The Effect of Hand Position Changes on Electromyographic Activity of Shoulder Stabilizers during Push-up Plus Exercise on Stable and Unstable Surfaces

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Abstract. [Purpose] The purpose of this study was to determine the effect of hand position changes on electromyographic activity of shoulder stabilizers during push-up plus exercise (PUPE) performed on both stable and unstable surfaces. [Subjects] This study was performed on a cohort of 20 normal adults divided into an unstable surface group (USG) (n=10) and a stable surface group (SSG) (n=10). [Methods] A sling device was used to provide an unstable surface, and a push-up bar was used to provide a stable surface. PUPEs were performed with hands in various positions: the neutral position (NP), the internal rotation position (IRP), or the external rotation position (ERP). Electromyography was used to determine and analyze the electromyographic activity of the upper trapezius muscle (UT), the lower trapezius muscle (LT), the serratus anterior muscle (SA), and the pectoralis major muscle (PM). [Results] Comparison of the results within the USG and SSG showed significant differences depending on the hand position used during the exercise. Comparison between the USG and SSG showed that the ERP hand posture resulted in significant differences in electromyographic activity of the SA in the USG. [Conclusion] The electromyographic activity of the SA indicated that performing PUPEs using the ERP on an unstable surface provided more effective intervention for shoulder stabilization than ERP on a stable surface.

Key words: Push-up plus, Hand position, Unstable surface

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INTRODUCTION

The shoulder and chest muscles regulate normal motion in the shoulder joint by stabilizing the scapula in the chest while the upper arms are raised¹⁾. The serratus anterior muscle (SA), the upper trapezius muscle (UT), the lower trapezius muscle (LT), the rhomboid muscle, and the levator scapula muscle form force couples that effect this stabilization²⁾. The SA, which is considered of primary importance in stabilizing the scapula, acts as a lever when the vertical axis through the sternoclavicular joint protracts and also causes abduction and upward rotation of the scapula, thereby keeping the scapula flat against the ribs. Instability of the scapula can cause abnormal electromyographic activity of the SA. Weakening of the serratus anterior muscle leads to excessive activation of the upper trapezius muscle and reduced activation of the serratus anterior muscle and lower trapezius muscle, reducing the dynamic stability of the scapula. When the arms are abducted, incomplete dynamic stability moves the humerus through contraction of the deltoid muscle and the supraspinatus muscle, triggering a clash between the subacromion and the head of the humerus. A weakened SA can be found in workers who have impinge-

ment syndrome in the shoulder joint, baseball players who have instability in the shoulder joint, and swimmers who experience pain in the shoulder joint. Reduction in the activity of this muscle is closely related to abnormal motion of the shoulder joint^{3, 4)}.

For those experiencing problems with movement of the scapula due to imbalance of muscle force couples, isometric and upper extremity exercise therapy programs aimed at restoring the normal position of the scapula should improve stability. To this end, upper extremity exercise programs using closed kinetic chain exercises, such as push-up exercises, push-up plus exercises (PUPEs), and isometric ball exercises, are quite often applied. When applying therapy to stabilize the shoulder joint, it is more effective for muscle strengthening to be performed on an unstable platform, which introduces dynamic movement, rather than performing static and continuous movement on a stable surface. The push-up exercise is a common exercise performed in a prone position by raising and lowering the body using the arms. When performing push-up exercises, it is more effective to use an unstable surface than a stable surface in order to increase muscle activity and simulate the proprioception of the shoulder joint. The sling is a device that hangs from the ceiling and facilitates the performance of stability exercises for weak muscles by stimulating proprioception due to the instability of the platform on which the exercises are per-

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formed. This system results in a dynamic exercise method for strengthening various muscles and thereby increases the stability of the joints and the proximal portion of the torso.

In PUPes, scapula protraction is added when the elbow joint is fully extended. Moseley et al.⁵⁾ reported that the PUPE was one of the most effective closed kinetic chain training methods for selectively strengthening the SA and for stabilizing the shoulder joint. Most previous studies on PUPes have been conducted using both stable and unstable platforms. However, few studies have measured the electromyographic activity of shoulder stabilizer muscles according to changes in hand position while using both surface conditions.

Therefore, the goal of this study was to investigate the electromyographic activity of the shoulder stabilizer muscles according to changes in hand position while performing the PUPE, a closed kinetic chain exercise, using a sling device as an unstable platform and a push-up bar as a stable platform.

SUBJECTS AND METHODS

This study included 20 healthy young male students in their 20s attending Y University in Chungbuk Province, Korea. The subjects were all right-hand dominant. Subjects who did not have musculoskeletal or neurological diseases in the upper or lower extremities, did not have a lesion in the spine or the upper extremities, and did not have a history of surgery were selected and randomly divided into groups. The subjects were divided into an unstable surface group (USG) ($n=10$) and a stable surface group (SSG) ($n=10$). The average age of the subjects in the USG was 23.7 ± 1.21 years, the average height was 175.16 ± 4.42 cm, and the average weight was 73.01 ± 8.67 kg. The average age of subjects in the SSG was 23.3 ± 1.45 years, the average height was 174.27 ± 3.29 cm, and the average weight was 74.41 ± 7.49 kg. The subjects were informed about the purpose and method of this study prior to the experiments, and voluntarily provided consent to participate.

To provide an unstable surface while performing PUPE, a sling device (Terapimaster plus, Nordisk Terapi AS, Norway) was used, and a push-up bar (FE 0168, Korea Sports, Seoul, Korea) was used to provide a stable surface. Both the sling device and the push-up bar were set at a height of 10 cm from the ground.

The subjects who performed PUPes using the sling device assumed a quadruped starting posture, keeping both the hands and knees shoulder-width apart, so that the body weight was supported by the hands and knees. When the hands gripped the sling device, they were at a height of 10 cm and perpendicular to the ground. While flexing the shoulder joint, the femoral/knee joint flexion was at 90 degrees in the quadruped posture, and the head, spine, and pelvis were positioned in a straight line, in a neutral state, with the eyes gazing at a point on the ground. The elbow joint was fully extended, and the ankle joint was maintained in a plantar flexion posture. In order to keep the cervical vertebrae in a neutral position, the cervical and thoracic vertebrae were set in a straight line. The subjects were cued

to start the PUPE when they heard the command "start" and maintained their position for 5 seconds in the quadruped posture. Hand positions were alternated to the neutral position (NP), in which the upper extremities remained in the neutral position; the internal rotation position (IRP), in which the upper extremities were internally rotated to 90 degrees; and the external rotation position (ERP), in which the upper extremities were externally rotated to 90 degrees. If the standardized starting posture, movement, and finish posture were not maintained, data were not recorded. The experimenter instructed the subjects to assume the correct posture and measured each posture twice. Three minutes of rest were provided between each measurement. Subjects were instructed both verbally and by demonstration. Then, the subjects were allowed to exercise for 10 minutes to sufficiently familiarize themselves with conversion from the quadruped posture to the PUPE posture. At this time, the subjects were told that the thoracic vertebrae should not be lifted excessively as a compensatory mechanism. Hand position changes were performed randomly. The subjects using the push-up bar performed PUPes under the same conditions as the subjects using the sling device.

An MP150 (Biopac Systems, Santa Barbara, CA, USA) with a 2-cm diameter Ag-Ag/Cl electrode was used to measure changes in the electromyographic activity of the muscles related to stabilization of the scapula. For manual muscle testing, maximum voluntary isometric contractions (MVIC) were measured to quantify the action potential of all the muscles. Since the subjects were all right-hand dominant, surface electrodes were attached to the upper extremities on the right side at the region of the back halfway between the spinous process of C7 and the acromion for measurement of the UT; the region near the inner 1/4 position between the thoracic vertebrae and the inferior angle of the scapula for measurement of the LT; the region in front of the latissimus dorsi muscle at the No. 5 and No. 6 ribs for measurement of the SA; and at a region 2 cm from the inner side of the anterior axillary border.

The EMG signals were processed as full-waves once they were collected at a sampling signal acquisition rate of 1,000 Hz. The data were summarized using the AcqKnowledge version 3.81 (Biopac Systems, Santa Barbara, CA, USA) software, performing band-pass filtering at 30–500 Hz and processing the signal by filtering at 60 Hz to remove noise. The raw data measured for standardization were converted to root mean squares (RMS). The measurement values from the first and last seconds were excluded; thus, only the values measured during the three middle seconds were included in the analysis. Each RMS value was divided by the maximum value of isometric contraction (MVIC), and then the results were obtained by performing normalization of a range between 0% and 100% to the % MVIC values.

For statistical processing, a repeated measures one-way ANOVA was performed in order to determine the electromyographic activity of the muscles within the group according to the hand position changes. An independent samples t-test was also performed to establish the significance of the electromyographic activity of the muscles between

Table 1. Changes in the electromyographic activities of the shoulder stabilizer muscles in relation to hand position between the groups (Units: %)

Muscle	Group	NP	IRP	ERP
UT	USG	^a 19.5 ± 28.6	12.9 ± 8.4	11.0 ± 8.3
	SSG	15.8 ± 10.2	16.0 ± 12.9	12.9 ± 7.8
LT	USG	5.7 ± 4.4	6.2 ± 4.9	5.9 ± 3.9
	SSG	3.7 ± 2.4	4.2 ± 2.9	4.7 ± 3.2
SA	USG*	43.2 ± 12.1	39.1 ± 17.9	60.6 ± 10.3 [†]
	SSG*	39.5 ± 12.2	33.2 ± 7.9	45.9 ± 8.5
PM	USG	43.8 ± 17.8	37.3 ± 14.2	44.3 ± 23.9
	SSG	34.3 ± 16.2	39.1 ± 18.7	45.5 ± 28.6

USG, unstable surface group; SSG, stable surface group; UT, upper Trapezius; LT, lower trapezius; SA, serratus anterior; PM, pectoralis major; NP, neutral position; IRP, 90° internal rotation position; ERP, 90° external rotation position. ^aMean±SD, *Repeated one-way ANOVA. [†]Independent sample t-test.

*†p<0.05

the groups according to the changes in hand position.

RESULTS

The results showed significant differences in electromyographic activity when comparing changes in hand position within each group (USG and SSG) ($p<0.05$). There were significant differences in the electromyographic activity of the SA in the ERP among the changes in hand position in the between-group comparison ($p<0.05$) (Table 1).

DISCUSSION

In this study, we examined the electromyographic activity of the UT, LT, SA, and PM according to NP, IRP, and ERP hand positions, when performing the PUPE, a closed kinetic chain exercise, using a sling device to provide an unstable surface and a push-up bar to provide a stable surface.

Oh et al.⁶ reported that, as it is a dynamic exercise method, a sling exercise on an unstable surface, as opposed to one on a stable surface, strengthened various muscles by improving the stability of proximal joint parts. Accordingly, the present study investigated the PUPE with changing hand positions under two different conditions: on an unstable surface using a sling device, and on a stable surface using a push-up bar.

In a study of 30 healthy adults, Ludewig et al.⁷ stated that electromyographic activity of the SA improved and that of the UT was reduced while subjects were performing push-up exercises, claiming this type of exercise is best for strengthening the SA. Choi⁸ reported that in patients experiencing chronic shoulder pain for more than three months, push-up exercises for seven weeks showed no difference in electromyographic activity of the anterior deltoid muscle and LT but that the electromyographic activity of the UT was significantly reduced and that of the SA was significantly increased. In this study, the electromyographic activity of the SA was higher when exercises were performed on an unstable surface than on a stable surface using the ERP hand position, whereas no differences were found in the UT and LT. This means that the changes in hand position did

not have a significant influence on the electromyographic activity on the UT and LT.

De Oliveira et al.⁹ reported that the SA showed no difference between push-up exercises for upper extremities performed on a stable surface and those performed on an unstable surface using a large rubber ball. According to Park and You¹⁰, PUPEs were more effective than push-up exercises in activating the SA. In particular, it was more effective to exercise on an unstable surface than on a stable one. However, Lehman et al.¹¹ reported that changes in height during PUPEs resulted in significant differences in the electromyographic activity of the SA, irrespective of the stability of the surface.

Yoon et al.¹² showed that the electromyographic activity of the SA was highest in the ERP and lowest in the NP on a stable surface. Lee et al.¹³ showed that exercises performed in the NP showed higher electromyographic activity than those performed in the IRP when comparing only those two hand positions. The present study results showed higher electromyographic activity of the SA on an unstable surface than on a stable surface when using the ERP. This is because the biceps brachii and triceps could support upward and downward movements of the shoulder joint on the unstable surface better than on the stable surface and the UT, LT, and PM could support the anterior and posterior movements, thereby inhibiting shoulder movement and further maintaining stability. Among the hand positions, the ERP influenced stability by more than the IRP and NP, increasing the electromyographic activity of the SA.

The present study has some limitations. First, because the study included only a small number of normal adult male subjects, the results cannot be generalized. Second, only the right (dominant side) upper extremity muscles were measured, so the changes on the other side are unknown. Third, the sling device, used as the unstable surface, was hung from the ceiling with a rope; it was hard to continue holding the sling with the hands under static conditions. Fourth, the sling handle was made of thin cloth, which slipped slightly and was hard to control. Future studies are needed to investigate the effects of changes in the positions of the hands and feet on the shoulder stabilizer muscles during the PUPE

on both stable and unstable surfaces.

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