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The Effects on Shoulder Stabilizer Activation of Finger Flexor Activation during the Push-up Plus Exercise

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Abstract. [Purpose] We investigated the effect of the finger flexor muscles activation on the stabilizer muscle of the shoulder joint during push-up exercise using a push up grip to increase the muscle activation of the finger flexor, had a distal part. [Subjects] The subjects were 18 healthy male adults in their 20s who normal ROM and no musculoskeletal disease of the shoulder complex and the upper limbs. [Methods] The subjects performed push-ups (vertical and transverse grips, and on flat ground) three times. The muscle activity was measured three times when performing the exercise using the push-up grip (vertical and transverse grips) and on flat ground, and the mean values were used for the analysis. To prevent the effect of muscle fatigue of the shoulder stabilizer muscles, the three different exercise positions were randomly performed. [Results] The muscle activations induced under the three different conditions were compared and the results showed that there were significant differences among the wrist flexor bundle, wrist extensor bundle, biceps brachii, triceps brachii, pectoralis major, deltoid, serratus anterior muscles. [Conclusion] It is possible that finger flexor and extensor muscle activation elevated to increase stability in performing the exercise on the push-up grip as it is ales stable position than the push-up plus exercise on flat ground. We assume that the distal part muscle activation affected the muscle activation of the shoulder stabilizer, proximal part, muscles.
Key words: Electromyogram, Push up plus exercise, Shoulder stabilizer muscle

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INTRODUCTION

One recent study reported that high muscle activation was observed in the shoulder stabilizer muscle even under a light load during abduction-adduction using the distal part flexor muscle in an open kinematic chain, and movement using finger flexor muscle activation greatly affected the muscle activation of the shoulder stabilizer muscles[1)]. The shoulder stabilizer muscles are associated with forearm muscle activation, which indicates that movement of the distal part is very closely related to the movement of the proximal part.

The shoulder joint is damaged by abnormal shoulder kinematics due to imbalance in muscle activation such as in rotator cuff muscle injury[2)]. Moreover, serratus anterior muscle activation plays the role of increasing the stability of the medial border and inferior angle of the scapula. When weakened, serratus anterior muscle activation is an important factor in causing abnormal ROM (range of motion) of the shoulder joint through winging scapula, thereby decreasing the function of the shoulder joint[3)].

Many studies have recently been conducted on shoulder stabilizer muscles for the treatment of impairment of shoulder function. Open-chain exercise is widely administered as an exercise program as it provides increase acceleration and enhanced functional action by allowing free movement of the distal parts of the limbs and exercise with fixed proximal parts[4)]. However, the open chain exercise is inappropriate for treatment with complex exercise because it does little to stimulate the proprioceptive sense, In general, studies have reported that closed chain exercise is appropriate. Closed chain exercise not only increases muscle strength and endurance, but also decreases shearing force through the mechanical pressing of the joint facets. Thus, it is an exercise program for dynamic stability and position maintenance of joints[5)]. Among the closed-chain exercises, the push-up plus exercise is known to increase the shoulder stability by elevating the muscle activation of the shoulder stabilizer muscles[6,7)].

The push-up exercise is a representative shoulder stabilization exercise among the closed chain kinematic exercises, and studies of it have investigated the angle of the shoulder and the state of the floor. However, few studies of the relationship between the finger flexor muscle activation and the shoulder stabilizer muscle activation have been

conducted. Therefore, in this study, we investigated the effect of the finger flexor muscle activation on the stabilizer muscles of the shoulder joint during push up exercise using a push-up grip to increase the muscle activation of finger flexor, a distal part.

SUBJECTS AND METHODS

The subjects were 18 healthy male adults in their 20s who had normal ROM and no musculoskeletal disease in the shoulder complex and the upper limbs. Informed consent forms indicating voluntary participation were collected from each of the subjects.

A camera and a personal computer monitor were used to provide visual information regarding the scapular motion in the push-up plus position. All the subjects were able to observe their own movement through the computer monitor while performing the push-up plus exercise so that the scapular could be accurately protruded by self-checking[6]. While performing the push-up plus exercise, the subjects were asked to place their hands at shoulder width and align the acromion, the middle finger, and the capitatum. A push-up grip (NIKE, EFO114-085, USA) was which was supported with a box with 10 cm of height so that the exercise could be performed at the same level (Fig. 1.). The muscle activity was measured for three times when performing the exercise using the push-up grip (vertical and transverse grips), and on the flat ground, and the mean values were used for the analysis. To prevent the effect of muscle fatigue of the shoulder stabilizer, three different positions (Flat Ground, Vertical-Bar, Transverse-Bar) were randomly arranged.

For the collection of accurate data in the electromyogram, shaving was performed on the electrode-attached region with a razor, the horny substance was removed with sandpaper, and the electrode was attached after cleaning with alcohol swab.

To measure the extensor and flexor in the forearm, electrodes were attached to the forearm extensor bundle and forearm flexor bundle. Among the shoulder stabilizer muscles, serratus anterior muscle, deltoid middle fiber, pectoralis major, biceps brachi, and triceps were selected.

ProComp Infiniti^{TM} (Thought Technology Ltd., Canada) was employed for the measurement of the muscle activation of each muscle. A surface electrode (Triode surface electrode, Thought Technology Ltd., Canada) consisting of a tripolar electrode (positive-ground-negative) was used. The frequency range of the electromyogram signals was set to 20 to 500 Hz, and the sampling frequency was set to 1024 Hz.

The root mean square of each muscle was measured for five seconds in the anatomical position. The relative muscle contraction was calculated referring to the 100% of the mean electromyogram signal measured for the three seconds in the middle, excluding the data of the first one second and the last one second, and expressed as the muscle activation in % RVC for one-time performance of push-up plus exercise.

The measured data was processed by one-way ANOVA using with SPSS (version 12.0) for Windows to compare the shoulder stabilizer activation among on the finger flexor muscle activation. The level of significance was chosen of 0.05.

RESULTS

The forearm muscle activity relative to the wrist flexor bundle was 129.56 at flat ground, 2187.65 at vertical bar, 2487.17 at transverse bar, which showed significant differences ($p<0.05$). And wrist extensor bundle was 2114.47 at flat ground, 5796.93 at vertical bar, 3907.09 at transverse bar, which showed significant differences ($p<0.05$). The post-hoc test found statistically significant differences between flat ground and vertical bar, flat ground and transverse bar at wrist flexor bundle, and between flat ground and vertical bar, vertical bar and transverse bar at wrist extensor bundle ($p<0.05$). The muscle activity relative to the biceps muscle was 1123.49 at flat ground, 2689.45 at vertical bar, 1409.96 at transverse bar, which showed significant differences ($p<0.05$). The post-hoc test found statistically significant differences between flat ground and vertical bar, vertical bar and transverse bar ($p<0.05$). The muscle activity relative to the triceps muscle was 2505.70 at flat ground, 4378.30 at vertical bar, 5108.24 at transverse bar, which showed significant differences ($p<0.05$). The post-hoc test found statistically significant differences between flat ground and transverse bar, vertical bar and transverse bar ($p<0.05$). The muscle activity relative to the pectoralis major was 1067.10 at flat ground, 2308.17 at vertical bar, 2304.62 at transverse bar, which showed significant differences ($p<0.05$). The muscle activity relative to the deltoid muscle was 1420.98 at flat ground, 2651.14 at vertical bar, 2835.06 at transverse bar, which showed significant differences ($p<0.05$). The post-hoc test found statistically significant differences between flat ground and vertical bar, flat ground and transverse bar at pectoralis major and deltoid muscle ($p<0.05$). The muscle activity relative to the serratus anterior was 1086.71 at flat ground, 3846.66 at vertical bar, 3402.10 at transverse bar, which showed significant differences ($p<0.05$). The post-hoc test found statistically significant differences between flat ground and vertical bar, flat ground and transverse bar ($p<0.05$) (Table 1).

DISCUSSION

In this study, we analyzed the muscle activation of the shoulder stabilizer muscles depending on the distal part muscles activation during push-up plus exercise. The result showed that the muscle activation of the flexor bundle was higher in the Vertical-Bar and Transverse-Bar positions, to hold the grip, than in the push-up plus exercise in the flat ground position. The activation of the muscles around the shoulder complex such as Biceps brachi, Triceps, Pectoralis major, Deltoid and Serratus anterior was increased as the activation of the flexor bundle and forearm extensor bundle in the forearm was increased to maintain the balance in the distal parts while performing the push-up plus exercise. This may be because of the preceding contraction of the shoulder

Table 1. Forearm muscle and shoulder stabilizer activation by using finger flexor muscles (unit: %RVC)

Muscle	Flat Ground	Vertical-Bar	Transverse-Bar
WFB*	1294.56 ± 257.96[a]	2187.65 ± 200.05[b]	2481.17 ± 287.51[b]
WEB*	2114.47 ± 503.44[a]	5796.93 ± 977.14[b]	3907.09 ± 936.41[a]
BI*	1123.49 ± 121.01[a]	2689.45 ± 388.10[b]	1409.96 ± 218.17[a]
TRI*	2505.70 ± 423.85[a]	4378.30 ± 726.17[a]	5108.24 ± 702.58[b]
PM*	1067.10 ± 190.15[a]	2308.17 ± 239.31[b]	2304.62 ± 438.23[b]
DEL*	1420.98 ± 140.52[a]	2651.14 ± 342.41[b]	2835.06 ± 337.04[b]
SA*	1086.71 ± 165.19[a]	3846.66 ± 1045.36[b]	3402.10 ± 678.40[b]

WFB: Wrist flexor bundle, WEB: Wrist extensor bundle, BI: Biceps brachi, TRI: Triceps, PM: Pectoralis major, DEL: Deltoid, SA: Serratus anterior.
NOTE. Each value represents the mean ± SE. The values with different superscripts in the same column are different significantly ($p<0.05$) by Tukey measure.

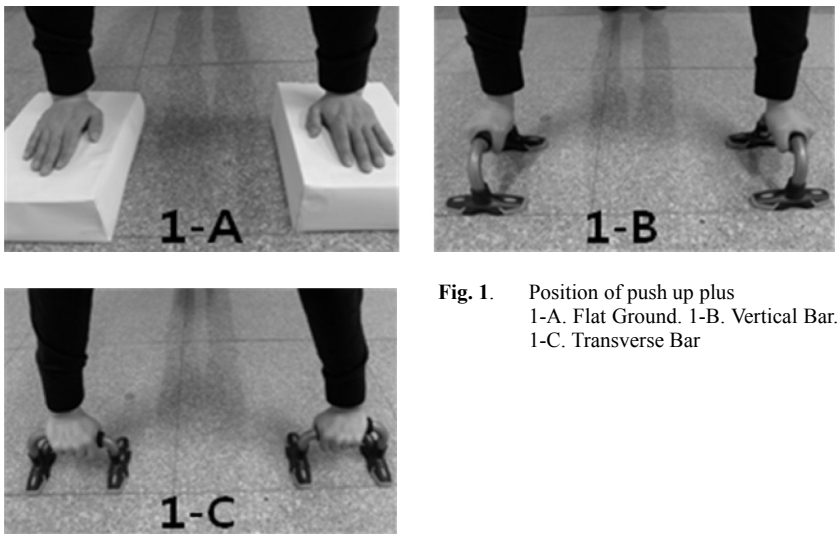

Fig. 1. Position of push up plus
1-A. Flat Ground. 1-B. Vertical Bar.
1-C. Transverse Bar

complex stabilizer to produce the forearm muscle activation. This result is consistent to the result of the previous study on open kinematic chain that muscle activation of proximal part is required for the movement of distal part.

The biceps brachi muscle activation was higher in the push-up exercise performance in the Vertical-Bar position than in the Transverse-Bar position. This result may be because the shoulder joint abduction angle was smaller, and the flexion and extension of shoulder joint were used more in the Vertical-Bar position than in the Transverse-Bar position.

While the biceps brachi muscle activation was higher in the push-up exercise performance in the Vertical-Bar position than in the Transverse-Bar, the triceps muscle activation was higher in the push-up exercise performance in the Transverse-Bar than in the Vertical-Bar position. This result may be because the shoulder horizontal abduction angle was larger when performing the push-up plus exercise using the transverse bar than when using vertical bar, and thus the push-up plus exercise is performed more by the shoulder flexion that is the role of the biceps muscle than by the elbow extension that is the role of the triceps muscle.

This result might have caused as the finger flexor and extensor muscle activation was elevated to increase the stability in performing the exercise on the push-up bar that was more instable than the push-up plus exercise on the flat ground. It is assumed that the distal part muscle activation might have affected the muscle activation of the shoulder stabilizer that is a proximal part muscle.

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