

# The Different Muscle Activation of Upper Extremity and Core Muscle by the Changes of Leg Support Surface during Push-up Exercise

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**Purpose:** This study was designed to evaluate the effects of the different condition of leg support surface on the upper extremity and core muscle activity during the push-up exercise.

**Methods:** Fifteen healthy subjects that were practicable push-ups were recruited in this study. Subjects were instructed the push-up exercise in the different condition of the leg support surface. Each condition of support surface was set to the high and lower, and the unstable and stable condition. Muscle activation was measured by using the surface electromyography (EMG), and recorded from the triceps brachii, serratus anterior, latissimus dorsi, rectus abdominis, abdominal external oblique, and erector spinea muscle.

**Results:** In the results of experiments, there was no significant difference of muscle activation in upper extremity between the high unstable and high stable support surface. By contrast, muscle activation of the rectus abdominis and abdominal external oblique was significantly higher in the low unstable support surface, compared with those of the low stable support surface. It is well known that the core muscle was important to stabilization of trunk stability.

**Conclusion:** This result demonstrates that the low and unstable support surface for the lower extremity was suited for training of core muscle for trunk stabilization during the push-up exercise.

**Keywords:** Core muscle, Push-up exercise, Electromyography

## INTRODUCTION

The push-up exercise is one of an easy and popular exercise that can be widely used in general exercise programs in order to strengthen the upper extremity. In addition, it is evaluated as an effective exercise method that can contribute to a healthy recovery by preventing shoulder damage and improving the muscle strength near the joints after injury.<sup>1-3</sup> The push-up exercise is known to be a representative closed kinetic chain exercise that targets the pectoralis major and triceps brachii, as well as the scapular stabilizing muscles. As such, the push-up exercise can activate co-contraction of various muscles, which can improve dynamic stability of joints and upright posture maintenance. Moreover, it provides facilitation of proprioceptive feedback by stimulating afferent receptors around joints, and en-

hancing muscle strength and endurance.<sup>2,4</sup>

The push-up exercise can be performed either on a stable support surface such as floor or wall, or on an unstable support surface, such as a Swiss ball or Variations in the push-up exercise may change muscular activation pattern. Many studies have reported that muscle activity of upper extremity changes when they compared the unstable push-up exercise with the stable push-ups.<sup>5-7</sup> The shoulder stabilizer muscles, such as the serratus anterior, levator scapulae, rhomboid, upper and lower trapezius, were increased during the push-up exercise on an unstable surface. Moreover, there are other muscle groups, such as anterior shoulder and core muscle, are involved and it effectively improves balance by stimulating muscle proprioceptors. In addition, many previous studies reported that experiments under various environmental conditions were con-

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ducted to examine the therapeutic effects of push-up exercise.<sup>7-9</sup> It is known that there are differences in the muscle activities of the upper extremity muscles with regard to the shoulder width, hand position, slope and height of a support surface during push-up exercise.<sup>10-12</sup> However, scores of the recent studies on exercise therapy, including push-up exercise, have reported on the effects of exercises on an unstable surface to indicate that such exercises improve the strength of core muscles that is mainly needed to maintain a posture.<sup>13,14</sup> The core muscles which are deep muscles in the trunk are largely divided into abdominal muscles and lower-back muscles. The abdominal muscles include the rectus abdominis muscle, the abdominal external oblique muscle, the abdominal internal oblique muscle, and the abdominal transversus muscle.<sup>15</sup> The main muscles of lower-back muscles are the multifidus and erector spinae muscle.<sup>15,16</sup>

Sling exercises and Swiss ball exercises were used in the studies aimed at examining the effects of exercises on an unstable surface, and the effects of such exercises have been proven improve muscles activities in the trunk and shoulders through many studies.<sup>14</sup> Nonetheless, push-up exercise on an unstable surface is focused on providing an unstable support surface of hands and is limited to measuring the patterns of change in muscle activities of the upper extremity muscles. Though there are some recent studies on push-up exercise, reporting on the patterns of change in muscle activities by making a support surface of the lower limbs unstable, they are limited to measuring and proving the patterns of change in the muscle activities of only the upper extremity muscles.<sup>17</sup> Therefore, identification of different activation in upper extremity muscle and core muscle during push-up exercise on an unstable surface can provide useful information for clinicians and researchers in the therapeutic exercise.

The present study aims to investigate differences in muscle activities of the upper extremity muscles and the core muscles during push-up exercise on an unstable surface and a stable surface of the lower limbs.

## METHODS

### 1. Subjects

For the purpose of the present study, 15 male college students who did not have the history of muscular illness to do push-ups were selected. After being informed of the purpose and method of the

study, they were the ones who agreed to voluntary participation of the study.

### 2. Experimental equipment

Telemetry 2400T (Noraxon, USA) used in the experiment is a device that uses surface electromyograms (EMG) for measuring muscle activities during push-up exercise. Noraxon Myo Reserach Master Edition 1.08 XP Software was used in the experiment to collect and analyze the muscle activities. On measuring sites, circular type 2 Ag/AgCl electrodes (3M, USA) were used. Gym balls and rubber balls were used as unstable surfaces while flat height-adjustable benches were used as stable surfaces after adjusting their height similar to those of the gym ball and the rubber ball.

### 3. Electromyography measurement

To carry out the present study, hair on the skin where sensors would be attached was removed and its surface was cleaned with alcohol in order to minimize skin resistance. Electrodes were attached to the triceps brachii, the serratus anterior, the latissimus dorsi, the rectus abdominis muscle, the abdominal external oblique muscle and the erector spinae muscle of the study subjects in order to measure the muscle activities of their upper extremity muscles and core muscles.<sup>13,14,17</sup> Active electrodes were attached to muscle bellies that show the clearest muscular contraction with maximum muscular contraction while the subjects were in the position for a Manual Muscle Test (MMT) of each muscle.<sup>10</sup> In addition, amplified waves were filtered through a Bandpass filter of 10-350 Hz for signal processing. The mean value of root mean squares (RMS) was used for each muscle's activity.

### 4. MVIC measurement

Maximal Voluntary Isometric Contraction (MVIC) was performed and measured while the subjects were in the position for a MMT in order to normalize the value of EMG activity.<sup>11,18</sup> The MVIC was measured for five seconds and for three seconds except the first and the last second, the mean EMG signal was used. The normalized value of muscle activities in the upper extremity muscles and the core muscles was computed after setting the MVIC value at 100% and dividing the value of each muscle's activity during push-up exercise by the MVIC value.

### 5. Experimental procedure

The experiment was carried out after checking the signals of the attached electrodes. However, push-up exercises on an unstable surface and a stable surface were performed in a random order and the push-up movements were classified into arm-folding and arm-unfolding movements. The push-up exercise on a stable surface was performed with the hands at the shoulder width and the feet on stable support surfaces of 55 cm and 25 cm off the ground, and its mean value was calculated after repeating the exercise for three times. On the other hand, the push-up exercise on an unstable sur-

face was performed with the hands at the shoulder width just like in the exercise on a stable surface, however the feet on rubber balls of 55 cm and 25 cm in height, and its mean value was calculated after repeating the exercise for three times (Figure 1). After the subjects performed the push-up exercise under one condition and a 30-minute break was given in order to prevent them from accumulating fatigue before the next push-up exercise under the other condition.

### 6. Data analysis

The signals were processed in the following manners. Amplified waves were filtered through a Bandpass filter of 10-350 Hz. The mean value of root mean squares (RMS) was used for each muscle's activity. SPSS 20.0 for windows (IBM Corporation, USA) was used for comparative analysis of the measured data in the present study. The collected data was analyzed using an independent t-test, and statistical significance was set at  $p < 0.05$ .

## RESULTS

### 1. General characteristics

The mean age of the study subjects was  $24.14 \pm 0.53$  years old (23-25 years) with the average height of  $174.43 \pm 5.24$  cm (168-187 cm) and the average weight of  $71.43 \pm 8.68$  kg (62-90 kg).

### 2. Difference in muscle activities of upper extremity muscles

The study subjects showed lower muscle activities of the triceps brachii, serratus anterior and latissimus dorsi during the push-up exercise on a high and unstable support surface than on a stable support surface by 3.34%, 3.70%, and 1.90%, respectively, however, there were no statistically significant differences ( $p > 0.05$ ).

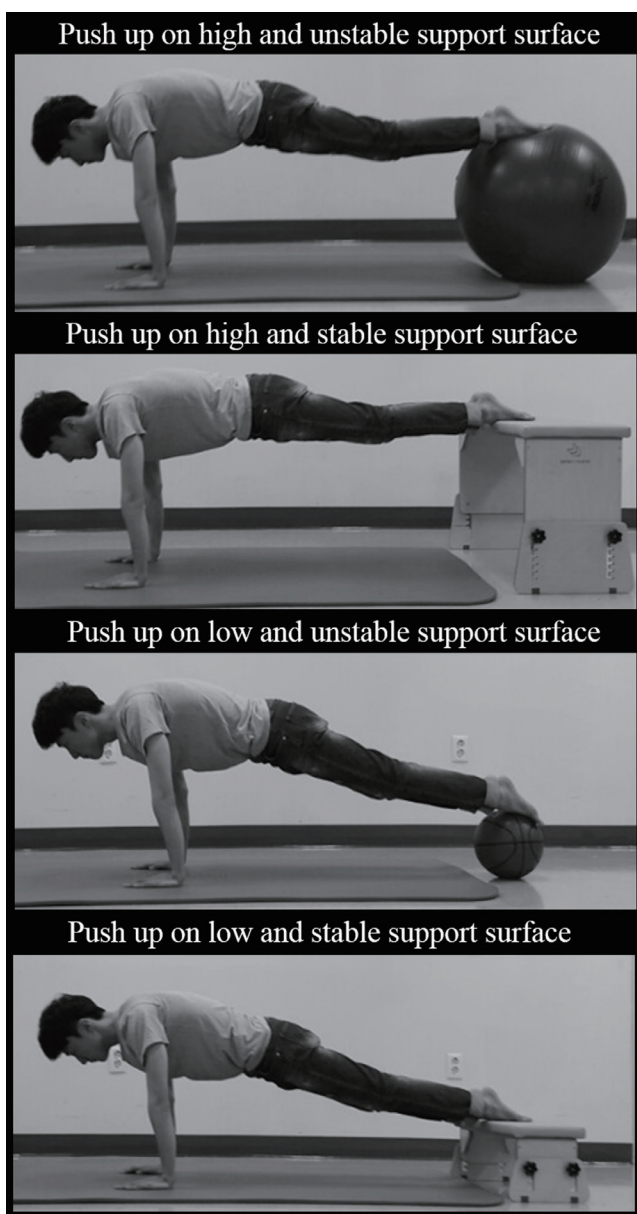


Figure 1. Different conditions of push up exercise.

Table 1. Difference of muscle activation in upper extremity muscle according to the height of lower extremity and condition of support surface

		Upper extremity muscle		
		Triceps brachii	Serratus anterior	Latissimus dorsi
High	Unstable	22.05% (8.07)	30.19% (11.46)	15.43% (7.76)
	Stable	25.39% (9.96)	33.89% (10.93)	17.33% (9.3)
	p-value	0.338	0.389	0.562
Low	Unstable	24.96% (8.26)	38.36% (10.15)	16.34% (9.56)
	Stable	21.65% (10.17)	27.86% (9.6)	14.11% (5.99)
	p-value	0.353	0.116	0.467

Values represent mean (standard deviation).

**Table 2.** Difference of muscle activation in core muscle according to the height of lower extremity and condition of support surface

		Core muscle		
		Rectus abdominis	Abdominal external oblique	Erector spinae
High	Unstable	21.11% (11.07)	19.86% (8.87)	3.54% (1.34)
	Stable	15.64% (9.00)	17.51% (8.90)	5.04% (3.06)
	p-value	0.164	0.49	0.338
Low	Unstable	22.31% (11.74)	23.57% (10.17)	4.91% (1.94)
	Stable	13.06% (8.24)	16.05% (7.56)	4.14% (2.04)
	p-value	0.023*	0.035*	0.319

Values represent mean (standard deviation).  
\*p < 0.05.

On the other hand, the subjects showed higher muscle activities of the triceps brachii, serratus anterior and latissimus dorsi during the push-up exercise on a low and unstable support surface by 3.31%, 10.50%, and 2.23%, respectively, but there were no statistically significant differences ( $p > 0.05$ ) (Table 1).

### 3. Difference in muscle activities of core muscles

The study subjects showed higher muscle activities of the rectus abdominis muscle and the abdominal external oblique muscle during the push-up exercise on a low and unstable support surface than on a stable support surface by 9.25% and 7.52%, respectively, and there were statistically significant differences ( $p < 0.05$ ).

Nonetheless, there were no statistically significant differences in the erector spinae muscle ( $p > 0.05$ ). When the subjects performed the push-up exercise on a high and unstable support surface, the muscle activities of the rectus abdominis muscle, abdominal external oblique muscle and erector spinae muscle were either higher or lower by 5.47%, 2.37%, and -1.50% respectively, than on a stable support surface, however, there were no statistically significant differences ( $p > 0.05$ ) (Table 2).

## DISCUSSION

The present study was conducted to investigate differences in muscle activities of the upper extremity muscles and the core muscles during push-up exercises on different support surfaces of the lower limbs. According to the results of the experiment, similar muscle activities were observed in both the upper extremity muscles and the core muscles during the push-up exercise on a high support surface of the lower limbs, whether the surface be stable or unstable.

However, on a low and unstable support surface of the lower limbs the push-up exercise appeared to induce a significant level of muscle activities of the abdominal muscles while it induced no particular differences in the muscle activities of the upper extremity muscles. It is thought that the push-up exercise on a low and unstable support surface leads to much more muscle activities of the abdominal muscles than the exercise on a high and unstable support surface.

The push-up exercise on a low and unstable support surface is expected to improve the muscle activities of not only the upper extremity muscles but also the core muscles, and enhances the exercise effects. From the previous studies of push-up exercise performed under various conditions, it has been known that the exercise can improve the strength of selective safe muscles in the shoulder joints with regard to changes in the length of the support surface.<sup>8</sup> In addition, on top of the length of the support surface, the height and position of hands create differences of the muscle activities in the shoulders.<sup>19</sup> Lear et al.<sup>10</sup> reported that the push-up exercise using the combination of two different conditions enhanced the stability of the shoulder joint.

Moreover, exercises on an unstable surface have been proven to enhance the muscle activities of the upper extremity muscles through many studies.<sup>3,16</sup> In addition, the exercises have been reported to induce not only more muscles activities but also more endurance of the muscles, and help improve coordination of muscles.<sup>21</sup> In particular, exercises on an unstable surface have been known to maximize the exercise effects as they contract both the agonist muscle and the synergistic muscle simultaneously to induce improvement in the strength, balancing ability and stability of the muscles by stimulating the neurotransmitter system.<sup>19</sup> In addition, Oh et al.<sup>22</sup> reported that when a push-up exercise on a stable surface and a push-up exercise with a sling on an unstable surface were compared, the exercise on an unstable surface induced high muscle activities of the upper extremity muscles. However, a variety of the recent studies have reported on not only muscle activities of the upper extremity muscles during exercises on an unstable surface but also comparison of different patterns in muscle activities of the core muscles, which are related to the trunk.<sup>13,14,23</sup>

In terms of core muscle, Petrofsky et al.<sup>13</sup> reported that different core muscle activation during abdominal crunches between stable surface and unstable surface using Swiss ball. They suggested that the exercise on an unstable surface can induce higher muscle activi-

ties of the core muscles, compared with those of stable surface. Furthermore, according to Escamilla et al.,<sup>14</sup> an abdominal exercise on a Swiss ball improved muscle activities of the core muscles in comparison to muscle activities induced during push-up and sit-up exercises on a Swiss ball.<sup>14</sup> Considering the aforementioned findings of the previous studies in general, it is thought that they are in line with the findings of the present study, and moreover, exercises on an unstable surface can make the core muscles in the trunk more active.

In conclusion, through the present study, push-up exercise on a low and unstable surface of the lower limbs was shown to induce much higher muscle activities of the core muscles in the trunk. Such results are thought to suggest other effects of push-up exercise which was mainly used in improving the strength of the upper extremity muscles, and indicate that the exercise can be an effective exercise therapy to improve the strength of both the upper extremity muscles and the core muscles. The present study has limitations as it was confined to healthy male adults in their twenties, therefore, its results are inadequate to generalize to men and women of all age groups and patients. Hence, there is a need to broaden the test group to various age groups and women in future studies to investigate differences in muscle activities, and moreover, it is thought that additional studies are called for to analyze muscles activities during push-up exercise on a support surface of the knees among the elderly and infirm and women who otherwise, have difficulty to perform a typical push-up exercise. Then, the findings of such future studies can be used as data to develop exercise therapies to treat patients and other exercise programs.

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