

Effect of Craniocervical Flexion on Muscle Activities of Scapula Upward Rotator Muscle During Push-Up Plus Exercise in Subject With Winging of Scapula

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Abstract

The aim of this study to investigate the effects of craniocervical flexion on muscle activities of scapular upward rotators during push-up plus exercise in subjects with winging scapula. Eighteen males with scapular winging were recruited, and each subject performed knee push-up plus and other exercises, in two conditions (craniocervical flexion vs. natural head positions). A surface electromyography (EMG) was used to measure upper trapezius (UT), serratus anterior (SA), and lower trapezius (LT) muscle activity. A paired t-test was used to determine the statistical significance between the different condition with/without applying of craniocervical flexion. UT EMG activity significantly decreased and SA EMG activity significantly increased during knee push-up plus involving the craniocervical flexion compared to the natural head position. However, no significant differences ($p>.05$) were found in the activity of the LT muscle. The UT/SA ratios with and without craniocervical flexion showed a significant difference ($p<.05$). These results showed that the knee push-up plus other exercises performed with craniocervical flexion could strengthen the serratus anterior muscle and minimize the activity of the UT muscle.

Key Words: Craniocervical flexion; Head position; Push up plus; Scapular upward rotator; Scapular winging.

Introduction

The term, “winging of scapula,” refers to abnormal scapulothoracic positions and movements that can be attributed to various causes (Meiningner et al, 2011). Winging of the scapula is a type of scapular dysfunction that has two general causes. One is the paralysis of the long thoracic nerve, which results in difficulty in flexion the shoulder over 120 degrees, and the other is the weakness of the serratus anterior (SA) (Weon et al, 2011). The SA is an important muscle that stabilizes the winging of scapula, scapular anterior tilting, the inferior angle and the

medial border of the scapula (Escamilla et al, 2009; Neumann, 2002). It is also the most important muscle used for the upward rotation of the scapula (Dvir and Berme, 1978). The weakening of SA is an important cause of shoulder pain, shoulder impingement syndrome, and the winging of scapula (Ludewig and Cook, 2000; Lukasiewicz et al, 1999). Many studies have reported that scapular dyskinesis is caused by the imbalance of the scapular upward rotators (Colls et al, 2004; Colls et al, 2007; Ludewig and Cook, 2000; Lukasiewicz et al, 1999). They argued that the excessive contraction of the upper trapezius (UT) and the reduced contraction of the lower trapezius

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(LT) and the SA during the shoulder flexion could contribute to abnormal scapulohumeral rhythm and the winging of scapula (Cools et al, 2004; Cools et al, 2007; Ludewig and Cook, 2000). Unbalanced muscle activities are one of the many causes of abnormal scapular movement and positions (Ludewig and Cook, 2000). Therefore, Decker et al (1999) suggested that lowering the muscle activity of the UT and increasing the muscle activity of the SA and the LT were effective methods of training the scapular upward rotator muscles.

To prevent dysfunction and promote the rehabilitation of shoulder joints, exercise programs for the recovery of the balanced control ability of muscles that generally affect shoulder stabilization are preferred (Jeon et al, 2011). The effects of various exercises designed to reinforce the SA have been demonstrated through previous studies (Decker et al, 1999; Ludewig et al, 2000; McClure, 2004; Moseley et al, 1992), and focus is being placed on the closed kinetic chain in particular (Ludewig et al, 2004). Closed kinetic chain exercise is often used as an exercise therapy program for the dynamic stability and posture maintenance of joints, because it causes the coordinated contraction of many muscles due to the mechanical pressure of the articular surface. It also improves endurance and muscular strength while securing more proprioceptive senses due to the stimulation of the afferent receptors (Ellenbecker and Davies, 2001). Ellenbecker and Davies (2001) recommended push-up plus exercise as an effective closed kinetic chain exercise for the training of scapular stability cooperative muscle and the SA. The push-up plus exercise adds the maximum extension of the elbow joint, followed by scapular protraction, to the general push-up motion. Ludewig et al (2004) reported that the muscle activity of the SA in general push-up plus exercise was high when four types of push-up plus exercises were applied to subjects who showed an imbalance of the UT/SA or excessively unbalanced muscle activity of the UT. Decker et al (1999) suggested that among the eight

exercises used for shoulder joint rehabilitation, push-up plus, knee push-up plus, and dynamic hug exercises were appropriate for the reinforcement of the SA. Furthermore, after investigating the correlations of the UT/SA in push-up plus exercises in various conditions, they claimed that there was a significant inverse correlation between the UT/SA during the push-up plus exercises with both feet on a chair, and there was no significant muscle activity in the LT.

Craniocervical flexion (CCF) is generally used to provide craniocervical stability and to promote deep cervical stability (Falla et al, 2012; Kelly et al, 2013). CCF is also a way to retrain and evaluate the muscular contraction of the deep neck flexors (Jull et al, 1999). The deep neck flexor is essential for supporting the cervical lordosis and forming the cervical posture (Boyd-Clark et al, 2001; Boyd-Clark et al, 2002; Conley et al, 1995; Mayoux-Benhamou et al, 1994; Vasavada et al, 1998). The forward head posture (FHP), which is an incorrect cervical arrangement, usually shortens the neck extensors at the posterior, tightness shoulder muscles as well as the anterior neck muscles, and has kinematic affects on the scapular position (Kebaetse et al, 1999). Lewis et al (2005) suggested that the FHP caused the downward rotation, anterior tilt, and protraction of the scapula. To prevent shoulder pain associated with abnormal neck postures, many researchers have emphasized the maintenance of a neutral head posture during the functional movement of the arms (Edmondston et al, 2007; McLean, 2005).

Although the push-up plus exercise is recommended for the reinforcement of the strength of scapular upward rotator muscles and the selective reinforcement of the serratus anterior, most studies were conducted for normal people, and studies for those with the winging of scapula are insufficient. Furthermore, whereas the muscle activities of the scapular upward rotator muscles have been analyzed through various types of support surfaces, exercise positions, and feet heights during the push-up plus

exercise, few studies have analyzed the muscle activities of the scapular upward rotator muscles while applying CCF during the push-up plus exercise. Therefore, this study was conducted to investigate the effects of CCF on the muscle activities of the scapular upward rotator muscles during the push-up plus exercise in people with the winging of scapula. Two hypotheses were set up for this study. The first hypothesis was that when CCF was applied during the push-up plus exercise, the muscle activities of the SA and the LT would increase while the muscle activity of the UT would decrease, compared to when CCF was not applied. The second hypothesis was that the ratio of UT/SA when CCF was applied during the push-up plus exercise would decrease compared to that when CCF was not applied.

Methods

Subjects

The subjects of this study were 18 male adults with the winging of scapula, chosen from among the students in Yonsei University; they agreed to participate in this experiment after listening to sufficient explanation about the purpose and method of this study. The selection criteria for the winging of scapula was a distance of 2 cm or less between the chest wall and the inferior angle of the scapula, which was measured with a scapulometer (Weon et al, 2011). Weon et al (2011) measured the test-retest reliability for the winging of scapula with a scapulometer, and

the intraclass correlation coefficient was .97 (95% confidence interval: .87-.99), and the standard error of the measurement was .1 cm. The exclusion criteria for subjects were limitation or instability in the range of motion of the shoulder joint, shoulder or neck pain, thoracic outlet syndrome, frozen shoulder, numbness or tingling in the upper body, a history of shoulder surgery or injury, and at least 5 hours of upper body exercise per week. The general characteristics of the subjects are listed in Table 1.

Instruments

The surface electromyograph (EMG) Telemyo 2400T (Noraxon Inc., Scottsdale, AZ, USA) was used to measure the muscle activities of the dominant UT, LT, and SA, according to the head posture during the push-up plus exercise. To reduce skin resistance, hairs on the electrode attaching sites were removed, the horny layers were removed by rubbing the skin with fine sandpaper, and the skin was wiped with a disinfectant alcohol. For electrodes, Ag/AgCl electrodes were used, and the distance between electrodes was maintained at 2 cm. The electrodes were attached in parallel to the muscle fiber direction. For data analysis, the Noraxon MyoResearch Master Edition 1.08 XP software (Noraxon Inc., Scottsdale, AZ, USA) was used. The sampling rate of the EMG signals was set to 1000 Hz. The frequency bandwidth was 20-450 Hz, and a 60 Hz notch filter was used. The EMG signals were processed by root mean square (RMS) and converted to ASCII format for analysis.

Electrodes and normalization

The electrode attachment positions for measuring the muscle activities of dominant UT, LT, and SA are as follows. They were attached to the middle of the seventh cervical spinous process and the scapular acromion for the dominant UT, at 55 degrees from the inferior angle of the scapula for the LT, and below the axillary at the same height as the inferior angle of the scapula for the SA (Criswell, 2011). The

Table 1. General characteristics of subjects (N=18)

	Mean±SD ^a	Range
Age (yr)	21.7±1.7	20.0~24.0
Height (cm)	157.7±3.6	172.0~181.0
Weight (kg)	65.0±6.9	51.0~70.0
BMI ^b (m ² /kg)	2.2±.2	14.0~23.0
Height of winging scapular (mm)	18.4±1.9	2.0~2.2

^amean±standard deviation, ^bbody mass index.

ground electrode was attached to the center of the dominant acromion. The dominant upper extremities were determined by oral questions. The dominant upper extremities of 15 subjects were on the right side, and those of 3 subjects were on the left side. To normalize the action potentials of the measured muscles, the reference voluntary contractions (RVC) of the UT, LT, and SA were measured. For the position at measurement, the shoulder of the subject was flexion at 90 degrees on the scapular plane, and a 6.5 kg sandbag was bound to the forearm of the subject during the data collection (Park and Yoo, 2011). The subjects maintained this position for five seconds without moving their center of gravity, and the middle three seconds of the five-second contraction period were used for data collection. Subjects took a rest for one minute between performances. The average of the muscle activities collected from three performances was used as the voluntary contraction.

Procedures

All the subjects performed the push-up plus exercise under two conditions. In the first condition, the push-up plus exercise was performed without the CCF, and in the second condition, it was performed with CCF. To standardize the push-up plus postures and the performance of the movements in the two conditions and to limit unnecessary movements, the starting position, exercise process, and ending position were defined. First, in the starting position, the

subject took the quadruped position, with their feet and hands spread at shoulder width, and they supported their weight on their knees and hands (Decker et al, 1999). After that, a target bar was placed at the fourth thoracic vertebra, and a shoulder bar was installed at one side. The target bar was installed to help the subject pull their scapula to the same position, and a shoulder bar that was vertical to the floor was installed to help them maintain the same shoulder flexion angle and to move upward instead of forward or backward. Secondly, the subjects started the push-up plus exercise when the researcher said "Start". They performed the push-up plus exercise in the quadruped position for two seconds and maintained the position for five seconds with the help of a metronome. Thirdly, the performance was regarded as successful if, after the push-up plus exercise, the fourth thoracic vertebra contacted the target bar, and the shoulder did not separate from the shoulder bar in the ending position. If subjects failed to maintain the standardized starting position, performance of exercise, and ending position, data were not collected. The researcher measured three times while helping the subjects keep accurate positions and gave them a two-minute rest between the performances. The subjects learned how to change from the quadruped position to the push-up plus position through 15 minutes of familiarization. After this familiarization period, every subject could take the push-up plus position without difficulty or inconvenience (Figure 1). In



Figure 1. Knee push up plus without craniocervical flexion.

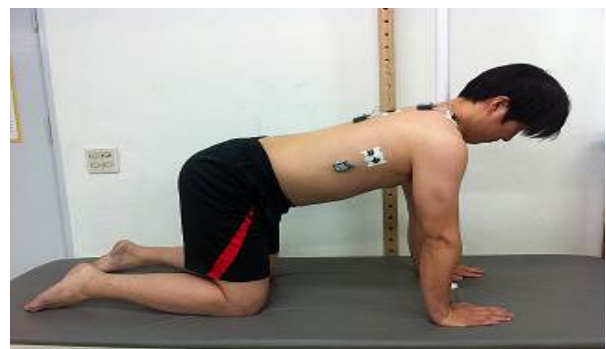


Figure 2. Knee push up plus with craniocervical flexion.

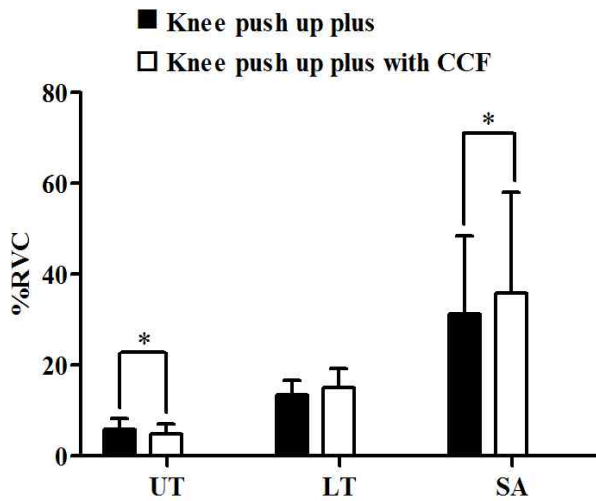


Figure 3. Comparison of the scapular upward rotator muscles between knee push up plus exercise and knee push up plus with CCF exercise (RVC: reference voluntary contraction, UT: upper trapezius, LT: lower trapezius, SA: serratus anterior, * $p<.05$).

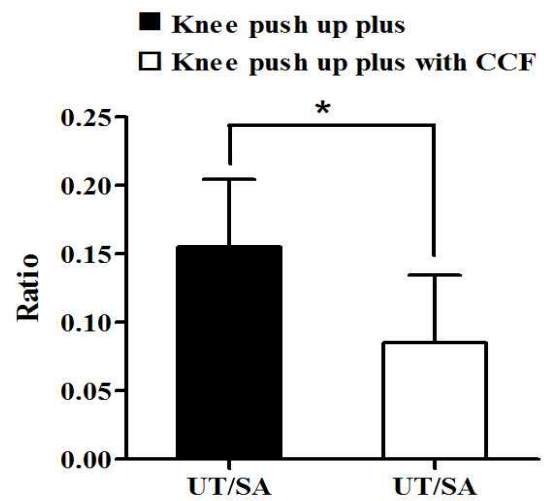


Figure 4. Comparison of the muscle activity ratio lower upper trapezius and serratus anterior between knee push up plus exercise and knee push up plus with CCF exercise (UT: upper trapezius, SA: serratus anterior, * $p<.05$).

the second condition, the subjects changed to the push-up plus position in the same way as in the first condition, but with CCF (Figure 2).

Statistical analysis

A paired t-test was conducted to compare the differences in the muscle activities of the UT, SA, and LT as well as the UT/SA ratio in the two conditions according to the head posture during the push-up plus exercise. The statistical significance level was set to $\alpha=.05$. The commercial statistic application SPSS ver. 20.0 software (SPSS Inc., Chicago, IL, USA) was used for statistical processing of the data.

Results

The muscle activities of the UT, SA, and LT under the two conditions are shown in Table 2 and Figure 3, and the UT/SA ratios are shown in Table 3. When CCF was applied to the push-up plus exercise, the average muscle activity of the UT was 6.36%, which was significantly lower than the average muscle activity of the UT without CCF, 7.47% RVC ($p<.05$). The average muscle activity of SA was 51.59%, which was significantly higher than the average muscle activity of SA without CCF, 43.36% ($p<.05$). However, the average muscle activities of LT with CCF and without CCF were 18.03% and

Table 2. Comparison of the muscle activity

Muscles	Without CCF ^a	CCF ^b	t	p
Upper trapezius	7.47±4.23 ^c	6.36±3.44	3.11	<.05*
Lower trapezius	15.62±11.09	18.03±12.16	-1.38	.18
Serratus anterior	43.36±19.23	51.59±20.24	-2.14	<.05*
Ratio of UT ^d /SA ^e	.19±.12	.12±.05	3.47	<.05*

^aknee push-up plus without craniocervical flexion, ^bknee push-up plus with craniocervical flexion, ^cmean±standard deviation, ^dupper trapezius, ^eserratus anterior, *significantly difference from with/without CCF during push-up plus exercise.

15.62%, respectively, and there was no significant difference between them ($p>.05$). Nevertheless, the UT/SA ratios with and without CCF showed a significant difference ($p<.05$) (Figure 4).

Discussion

Many muscle strengthening exercises are being conducted to treat the winging of scapula. Among them, the push-up plus exercise is recommended by many researchers for evaluating the differences and ratios of the SA and UT, in order to examine the causes of damage caused by the imbalance of the scapular upward rotation muscles as well as to selectively strengthen the SA. However, most studies focus on exercise for strengthening the SA, and there are few studies on muscle strengthening exercises for people with the winging of scapula. Although many studies have varied the exercise positions, feet heights, and support surfaces during the push-up plus exercise, studies on the activities of the SA and the scapular upward rotation muscles with CCF are insufficient. Therefore, this study was conducted with 18 subjects with the winging of scapula in order to investigate the effects of the scapular upward rotation muscles on muscle activities when CCF was applied during push-up plus exercise. The accurate measurement method for the degree of the winging of scapula is to measure the degree of the scapular lift from the chest wall with X-ray or magnetic resonance imaging. In this study, however, the distance between the chest wall and the inferior angle of the scapula was measured with the scapulometer, introduced for such study by Weon et al (2011) as a tool for objectively and quantitatively measuring the winging of scapula. Those for whom this distance was at least 2 cm were chosen as the subjects for this study.

Results showed that the muscle activity of the SA significantly increased when CCF was applied during the push-up plus exercise compared to other cases

($p<.05$). The muscle activity of the UT also significantly decreased when CCF was applied during the push-up plus exercise ($p<.05$). In the case of the LT, however, there was no significant difference, although the muscle activity with CCF increased compared to that without CCF ($p>.05$). Furthermore, the UT/SA ratio that shows the selective muscle contraction of the SA showed a significant difference when CCF was applied ($p<.05$). This implies that the application of CCF is a strategy that can selectively strengthen the SA. In this study, the application of CCF decreased the muscle activity of the UT while increasing that of the SA and LT. This result suggests that the application of CCF changes the length-tension relationship of the levator scapulae during the scapular upward rotation. McLean (2005) reported that the muscle activity of the levator scapulae significantly increased in the forward head posture over that in the neutral head posture. The UT is the agonist of scapular upward rotation, and the levator scapulae act as antagonist to the scapular upward rotation. The increasing tension of the levator scapulae will interfere with the upward movement of the scapula, and the muscle activities of the UT and LT will increase to overcome this increasing tension of the levator scapulae. The application of CCF promotes the upward rotation due to the decreasing tension of the levator scapulae, and the application of the push-up plus exercise will decrease the muscle activity of the UT. This is because the SA and UT muscles cooperate with each other for scapular upward rotation, but if their points of protraction and retraction suppress each other's motions, they act as agonist or antagonist to each other (Neumann, 2002).

The maintenance of the neutral position of the cervical vertebrae through CCF affects muscle activity through biomechanics changes. The decreased cervical flexion moment through CCF decreases the muscle activity of the neck extensors that play the role of balance weights for the cervical flexion, which in turn decreases the muscle activity of the UT, as found by this study. In this study, the mus-

cle activity of the LT increased, but this change was insignificant. Hardwick et al (2006) reported that the muscle activity of the LT increased at the angle of the humerus on the scapular plane. Ekstrom et al (2003) claimed that the most appropriate exercise for increasing the muscle activity of the LT was to lift the arms in parallel to the muscular fibers of the LT while lying on your face. Park and Yoo (2011) suggested that the muscle activity of the LT increased in movements that require dynamic stability, such as lifting the arms, rather than in those that require static stability. Previous studies also investigated the relationship of the muscle activity ratio between the cooperative muscles as well as the actual muscle activities of the UT and SA in various shoulder movements (Cools et al, 2007; Ludewig et al, 2004; Martins et al, 2008). Ludewig et al (2004) reported that the muscle activity ratio UT/SA increased in people with shoulder joint pain and dysfunction and suggested that the push-up plus exercise could selectively strengthen the SA because it significantly decreased the UT/SA ratio. Therefore, the application of CCF during the push-up plus exercise, which decreased the UT/SA ratio, can provide a method of selectively strengthening the SA to people with the winging of scapula.

This study has a few limitations. First, it may be difficult to generalize the findings of this study, because the subjects were all male. This was because they had to undress their upper bodies for the measurement of the SA, UT, and LT. Secondly, the sternocleidomastoid muscle is a cooperative muscle for CCF and affects cervical stabilization; the pectoralis major muscle is a cooperative muscle for shoulder protraction. Thirdly, this study did not research patients with impingement rotator and cuff pathology who experienced shoulder pain; nor did it analyze the kinematic data of the shoulder when CCF was applied to the push-up plus exercise. Future studies will need to analyze the changes in muscle activity of the scapular rotator muscles and the kinematic data during the push-up plus exercise in various

postures together with the application of CCF.

Conclusion

This study was conducted to investigate the effects of the application of CCF on the muscle activities of the scapular upward rotator muscles during the push-up plus exercise in adults with the winging of scapula compared to the condition without CCF, the push-up plus with CCF significantly decreased the muscle activity of the UT, whereas significantly increased the muscle activity of the SA. The UT/SA ratio also showed significant differences. Therefore, the application of CCF during the push-up plus exercise may suggested as an effective exercise for strengthening the scapular upward rotation muscles in people with the winging of scapula.

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