

The Effects of Active Scapular Protraction on the Muscle Activation and Function of the Upper Extremity

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Abstract. [Purpose] The purpose of this study was to determine the effects of adjusting the scapula into its ideal position through active scapular protraction on the muscle activation and function of the upper extremity. [Subjects] Twenty female college students aged 19–21 without any physical or functional disability were the subjects of this study. They had no history of injury to their upper extremities or hands. [Methods] After the initial measurements the experimental group was asked to perform active scapular protraction; then, their grip strength and muscle activation were measured again. Every action was maintained for 5 seconds and repeated 3 times. The mean values of the measurements were analyzed. A resting of 1 minute was given between each action. [Results] The results revealed a significant change in the experimental group's grip strength after active scapular protraction had been performed. The surrounding muscles of the scapula, such as the serratus anterior, upper trapezius, flexor carpi ulnaris, flexor carpi radialis and palmaris longus, showed significant changes in muscle activation after active scapular protraction. The muscles of the upper extremity also showed significant changes after active scapular protraction. [Conclusion] The adjustment of scapula into its ideal position through active scapular protraction increased the activations of the muscles surrounding the shoulder joint and improved the function of the upper extremity.

Key words: Active scapular protraction, Grip strength, Muscle activation

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INTRODUCTION

The upper extremities not only carry out delicate tasks such as eating, putting on clothes, washing, and writing, they also assist crawling, walking, and balance, working as a protective reaction. Thus, they play a very important role in daily activities¹⁾. The functions of the upper extremities are executed by proximal stability and distal functional movements. The muscles surrounding the scapula provide proximal stability for the upper extremity and act as a fix when the distal part is moving²⁾. The scapula also acts as an axis, transmitting the power and high energy of the lower extremities and trunk to the upper extremities³⁾. Therefore, the upper extremities which play an important role in functional performance of daily living activities⁴⁾, will work better when the stability of scapula is secured⁵⁾. Further, the scapula is connected to the humerus by the articular fovea. The glenohumeral joint is involved in most of the move-

ments of the upper extremity³⁾. Hence, when the scapula is in its ideal position, not only does it allow the shoulder joint to move smoothly, but it also provides stability to the shoulder joint, because the rotator cuff muscles will exert maximum strength on the glenohumeral joint⁶⁾. If the scapula was located in a position in which it is difficult to provide stability for the shoulder joint, pain in the shoulder and upper extremity and dysfunction would occur⁷⁾. Therefore, the adjustment of the scapula to its ideal position is vital for smooth upper extremity function⁶⁾.

The most important functions of the upper extremity for independent and smooth activities of daily living are the functions of the hand. A representative function of the hand is to hold something. The strength of the fingers when holding something is known as grip strength and it is an important index in the evaluation of motor function of the hand⁸⁾. Since grip strength is strongly positively correlated with muscular strength⁹⁾, grip strength can be used to evaluate changes in muscular strength effectively and economically. Grip strength has been used in a lot of studies because of its simple measurement^{10, 11)}. Grip strength is not simply the force generated by the fingers and wrist joint, it is also intimately connected with the muscular strength of forearm, and the brachial and shoulder joints¹²⁾. In connection with this, Park¹³⁾ mentioned that reaching movement was more efficient after passive pre-positioning of the scapula, and

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noted that hand function is influenced by the alignment of scapula.

Although the ideal position of the scapula is a vital element in upper extremity function in ADL, many times when training patients that have upper extremity malfunction, the position of the scapula is not considered. Research about the relation between the position of the scapula and the upper extremity, especially the study of the effect of active scapular protraction on the upper extremity, is insufficient. Therefore, the purpose of this study was to determine the changes in upper extremity function when the scapula has been ideally positioned using active scapular protraction, to provide basic information that is helpful when providing clinical treatment.

SUBJECTS AND METHODS

The research participants were selected from students of S University, in Busan. They were female college students aged 19–21. They participated in the experiment after being informed of the procedures and purposes of the experiment. They had no physical or functional disability, and they had no experience of injury to the upper extremity or hand. The female students who agreed to participate in the experiment were randomly divided into two groups. This study complied with the ethical principles of the Declaration of Helsinki, and written informed consent was received from each participant. The hand function of the experimental group was measured after active scapular protraction, and the hand function of the control group was measured by same method but without active scapular protraction. The average age of the experimental group was 20.6, their average height was 161.4 cm, and their average weight was 55.9 kg. The average age of control group was 19.9, their average height was 162.5 cm, and their average weight was 55.1 kg. The participants were told about the compensational movements that might occur during the experiment, and they were taught how to avoid compensational movements during the experiment. In addition, to make sure the participants could maintain the motions accurately, trial practices were carried out 3 times before the experiment.

The grip strength of the control group was measured without active scapular protraction. While the grip strength was being measured, electromyography was also performed. The grip strength of the experimental group was measured twice, with the second measurement being made after abduction of the shoulder joint to 90 degrees, by rotating externally and upwards, which is also known as active scapular protraction. Electromyography was performed during the grip strength measurements. Following the “start” cue, each action was maintained for 5 seconds and the action was repeated 3 times. The rest time between each action was 1 minute. The grip strength was measured using a hand dynamometer (Hydraulic Hand Dynamometer, Fabrication Enterprises, USA). The size of hand didn't matter. The handle was fixed on level 2. The grip strength was measured standing straight with the shoulder joint in 90 degrees flexion and abduction. The elbow joint was in extension, and the forearm and wrist joint were in the neutral position.

The activities of the muscles surrounding the scapula

and the hand flexion muscles were measured using surface electromyography (Keypoint, Medtronic, USA) while the grip strength was being measured. Disposable unipolar surface electrodes (1.5 cm × 2.5 cm) were used, and a unipolar surface electrode of 3 cm diameter was used for the ground electrode. To reduce the skin resistance of electromyography, hair was removed and sterilizing alcohol was used to exfoliate the skin. A small amount of electrolyte gel was used to attach the electrodes onto the skin. The attachment sites of the surface electrode were the serratus anterior, infraspinatus, upper trapezius, flexor carpi ulnaris, flexor carpi radialis and palmaris longus. The electromyogram signals were recorded while the maximum grip strength was being measured, and the first and last seconds of the 5-second measurement were discarded. The electromyogram signals of the middle 3 seconds were used in the analysis. The electromyogram signals were converted to root mean square (RMS) values.

Since there were 20 people in the experiment, the Shapiro-Wilk test was conducted to verify the normality of the data. A nonparametric method was used because the data were not normally distributed. The Mann-Whitney test was used to compare the common characteristics of the two groups, and the differences in grip strength and muscle activation. The Wilcoxon Signed Rank test was used to determine the effect of active scapular protraction on grip strength and muscle activation. For the analysis, we used SPSS for Windows (Ver. 20.0) statistical software, with a significance level of 0.05.

RESULTS

The results for grip strength and muscle activation are shown below in Table 1. Prior to active scapular protraction, the grip strength of the experimental group was 20.4 kg and that of the control group was 22.4 kg, with no significant difference. The muscle activation of the serratus anterior muscle of the experimental group was 279.1 μ V, and that of the control group was 258.9 μ V. The muscle activation of the upper trapezius muscle of the experimental group was 229.0 μ V and that of the control group was 499.2 μ V. The muscle activation of the infraspinatus muscle of the experimental group was 119.0 μ V and that of the control group was 129.8 μ V. The muscle activation of the flexor carpi ulnaris muscle of the experimental group was 654.5 μ V and that of the control group was 726.0 μ V. The muscle activation of the flexor carpi radialis muscle of the experimental group was 499.5 μ V and that of the control group was 541.7 μ V. The muscle activation of the palmaris longus muscle of the experimental group was 627.9 μ V and that of the control group was 822.0 μ V. Namely, there were no significant differences in the muscle activations of any of the muscles before active scapular protraction.

The experimental group's grip strength and muscle activations after active scapular protraction are shown below in Table 2. Prior to active scapular contraction, the experimental group's grip strength was 20.4 kg, but after the contraction it increased to 23.1 kg ($p < 0.05$). The muscle activation of the serratus anterior muscle before active scapular protraction was 279.1 μ V, and after the protraction it was

Table 1. The analysis of differences between the two groups (Unit: μV)

Variables	Group	Values	Mean Rank	Rank Sum
Grip strength	Experimental	20.4 \pm .7	9.5	94.5
	Control	22.2 \pm 1.6	11.6	115.5
Muscle activation				
Serratus Anterior	Experimental	279.1 \pm 73.0	11.1	111.0
	Control	258.9 \pm 62.1	9.9	99.0
Upper Trapezius	Experimental	229.0 \pm 64.0	9.8	98.0
	Control	499.2 \pm 267.9	11.2	112.0
Infraspinatus	Experimental	119.0 \pm 44.6	8.5	85.0
	Control	129.8 \pm 24.3	12.5	125.0
Flexor Carpi Ulnaris	Experimental	654.5 \pm 122.1	10.3	103.0
	Control	726.0 \pm 159.8	10.7	107.0
Flexor Carpi Radialis	Experimental	499.5 \pm 121.3	10.0	100.0
	Control	541.7 \pm 109.7	11.0	110.0
Palmaris longus	Experimental	627.9 \pm 128.8	10.3	103.0
	Control	822.0 \pm 253.5	10.7	107.0

Mean \pm SD**Table 2.** The changes in muscle activations and grip strength of the experimental group (Unit: μV)

Variables	Pre-protraction	Post-protraction	Mean Rank	Rank Sum
Grip strength*	20.4 \pm 2.3	23.1 \pm 2.6	3.0	3.0
			5.8	52.0
Muscle activation				
Serratus Anterior*	279.1 \pm 230.9	884.3 \pm 837.2	.0	.0
			5.5	55.0
Upper Trapezius*	229.0 \pm 202.4	423.3 \pm 304.4	1.5	3.0
			6.5	52.0
Infraspinatus	119.0 \pm 141.0	244.9 \pm 419.6	4.5	9.0
			5.8	46.0
Flexor Carpi Ulnaris*	654.5 \pm 386.0	931.6 \pm 788.8	7.0	7.0
			5.3	48.0
Flexor Carpi Radialis*	499.5 \pm 383.6	804.8 \pm 757.3	2.5	5.0
			6.3	50.0
Palmaris longus*	627.9 \pm 407.2	1322.2 \pm 1046.0	2.0	4.0
			6.4	51.0

Mean \pm SD, * $p < 0.05$

884.3 μV , a significant increase ($p < 0.05$). Similarly, the upper trapezius muscle activation significantly increased from 229.0 μV to 423.3 μV ($p < 0.05$), that of the flexor carpi ulnaris muscle from 654.5 μV to 931.6 μV ($p < 0.05$), that of the flexor carpi radialis muscle from 499.5 μV to 804.8 μV ($p < 0.05$), and that of the palmaris longus muscle from 627.9 μV to 1322.2 μV ($p < 0.05$). The infraspinatus muscle activation increased from 119.0 μV to 244.9 μV , but the increase was not significant.

The control group's first and second measurements of grip strength and muscle activation are shown below in Table 3. The first measurement of grip strength of the con-

trol group was 22.2 kg, which was the same as that of the experimental group before the active displacement of the scapula. However, it is significantly decreased to 20.7 kg in the second measurement ($p < 0.05$). The muscle activation of the serratus anterior muscle was 258.9 μV in first measurement and it decreased to 242.9 μV in the second measurement. That of the upper trapezius muscle was 499.2 μV and it decreased to 479.1 μV , but there was no significant difference. The muscle activation of the infraspinatus muscle in the first measurement was 129.8 μV , and it increased to 148.3 μV in second measurement. However, there was no significant difference. The muscle activation of the flexor

Table 3. The changes in muscle activations and grip strength of the control group (Unit: μV)

Variables	Pre-protraction	Post-protraction	Mean Rank	Rank Sum
Grip strength*	22.2 \pm 5.2	20.7 \pm 4.5	6.4 2.0	51.0 4.0
Muscle activation				
Serratus Anterior	258.9 \pm 196.3	242.9 \pm 154.9	6.6 4.4	33.0 22.0
Upper Trapezius	499.2 \pm 847.2	479.1 \pm 717.5	5.5 5.5	22.0 33.0
Infraspinatus	129.8 \pm 76.9	148.3 \pm 179.0	5.0 6.7	35.0 20.0
Flexor Carpi Ulnaris	726.0 \pm 505.2	696.2 \pm 522.9	4.8 6.5	29.0 26.0
Flexor Carpi Radialis	541.7 \pm 347.0	487.6 \pm 262.06	5.5 5.5	33.0 22.0
Palmaris longus	822.0 \pm 801.7	710.4 \pm 749.5	6.0 4.8	36.0 19.0

Mean \pm SD, * $p < 0.05$

carpi ulnaris muscle decreased from 726.0 μV to 696.2 μV , that of the flexor carpi radialis muscle decreased from 541.7 μV to 487.6 μV , and that of the palmaris longus muscle decreased from 822.0 μV to 710.4 μV , all without significant difference.

DISCUSSION

If the scapula is not in its normal position, the contraction pattern of the muscles surrounding the scapula changes, resulting in alteration of the connecting tissues which affects the muscle function. The lengthening or shortening of specific muscles results in them losing their ability to perform their function, and this can eventually cause postural change¹⁴.

Generally, imbalance of the shoulder joint or of the muscles surrounding the scapula changes the position of the scapula and scapulohumeral rhythm resulting in dysfunction of the shoulder joint^{15, 16}. Sahrman¹⁶ and Kibler⁶ stated that when rotating the scapula upwards, the couple force of the upper trapezius, lower trapezius and serratus anterior muscles, which act as stabilizer muscles, plays a vital role in scapula movement. So if the counterbalance of these muscles undergoes any changes, the pattern of scapula movement changes too. Zarins and Rowe¹⁷ noted that appropriate movement of the scapula is not achieved by the contraction of the individual muscles surrounding the scapula, but through the coordinated contraction and relaxation of many muscles. Hence, balancing the muscles surrounding the scapula through selective strengthening exercises for weakened muscles is an important treatment for normal movement. In order to increase the efficiency of upper extremity function, positioning the scapula in its ideal position is necessary ahead of the coordinated contraction of the muscles surrounding the scapula⁶. Therefore, many studies of exercises that strengthen the muscles stabilizing the scapula have been conducted.

Kibler et al.¹⁸, Kishner and Colby¹⁹ and Choi²⁰ studied whether strengthening exercises for the serratus anterior muscle, which is involved in stabilizing the scapula would improve muscular strength and upper extremity function, and they confirmed that increased muscular strength of the serratus anterior muscle improved upper extremity function.

We could not exclude the possibility that an exercise program to improve the muscular strength of the serratus anterior muscle would not affect the other muscles of upper extremity. To avoid difficulties in explaining the direct effect of the scapula being in its ideal position on the function of upper extremity, we designed this study to investigate the change of upper extremity function after active scapular protraction.

In our daily life, the shoulder joint activity or muscular strength of the upper extremity and hand grip strength is very important²¹. Since the functional movements of the hand are affected by the proximal part of the upper extremity, injury to the proximal part of the upper extremity can result in dysfunction, without any injury of the distal part of the upper extremity²². For this reason, grip strength and muscular strength of the muscles near the shoulder joint are strongly correlated. So, when there is injury to, or pain in the shoulder joint, grip strength test is very important in clinical evaluation²³. The results of this study show that there was an increase in grip strength of 13.14% after active scapular protraction, from 20.39 kg before contraction to 23.07 kg after contraction. This demonstrates that positioning of the scapula in the ideal position improves upper extremity function. The muscle activation of the muscles surrounding the scapula and upper extremity muscles also increased after active scapular protraction. The muscle activation of the serratus anterior muscle, which is one of the muscles surrounding the scapula, was 279.12 μV before active scapular protraction and it increased by 216.8% after protraction to 884.28 μV . The activation of the upper tra-

pezius muscle also increased from 228.99 μ V to 423.30 μ V, an increase of 84.86%. The activation of the flexor carpi ulnaris muscle, an upper extremity muscle increased by 42.33% after active scapular protraction from 654.51 μ V to 931.57 μ V. The activation of the flexor carpi radialis muscle increased from 499.51 μ V to 804.83 μ V, an increase of 61.12%, and the muscle activation of the palmaris longus muscle increased from 627.90 μ V to 1322.21 μ V, an increase of 110.58%. These results show that positioning the scapula in the ideal position can improve the muscle activation of the upper extremity muscles.

Cools et al.²⁴⁾ stated that the serratus anterior muscle plays the most important role in upward rotation as well as stabilization of the scapula. Also, weakness of the serratus anterior muscle causes winging or change of position of the scapula, and causes injury shoulder joint. Research is in progress to examine training of the serratus anterior muscle and its effects on upper extremity function. The serratus anterior muscle affects the stabilization of the shoulder joint. Kim²⁵⁾ studied the distance from the midline of the thoracic vertebra to the scapular vertebral border and changes in neck pain after a 4-week muscular strengthening exercise program for the serratus anterior muscle. The target of this exercise was patients who had an adducted scapula and neck pain. The muscular strengthening exercise for the serratus anterior muscle significantly increased the mean distance between the midline thoracic vertebrae to the scapular vertebral border and neck pain was reduced. Kim²⁵⁾ explained that the adducted scapula is caused by muscle imbalance of the serratus anterior muscle, and the muscle strengthening exercise moved the scapula to normal position. In addition, as the recovery of scapular position progressed, pain reduced. Cho²⁶⁾ also studied how positioning the scapula in an ideal position through passive protraction affected the function of the upper extremity and ADL of chronic stroke patients. Her results show that the upper extremity function and ADL of the group that had scapular setting improved more than those of the group that did not receive scapular setting. Hence, when the scapula is in its ideal position, upper extremity function is improved the function of the upper extremity works better when the stability of the scapula is secured⁵⁾. Our study results also showed that when the scapula was placed in an ideal position through active scapular protraction, the muscle activations of the muscles surrounding the shoulder joint were increased, demonstrating the effectiveness of scapular protraction at improving the function of the upper extremity.

Hence, when treating the upper extremity of a patient, or a normal, we should consider that the scapula should be adjusted to its ideal position. The subjects of this study were normal adults, hence there are some difficulties in generalizing the results to patients. Therefore, further study of the effects of active scapular protraction on the function of the upper extremity should be conducted to provide a clinical basis for the treatment of patients.

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