



Original Article

## Effect of the push-up exercise at different palmar width on muscle activities

YOU-SIN KIM<sup>1)</sup>, DO-YEON KIM<sup>2)</sup>, MIN-SEONG HA<sup>2)\*</sup>

<sup>1)</sup> Department of Leisure Sports, Jungwon University, Republic of Korea

<sup>2)</sup> Department of Physical Education, Pusan National University: 2 Busandaehak-ro, 63 Beon-gil, Geumjeong-gu Busan 609-735, Republic of Korea

**Abstract.** [Purpose] The purpose of the present study was to determine the effects of changes in palmar width on the muscle activities of the shoulder and truncus muscles during push-up exercise. [Subjects] Twelve healthy adult males participated in this study as subjects. [Methods] Push-up exercises were performed with three different palmar width in narrow (50%), neutral (100%), and wide positions (150%). We measured the muscle activities of the deltoideus p. acromialis, pectoralis minor, pectoralis major, serratus anterior, biceps brachii, triceps brachii, latissimus dorsi, and infraspinatus. [Results] Pectoralis minor, triceps brachii, and infraspinatus muscle activities were greater during push-ups performed with the 50% palmar width compared with the other palmar widths. Pectoralis major muscle activity was greater during push-ups performed with the 50% and 100% palmar widths compared with the 150% palmar width. Serratus anterior muscle activity was greater during push-ups performed with the 150% palmar width compared with the other palmar widths. [Conclusion] These results are expected to serve as reference materials for push-up exercise applications in training programs for trucus muscle strengthening or rehabilitation programs for scapula patients.

**Key words:** Push-up exercise, Palmar width, Muscle activities

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## INTRODUCTION

Push-up exercise (PUE) is a representative closed kinetic chain exercise (CKCE) that can strengthen shoulder and trucus muscles in daily living<sup>1–5)</sup>. CKCE is performed by applying resistance to the proximal and distal parts of limbs simultaneously while the distal is kept immobile<sup>6)</sup>. It is frequently used in exercise programs for dynamic stability of joints and upright posture maintenance because it causes co-contraction of various muscles, in addition to enhancing muscle strength and endurance, and provides more proprioception by stimulating afferent receptors around joints<sup>7)</sup>. In addition, PUE is mainly used for muscle strength evaluation of trucus muscles<sup>8)</sup>, and frequently used in rehabilitation programs for patients with shoulder damage<sup>9, 10)</sup>.

In PUE, because muscle activity varies depending on the position of the hands, the palmar width is a key factor in the exercise. Among previous studies on palmar width in PUE, Cogley et al.<sup>11)</sup> compared the muscle activity of a group with a large palmar width with that of one with a small palmar width, but the muscles examined in the study were limited to the pectoralis major and triceps brachii. Another study by Rho et al.<sup>12)</sup> classified palmar width into three types (narrow, neutral, and wide positions) and examined electromyography (EMG) of the pectoralis major and latissimus dorsi, but it did not mention the precise width between the hands. In addition, a study by Oh et al.<sup>13)</sup> study compared EMG of the infraspinatus, serratus anterior, upper trapezius, and triceps brachii across different palmar widths in PUE but had a limitation in research design in that palmar width was kept uniform ( $\pm 20$  cm), as it was not considered in their study. These studies suggest that research on palmar width in PUE as clinically practiced CKCE is lacking, and the claims of the studies fall short in terms of

\*Corresponding author. Min-Seong Ha (E-mail: yonseigym@naver.com)

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sufficient supporting evidence. In particular, when providing training programs to strengthen shoulder and truncus muscles or rehabilitation programs for shoulder joint patients, palmar width in PUE is expected to play a significant role in the rehabilitation period and performance of patients.

Thus, this study aimed to identify the optimal palmar width for each muscle in PUE by determining the differences in muscle activity of shoulder and truncus muscles in PUE with three types of palmar width applied separately. We hypothesized that PUE performed with narrow and wide palmar widths induces higher muscle activities than PUE with a neutral palmar width.

## SUBJECTS AND METHODS

Twelve right-handed male Korean university students majoring in physical education participated in this study as subjects. All subjects were healthy and had no previous history of damage in the wrist, shoulder, or elbow joint. All of them participated in the study voluntarily after being fully informed of the study objective. Subjects characteristics are shown in Table 1.

Palmar width was defined as the distance between the acromion in subjects. For each subject, the palmar width was considered the neutral position (100%), half the palmar width was considered the narrow position (50%), and 1.5 times the palmar width was considered the wide position (150%).

Before beginning the experiment, subjects were given information on push-up movements with the three palmar widths, and underwent a light warm-up to enable natural push-up movements. Each subject performed a total of nine push-ups with each of the palmar widths, and among the nine, five (from 3rd to 7th) push-ups were selected. One push-up was defined as one with complete flexion and extension of the arms.

For EMG analysis, T246H Ag-Ag/Cl surface electrodes (Bio-Protech Inc., Wonju, Republic of Korea) were attached to each muscle on the right side of subjects, and the sites for electrode attachment were determined based on the instructions of Merletti et al.<sup>14)</sup>; specifically, they were attached to the deltoideus p. acromialis (DA), pectoralis minor (PMI), pectoralis major (PMA), serratus anterior (SA), biceps brachii (BB), triceps brachii (TB), latissimus dorsi (LD), and infraspinatus (IS). For synchronization of 2D image data and EMG data of subjects' push-up movements, one Raptor-E Camera (Motion Analysis Inc., USA) and a Desk DTS EMG system (Noraxon USA Inc, Scottsdale, AZ, USA) with eight channels were used. All EMG signals were amplified, band-pass filtered at 10–250 Hz, and sampled at 1,024 Hz using MR-XP program (Noraxon USA Inc, Scottsdale, AZ, USA). The root mean square (RMS) values of each muscle were measured for three seconds in the PUE with the neutral palmar width. Muscle contractions were calculated relative to the mean EMG signal for two seconds in the middle portion of the EMG recording, excluding the measurements in the first 0.5 seconds and last 0.5 seconds. The muscle activities resulting from one push-up were calculated as the relative voluntary contraction (%RVC).

All data were presented as means  $\pm$  SEs. The IBM SPSS statistics software (version 21.0; IBM Corp., Armonk, NY, USA) was used for statistical analysis, and the statistical significance of differences was examined by one-way repeated ANOVA, with significance accepted at a value of  $p < 0.05$ . Bonferroni corrections were used for multiple comparisons.

## RESULTS

In the present study, EMG activity was greater in the PMI, TB, and IS muscles during push-ups performed with the 50% palmar width compared with the 100% and 150% palmar widths ( $p < 0.001$ ,  $p < 0.01$ ,  $p < 0.001$ ). PMA muscle activity was greater during push-ups performed with the 50% and 100% palmar widths compared with the 150% palmar widths ( $p < 0.001$ ). SA muscle activity was greater during push-ups performed with the 150% palmar width compared with the 100% and 50% palmar widths ( $p < 0.001$ ). However, the DA, BB, and LD muscles did not show any significant differences ( $p > 0.05$ ) (Table 2).

## DISCUSSION

This study aimed to present the optimal palmar width for each muscle in PUE when implementing PUE with three palmar widths (50%, 100%, and 150% of the palmar width in the neutral position) applied separately in 12 healthy men in their 20s by measuring the activity of the DA, PMI, PMA, SA, BB, TB, LD, and IS.

The results showed that the highest level of muscle activity in the PMI, PMA, TB, and IS was observed for PUE with the 50% palmar width. Previous studies reported findings consistent with the results of the present study. Specifically, Cogley et al.<sup>11)</sup>, who compared the results of EMG of the PMA and TB for a group with a wide palmar width (mean 85.8 cm) with those of a group with a narrow palmar width (mean 66.3 cm) in PUE reported that the group with the smaller palmar width showed significantly higher EMG activity for both muscles. Gouvali et al.<sup>15)</sup> also found that the EMG activity of the PMA was high when the palmar width was small, and Rho et al.<sup>12)</sup> reported that PUE with a small palmar width resulted in the highest PMA activity. In addition, according to a study by Oh et al.<sup>13)</sup>, the activity of the TB increased significantly when PUE was performed with a small palmar width, supporting the experimental results of the present study showing that PUE with the 50% palmar width is more effective in muscle strength performance of PMI, PMA, TB, and IS. However, PUE with the 150% palmar width resulted in statistically significantly higher activity in the SA. A study by Kang et al.<sup>16)</sup> stressed that the SA is the key muscle for increasing stability of scapula. They reported that when there is an imbalance in the stabilizing

**Table 1.** Subject characteristics (N = 12)

Variables	
Age (yrs)	21.4±0.5
Height (cm)	173.1±1.1
Body mass (kg)	70.5±1.4
Shoulder width (cm)	42.1±0.6

Values are means ± SEs

**Table 2.** Mean of the average muscle activity during push-up with various palmar widths

Muscles	Mean ± SE (%RVC)		
	50%	100%	150%
DA	89.3±5.6	100.0±7.1	97.5±6.3
PMI***	131.7±4.0 <sup>#</sup>	100.0±3.1	84.3±2.5
PMA***	115.0±4.3 <sup>†</sup>	100.0±3.4	92.3±2.9
SA***	71.2±2.6	100.0±4.4	119.2±4.9 <sup>††</sup>
BB	105.5±6.9	100.0±6.9	121.6±9.1
TB**	116.5±7.0 <sup>#</sup>	100.0±5.9	86.0±5.3
LD	92.4±5.6	100.0±6.0	103.5±7.1
IS***	162.7±10.3 <sup>#</sup>	100.0±5.1	75.7±4.2

Values are Means ± SEs. 50%: narrow position; 100%: neutral position; 150%: wide position; DA: deltoideus p. Acromialis; PMI: pectoralis minor; PMA: pectoralis major; SA: serratus anterior; BB: biceps brachii; TB: triceps brachii; LD: latissimus dorsi; IS: infraspinatus. \*\*\*p<0.001; \*\*p<0.01. <sup>#</sup>50%>100%>150%. <sup>†</sup>50%, 100%>150%. <sup>††</sup>50%<100%<150%

muscles of the scapula, exercise focusing on the SA is beneficial and that the relative contribution of the SA is also higher than those of other muscles<sup>17)</sup>. Similarly, Oh et al.<sup>13)</sup> reported that the activity of the SA increased significantly when the palmar width was large during PUE, which is consistent with the experimental results of the present study showing that PUE with the 150% palmar width is more effective in muscle performance of SA.

This suggests that the activity of the trunci muscles varies with different palmar widths in PUE; accordingly, for effective PUE, a narrow palmar position is recommended for the PMI, PMA, TB, and IS, and a wide palmar position is recommended for the SA. Thus, the findings of this study are expected to serve as reference materials for PUE applications in training programs for trunci muscle strengthening or rehabilitation programs for scapula patients.

However, generalization of the study findings may be limited due to the restricted sample selection and size. Therefore, further research with a wider range of subjects including women and scapula patients in addition to healthy male adults is needed in the future.

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