

# Comparison of Shoulder Stabilizer Muscle Activations during Push Up Plus Exercise by with Cervical Flexion and Extension

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**Abstract.** [Purpose] The purpose of this study was to analyze the activation of the muscles around the shoulder in relation to the cervical flexion and extension during the push-up plus exercise in order to provide the fundamental data to establish the posture that can maximize the effect of the shoulder stabilizer exercise. [Subjects] The subjects of the experiment were 18 healthy people, male adults in their age of twenties with normal ROM and without musculoskeletal disease at the shoulder complex and upper limb. [Methods] Muscular activity of the shoulder stabilizer muscles in cervical flexion and extension and the neutral position were measured by electromyography (EMG). [Results] The muscle activations among the cervical positions were compared and the results showed that there were a significant differences for the serratus anterior muscle, sternocleidomastoid muscle, cervical paraspinalis muscle and pectoralis major muscle. [Conclusion] These results show that different shoulder stabilizers are activated during the push-up plus exercise depending on not only the location of the neck but also the internal or external rotation and abduction/adduction angle of the shoulder joint, suggesting that establishment of an accurate position for the strengthening of each muscle is necessary.

**Key words:** Push-up plus exercise, Cervical position, Electromyogram

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## INTRODUCTION

In order to provide stability during movement of the shoulder joint, the upper and lower trapezius and the serratus anterior muscle should act as a coupling force and the role of the rhomboid, deltoid and levator scapula that provide shoulder stability is emphasized<sup>1)</sup>. Like this, Harmonious actions of the tissues around the shoulder are required to provide the shoulder joint stability, and weakness of even a single muscle can cause injury. In particular, winging scapula, which is caused by the weakness of serratus anterior muscle and trapezius and the neurological damage in the brachial plexus, long thoracic nerve and dorsal scapular nerve, are the most representative examples of the symptoms in which the medial border is detached and the inferior angle is extruded to the back side<sup>2,3)</sup>.

The Shoulder joint stability exercise is required for the prevention and treatment of suchlike imbalances of the muscles around the shoulder joint<sup>4)</sup> and the rapid

preoperative and postoperative recovery of the shoulder joint function<sup>5)</sup>. The balance of the shoulder joint stabilizer is considered in the therapeutic exercise programs for the prevention and rehabilitation of shoulder joint dysfunction. Recently, the closed kinematic exercise have frequently been employed in the upper limb therapeutic exercise programs<sup>2)</sup>. To strengthen the lower trapezius and serratus anterior muscle properly, in the push-up plus exercise has been used for the upper limb kinematic chain exercise programs of many studies. Push-up plus exercise is an exercise in which the scapular is protracted to the maximum at the final stage of a conventional push-up exercise<sup>6,7)</sup>.

Many studies have been conducted of various types of push-up and push-up plus exercise: Kim et al.<sup>6)</sup>. Reported that providing visual feedback is more effective since the maximum protraction of the scapular is not visually verified. Ludewig et al.<sup>2)</sup> compared the serratus anterior muscle and upper trapezius muscle activations of four different types of push-up exercise, and Moseley et al.<sup>4)</sup> studied the effect of the shoulder abduction on the muscles

**Table 1.** Shoulder stabilizer muscle activities during the push up plus exercise with cervical flexion and extension (unit: %RVC)

Muscle	Full flexion	Neutral position	Full extension
SA*	708.72 ± 364.68 <sup>a</sup>	957.33 ± 500.00 <sup>a</sup>	663.15 ± 162.92 <sup>a</sup>
SCM*	616.03 ± 278.62 <sup>b</sup>	536.49 ± 250.27 <sup>b</sup>	361.04 ± 208.94 <sup>b</sup>
CP*	359.15 ± 182.03 <sup>c</sup>	363.25 ± 176.74 <sup>c</sup>	504.94 ± 150.96 <sup>c</sup>
DM	1138.98 ± 908.05	1071.82 ± 802.06	1070.71 ± 834.57
LD	389.15 ± 253.33	352.99 ± 226.67	403.19 ± 259.09
UT	786.90 ± 518.37	848.42 ± 535.16	582.80 ± 393.05
LT	742.03 ± 534.79	582.72 ± 356.51	871.10 ± 568.18
PM*	2006.32 ± 1023.13 <sup>d</sup>	1292.16 ± 492.94 <sup>d</sup>	1939.60 ± 1023.30 <sup>d</sup>

\*p<0.05. SA: Serratus anterior muscle, DM: Deltoid middle fiber, UT: Upper trapezius. LT: Lower trapezius, PM: Pectoralis major, CP: Cervical paraspinalis. SCM: Sternocleidomastoid muscle, LD: Latissimus dorsi.

NOTE. Each value represents the mean ± SD. The values with different superscripts in the same column are different significantly (p<0.05) by the Tukey test.

around the shoulder during push-up exercise. However, few studies have not been carried out sufficiently regarding the location of the surrounding joints and the posture needed to maximize the activation of the muscles around the shoulder during the push-up plus exercise. We analyzed the activation of the muscles around the shoulder in relation to the cervical flexion and extension during the push-up plus exercise in order to provide the fundamental data to establish the posture that can maximize the effect of the shoulder stabilizer exercises.

## SUBJECTS AND METHODS

The subjects of the experiment were 18 healthy people, male adults in their age of twenties with normal ROM and without musculoskeletal disease at the shoulder complex and upper limb. The subjects were given an explanation about the experimental procedure and we received their written consents that indicating their voluntary participation in the study.

All the subjects were encouraged to always watch their own motion at all times on a computer monitor screen during the push-up plus exercise so that they could perform the scapular protraction accurately by themselves. Cameras and personal computer monitors were used to provide the visual information about the scapular motion in the push-up position. The subjects were able to observe their own scapular motions through the computer monitors and the images were taken by a camera established at the rear side of the subjects<sup>6)</sup>. To examine how the shoulder stabilizers were activated while the cervical spine was in different positions, the push-up plus exercise was carried out by the participants while their postures were kept in the maximal cervical flexion position, neutral position and the maximal cervical extension position. The hands and feet that were in contact with the ground surface were supported respectively by 15 cm boxes to avoid the contact of the head with the ground surface during the push-up plus exercise in the cervical flexion position. The average of the three times of repetitions in each position was used. Exercise in the three different positions was randomly

performed in order to exclude the effects of the muscle fatigue of the shoulder stabilizer.

To measure the activation of each muscle, ProComp Infiniti<sup>TM</sup> (Thought Technology Ltd., Canada) was used and a surface electrode (Triode surface electrode, Thought Technology Ltd., Canada) that consisting of three electrodes (Positive-Ground-Negative) was employed. The frequency range of the electromyograph signal was set to be 20~500 Hz and the sampling frequency was 1,024 Hz.

Depilation was performed by a razor on the attaching sites, the horny substance was removed with a sandpaper. The electrodes were attached after cleaning the sites with an alcohol swab to gather accurate electromyogram data.

The selected scapular stabilizers were serratus anterior muscle, upper trapezius, lower trapezius, deltoid middle fiber, latissimus dorsi and pectoralis major. The electromyograph attached selectively to the cervical paraspinali at the 1.5 cm externally from position of the 4th cervical transverse process among the cervical extensors and to the sternocleidomastoid muscle among the cervical flexors and it was on the dominant side of the muscles of the individual subjects.

The root mean square data of each muscle was measured for five seconds in the anatomical position. The muscle activation during the exercise was expressed as % RVC by calculating the relative muscle contraction of the 100% average muscle contraction in the middle one second of 3 seconds in the measurements; i.e. by ignoring the first and last second of the measurement.

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

## RESULTS

The subjects of this study were 18 healthy people, male adults in their twenties. Their average age was 24.05 ± 1.47 years, their average body weight was 70.77 ± 4.70 kg, and their average height was 175.72 ± 3.10 cm.

The muscle activations in the different on the cervical

positions were compared and the results showed that there were a significant differences for among the serratus anterior muscle, sternocleidomastoid muscle, cervical paraspinalis muscle and pectoralis major muscle (Table 1) ( $p < 0.05$ ).

## DISCUSSION

Among the diverse diseases of the shoulder complex, winging scapula resulting from serratus anterior weakness is a representative and it is caused by muscle weakness. Studies of diverse serratus anterior muscle strengthening exercises as for way to reduce winging scapula have been conducted<sup>9)</sup>. However, recent studies have generally investigated the correlation between the distal part and proximal part in open kinematic exercise<sup>8)</sup> and provision of visual feedback during the push-up plus in the closed kinematic chain exercise<sup>6)</sup>. The muscle activation of shoulder stabilizers has been insufficiently studied in relation to positions of the cervical spine which is the proximal part of most of the shoulder stabilizers during the push-up plus, and closed kinematic chain exercise.

In this study, we have analyzed the muscle activation of the shoulder stabilizers during the push-up plus exercise in different on the cervical spine positions and the results showed that there were a significant differences for among the serratus anterior muscle, sternocleidomastoid muscle, cervical paraspinalis muscle and pectoralis major muscles. The highest activation of the serratus anterior muscle was found in the neutral position. This may be because the cervical lordosis was decreased by the contraction of the sternocleidomastoid muscle during the flexion of the cervical spine, which hindering the accurate motion of the serratus anterior muscle through making round shoulders and causing scapular protraction. In addition, it is also possible that the muscle fiber lengths of the muscles that can generate a strong force were not maintained since the scapular retraction occurred under the cervical spine extension, leading to the decrease in the muscle fiber length of muscles such as the serratus anterior muscle and upper trapezius muscles. According to the results, it was shown that the neutral cervical position is the most effective position since an appropriate tension and muscle fiber

length are maintained in this position in the case of the push-up plus exercise for the strengthening of the serratus anterior muscle. In addition, the pectoralis major activation was highest in full cervical full flexion. This is presumably because the internal rotation of the glenohumeral joint was caused by the pectoralis major to located the shoulder joint in a stable position with the round shoulders induced by full cervical full flexion. This implies that the muscle activation during the shoulder stabilizer exercise is affected by the cervical spine positions since the muscle fiber length of the shoulder stabilizers varies depending on the positions.

These results show that different shoulder stabilizers are activated during the push-up plus exercise depending on not only the location of the neck but also the internal or external rotation and the abduction/adduction angle of the shoulder joint, suggesting that establishment of an accurate position for the strengthening of each muscle is necessary.

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