during weight bearing⁷⁾. This exercise is performed using props; among these props, the balance ball stimulates more proprioceptors by providing an unstable surface, thus contributing to the strengthening of muscles and posture recognition⁸⁾. Because it uses a string, the sling also

*Corresponding author. Kong Kwan Woo (E-mail: kanoo75@naver.com)

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provides an unstable support surface. The sling is easy to use and effective for stabilization exercises, the control of nerve muscles, and the strengthening of muscles⁹). Recently, exercise methods using a sling connected with a pulley have been introduced that require a greater sense of left and right balance for the exerciser and that consequently reduce asymmetry.

The purpose of this study was to apply the use of a balance ball, sling, and sling with a pulley to the push-up plus exercise in a creeping posture, comparing the effects of each exercise method on the activity ratio and the left and right asymmetry of muscles around the shoulder.

SUBJECTS AND METHODS

Fifteen subjects participated in this study with an average age of 27.4 ± 2.5 years, an average height of 173.5 ± 5.2 cm, and average weight of 69.2 ± 5.8 kg. The participant selection criteria for this study were as follows: first, no medical history of dysfunction in the musculoskeletal system, and second, no regular or systematic exercise at the time of participant selection. All the subjects of this study voluntarily agreed to participate after listening to an explanation of the purpose and methods. The present study was approved by the Daegu University Institutional Review Board and accorded with the ethical principles of the Declaration of Helsinki.

The 15 subjects were randomized into three groups, and each group conducted the different exercises sequentially by drawing lots, with a 15-minute break after each exercise. Before conducting the experiment, each group received training for the push-up plus exercise in a creeping posture for five minutes. The participants maintained the posture for 10 seconds according to the tester's instruction: "Push your shoulder forward and maintain the position." They then lowered their shoulders and rested, as instructed. After resting for 10 seconds, the participants repeated each exercise three times resting for 10 seconds after each exercise. After spreading their arms at shoulder width, bending their hip joint at 90 degrees, and bending their knee joints at 90 degrees, each member of the first group (the balance-ball group: group B) applied both hands to a balance ball. The second group (the sling group: group S) held a sling fixed 10 cm from the floor, and the third group (the pulley group: group P) held two slings connected to a pulley.

The muscle activity during the maximum isometric contraction of the UT, pectoralis major (PEC), and SA muscles were measured three times using Telomyo-DTS (Telomyo-DTS, Noraxon, USA) and then averaged. To determine the maximum isometric contraction value, a therapist applied maximum resistance for five seconds against the motion of each muscle, and a five-minute break was given between measurements to prevent muscle fatigue. The muscle activity values were used from the middle three seconds (i.e., excluding the first and last seconds).

For the attachment sites of surface electrodes, the skin was cleaned with sandpaper after hair removal and before disinfection with an alcohol swab. For the UT muscle, the electrode was attached to the center position between the seventh spinous process of the neck bone and the lateral side of the acromion. For the PEC muscle, the electrode was attached 2 cm medially along the axillary folds. For the SA muscle, the electrode was attached to the front of the broad back muscle, which is the lateral part of the inferior angle of the scapula¹⁰). The sampling rate for electromyogram signal processing was 1,000 Hz, while the original signals of the electromyogram were filtered with a 40–400 Hz band-pass filter, and noises were removed with a 60 Hz notch filter. The collected signals were processed by root mean square (RMS) so they could be quantified.

To determine the relative contribution of the three muscles, the relative composition ratio of the muscle activity, which represents the activity of each muscle, was determined as a percentage of the sum of the maximum voluntary isometric contraction (MVIC) values for UT, PEC, and SA muscles at 100%. Then, to obtain the sum of the asymmetry values for each exercise, the asymmetry values for the left and right side of the three muscles were determined and summed up. The asymmetry value was determined by dividing the median of the left and right muscle activity values by the absolute value of the difference between the left and right muscles in each activity, and the resulting value was then multiplied by 100. For data analysis, SPSS 18.0 for Windows was used to compare the muscle activity ratio and degree of asymmetry for UT, PEC, and SA muscles. Then, one-way ANOVA was used to compare the degrees of asymmetry for each of the three exercise methods. For post analysis, the least significant difference (LSD) was used, and the statistical significance level (α) was set to 0.05.

RESULTS

In the intergroup comparison, the activity level of the PEC muscles among group B significantly decreased ($p < 0.05$), but no significant difference was found for the activities of UT and SA muscles ($p > 0.05$). An analysis of the activity ratio for the PEC, UT, and SA muscles revealed a significant decrease ($p < 0.05$) in the activity ratio of the PEC muscle for the group B, and the SA activity ratio of group B significantly increased ($p < 0.05$). Based on post analysis, the differences in the PEC and SA activity ratios of group B were significant ($p < 0.05$) when compared with those of all other groups (Table 1). However, the variations in the differences between exercises among the groups were not significant ($p > 0.05$).

DISCUSSION

The activity ratios for PEC and SA muscles in the B group showed significant differences when compared with other groups. However, the differences in the left and right asymmetry values among the three groups were insignificant.

Table 1. Muscle activity ratios of UT, PEC, and SA muscles in three different exercises

Ratio of muscle activity ^a (%MVIC)	Balance ball	Sling	Pulley sling
UT	10.7 ± 7.4 ^b	10.9 ± 7.7	10.9 ± 7.4
PEC	24.5 ± 10.4*	44.4 ± 10.5	38.5 ± 14.5
SA	64.9 ± 10.2*	44.73 ± 8.5	50.8 ± 13.9

^a (The muscle activity of each muscle/The sum of the muscle activity of the three muscle)*100

^b Mean ± SD, *p<0.05

UT: upper trapezius; PEC: pectoralis major; SA: serratus anterior; MVIC: maximum voluntary isometric contraction

When the level of SA activity is decreased, the activity of the UT muscle is increased, and appropriate upward rotation of the scapula becomes impossible. This change of the mobilization sequence interferes with the upward rotation of the scapula and generates a raised scapula¹¹). To prevent winging scapula and activate the SA, the push-up plus exercise is recommended¹²). The protrusion of the scapula, which is involved in the push-up plus motion with the shoulder bent at 90 degrees, can activate the SA^{13, 14}). This muscle activation can promote the upward rotation of the scapula to the maximum and reduce the alar scapula phenomenon. Studies on the push-up plus exercise have reported that enhancing muscle activity by stimulating the proprioceptors is more effective when the exercise is combined with sensorimotor control training on an unstable floor^{15–17}). In this study, a sling connected to a pulley was added to such an unstable surface, and its effect on the selective activity of SA muscles was examined. As a result, the SA activity ratio of group B was significantly higher than that of other groups, and the PEC activity ratio of group B was significantly lower than that of other groups. This result suggests that the push-up plus exercise in a creeping posture using a sling or a sling with a pulley was inefficient for the selective activation of the SA muscle because the participation of other muscles was increased.

The exercises using a sling or a sling with a pulley showed greater co-contraction of other muscles because their instability was higher compared to the exercise using a balance ball. Therefore, a method that can selectively activate the SA muscle for the upward rotation of the shoulder is the push-up plus exercise in a creeping posture using a balance ball. However, to emphasize co-contraction with other muscles after the successful selective contraction of SA, it is appropriate to induce the co-contraction of other shoulder muscles by applying, step-by-step, the scapula protrusion exercise in a creeping posture using a sling or a sling with a pulley. This is because the muscles that play an important role in the upward rotation is SA, but at the time of the upward rotation, they are finally completed by the co-contraction of various muscles¹⁸).

One characteristic of the exercise using a sling or sling with pulley is that the directions of the string and the body can be adjusted. In future studies, therefore, the amount of instability applied to the body needs to be reduced by adjusting the height and angle of the string to investigate the effects of the exercises at various angles on the activity ratios of the shoulder muscles.

As to the other purpose of this study, which was to investigate the left and right asymmetry effects of the push-up plus exercise in a creeping posture using a sling with a pulley, no significant difference was found when comparing the activity ratios of the left and right shoulder muscles. This result suggests that all three exercises equally recruited the left and right shoulder muscles on an unstable surface. However, more research is needed to analyze the left and right balance involved trunk and lower extremities when performing a push-up plus exercise using a sling with a pulley.

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