

The Effect of Push-up Plus Exercise with Visual Biofeedback on The Activity of Shoulder Stabilizer Muscles for Winged Scapula

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Abstract. [Purpose] The purpose of this study was to evaluate the effects of push-up plus exercise with visual biofeedback on the activity of the shoulder stabilizer muscles in individuals with winged scapula. [Subjects] This study was conducted with two groups: a visual biofeedback push-up plus exercise group (n=6) and a control push-up plus exercise group (n=6). [Methods] Muscular activity of the shoulder stabilizer muscles of both groups were measured by electromyogram (EMG), both before and after the exercise. [Results] The control group showed a significant difference pre-and post-exercise in the activity of the serratus anterior muscle during elbow extension, but differences in other muscles were insignificant. The visual feedback group showed significant differences pre-and post-exercise in activity of the upper and lower trapezius during elbow extension, in the serratus anterior muscle during elbow flexion and extension and scapula protraction, and in the pectoralis major muscle during elbow flexion. [Conclusion] Providing visual biofeedback during push-up plus exercise made the exercise more effective for winged scapula.

Key words: Push-up plus exercise, Visual biofeedback, Electromyogram

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INTRODUCTION

Therapeutic exercise programs for prevention and rehabilitation of shoulder joint malfunction should consider the balance among the scapula stabilizer muscles. For this reason, many recent therapeutic exercises for arms use closed-chain exercise¹⁾. Many studies have used push-up plus exercise in exercise chain programs for arms to properly reinforce the fibers of the lower trapezius and serratus anterior muscles. Push-up plus exercise aims to protract the scapula as much as possible during the last step of the traditional push-up

exercise²⁾. However, because the scapula is at the back of the body, it is difficult to control its movement. In a clinical setting, to improve the patient's control of the efferent contraction of the serratus anterior muscle, the therapist provides information on the position and control of the scapula through oral direction and stimulation. However, it is difficult for the patient to receive accurate information. Many studies therefore use biofeedback devices to improve body control ability. Biofeedback provides information about the muscles and their movements in real time. It has been known to be effective in eliciting proper

muscular contraction, maintaining body alignment, and normal movements³⁾. This study provided subjects with information on the position of the scapula through biofeedback from the efferent contraction of muscles using video cameras and computer monitors.

This study aimed to investigate the effects of visual biofeedback on individuals with winged scapula by comparing the activity of the shoulder stabilizer muscles (upper and lower trapezius muscles, serratus anterior muscle, pectoralis major muscle⁶⁾ between push-up plus exercises with and without visual biofeedback.

SUBJECTS AND METHODS

The subjects were 12 college students with winged scapula whose medial border was 1.5 cm or more apart, and for whom both medial borders became 3 cm or more apart in the start position of the push-up exercise, who had no limitations in daily movements, and who had not performed serratus anterior muscle reinforcement exercises during the previous six months⁴⁾. We gave them sufficient explanation about the test process and received written consent from each expressing voluntary participation.

The experimental group always watched their movements on a computer screen during their push-up plus exercise while concentrating on their scapulas, whereas the control group performed the push-up plus exercise without assistance⁵⁾. The visual biofeedback device used a camera and a PC monitor to provide visual information about scapula movements in the push-up position. A camera behind the subjects captured their scapula movements, which they could watch on the PC screen.

The subjects performed the exercise three times a week for four weeks: 3 cycles of 3 repetitions during the first week, 4 cycles of 5 repetitions during the second week, 5 cycles of 8 repetitions during the third week, and 6 cycles of 10 repetitions during the fourth and final week. Measurements were done before and after each exercise during the four weeks. The backward deviation of the medial border of the scapula was measured in a standing position and in the starting position for the push-up plus exercise, using two rulers: a horizontal ruler placed across both scapulas and a vertical ruler fixed to the spinous process of the thoracic vertebra

in the center of the scapula. To ensure accurate data collection, the sites for electromyogram (EMG) measurements were shaved with a razor, sandpapered to remove keratin, and wiped with alcohol on cotton.

The recording electrodes were Noraxon dual electrodes, 4 cm × 2.2 cm in size, with a 2 cm conducting zone, and the electrode pairs were spaced 2 cm apart. The ground electrodes were attached to the skin fold on the dominant side. The activity of each muscle was measured three times during maximal voluntary isometric contraction (MVIC) in the manual muscle test (MMT) position. The average EMG signal level for the middle three seconds of five seconds of data, that excluding the first and last seconds, was taken as 100% MVIC. The activity of each muscle was measured three times at three intervals: elbow flexion (EF) when the elbow joint was flexed at 90 degrees, elbow extension (EE) when the elbow joint was fully extended, and scapula protraction (SP). The average EMG signal level for the middle three seconds of the five seconds was determined.

Paired t-tests were conducted for the measurement data using SPSS for Windows (version 12.0) to determine the changes in muscular activity between pre and post exercise in the experimental and control groups, at the statistical significance level of 0.05.

RESULTS

The research subjects in this study included twelve participants between 19 and 28 years old, with an average age of 22.2 ± 1.8 (mean \pm SD). Their average height was 167.5 ± 6.1 cm, their average weight was 57.6 ± 6.8 kg, their average deviation of the medial border of the scapula when standing was 2.2 ± 0.5 cm, and their average deviation of the medial border of the scapula in the push-up position was 3.6 ± 0.7 cm. There were 6 men and 6 women, in equal proportions. The chi-squared tests for gender, age, height, weight, deviation of the medial border of the scapula when standing, and deviation of the medial border in the push-up position revealed no significant differences between the experimental and control groups.

For the control group, as shown in Table 1, the activity of the serratus anterior during elbow extension showed a significant difference between pre and post exercise ($p < 0.05$), but the differences

Table 1. Comparison of shoulder muscle activity in the control group and the experimental group(% MVIC)

		Control Group		Experimental group	
		Pre	Post	Pre	Post
UT	EF	36.82 ± 26.93	31.44 ± 25.46	EF	36.61 ± 24.54
	EE	10.96 ± 5.95	10.11 ± 5.13	EE*	11.83 ± 3.54
	SP	23.35 ± 20.61	18.11 ± 12.58	SP	22.03 ± 12.25
LT	EF	16.60 ± 8.61	13.19 ± 4.36	EF	18.66 ± 9.62
	EE	11.09 ± 11.90	10.40 ± 10.15	EE*	15.02 ± 9.43
	SP	8.43 ± 3.78	11.49 ± 9.32	SP	8.06 ± 3.43
SA	EF	18.56 ± 14.80	29.50 ± 16.24	EF*	24.07 ± 18.25
	EE*	32.74 ± 8.98	34.73 ± 10.35	EE*	28.58 ± 18.75
	SP	37.87 ± 18.42	38.78 ± 20.54	SP*	50.49 ± 45.33
PM	EF	35.91 ± 26.06	39.48 ± 22.64	EF*	32.05 ± 8.41
	EE	46.05 ± 27.06	36.76 ± 34.83	EE	34.48 ± 13.47
	SP	11.58 ± 5.87	8.76 ± 3.12	SP	20.78 ± 9.23

UT: upper trapezius, LT: lower trapezius, SA: serratus anterior, PM: pectoralis major, EF: elbow flexion, EE: elbow extension, SP: shoulder protraction. * p<0.05.

in the other muscles were not significant ($p>0.05$). For the experimental group, as shown in Table 1, significant differences pre and post exercise ($p<0.05$) were shown in the upper and lower trapezius during elbow extension, in the pectoralis major during elbow flexion, and in the serratus anterior during elbow flexion, elbow extension, and scapula protraction.

For the post test, as shown in Table 2, the activation of the serratus anterior during elbow extension and shoulder protraction showed a significant difference between the experimental group and the control group ($p<0.05$). And as shown in Table 2, the activation of the pectoralis major during shoulder protraction showed a significant difference between the experimental group and the control group ($p<0.05$).

DISCUSSION

This study investigated the change in muscular activity after exercise. In both experimental and control groups the activity of the serratus anterior increased while that of the upper trapezius decreased. The reason for this is that the upper trapezius of individuals with winged scapula shows excessive activity to compensate for the weakened serratus anterior due to an imbalance between these two muscles. The push-up plus exercise reinforced the weakened serratus anterior and so decreased the

Table 2. Comparison of shoulder muscle activity between the control group and the experimental group at post-exercise (% MVIC)

		C Group	E Group
UT	EF	31.44 ± 25.46	22.78 ± 15.82
	EE	10.11 ± 5.13	8.08 ± 3.73
	SP	18.12 ± 12.58	20.34 ± 10.55
LT	EF	13.19 ± 4.36	21.70 ± 11.46
	EE	10.40 ± 10.15	9.43 ± 6.14
	SP	11.49 ± 9.32	7.54 ± 2.34
SA	EF	29.50 ± 16.24	55.28 ± 27.48
	EE*	34.73 ± 10.35	58.53 ± 23.00
	SP*	40.94 ± 19.37	82.04 ± 49.83
PM	EF	39.48 ± 22.64	23.53 ± 9.70
	EE	36.76 ± 34.83	25.33 ± 9.10
	SP*	8.76 ± 3.12	17.33 ± 7.70

* $p<0.05$.

muscular activity of the upper trapezius¹⁾.

This study examined the distribution ratio of muscular activity during the push-up plus exercise for both the experimental and control groups. The activity of the serratus anterior muscle was higher in both groups, but greater in the experimental group. These changes in muscular activity in the experimental group were due firstly to the information on scapula movement provided to

subjects by visual biofeedback, which affected their ability to control the muscle⁶⁾. Real-time visual biofeedback led subjects to continuously increase the efferent contraction capacity of the serratus anterior to prevent their scapulas from winging³⁾. The continuous efferent contraction control maintained the optimum length-tension relationship of the muscles, resulting in increased activity of the serratus anterior muscle when visual biofeedback was provided. Secondly, the activity of the upper trapezius muscle was decreased when visual biofeedback was provided.

Ludewig's study explained that the activity of the serratus anterior muscle increases by more than 20% of maximal voluntary contraction because the upward rotation of the scapula is maintained during exercise¹⁾. However, Hardwick's study reported that the differences in activity of the serratus anterior muscle during the wall slide with brachial elevation at 90 degrees, the plus phase of a wall push-up plus, and the scapular plane shoulder elevation showed no statistical significance⁷⁾. This appears to be due to the fact that the subjects did not perform the push-up plus exercise against gravity, as was done in this study.

During the exercise, the upper trapezius together with the serratus anterior rotate the scapula downward through efferent contraction. Under such circumstances a decrease in the efferent contraction control of the serratus anterior would lead to stronger scapula retraction due to decreased scapula protraction and excessive action of the upper trapezius, resulting in a winged scapula⁸⁾. Therefore, providing information on the position of the scapula through visual biofeedback improved the efferent contraction control ability of the serratus anterior muscle, increasing activity of the serratus anterior muscle.

The push-up plus exercise appears to be an appropriate exercise for patients with winged scapula because it decreased the activity of the

upper trapezius while increasing the activity of the serratus anterior in both the exercise and control groups. In particular, serratus anterior activity increased more in the experimental group than in the control group. Therefore, providing visual biofeedback to individuals with winged scapula during the push-up plus exercise is a more effective exercise technique.

REFERENCES

- 1) Ludewig PM, Hoff MS, Osowski EE, et al: Relative balance of serratus anterior and upper trapezius muscle activity during push-up exercise. *Am J Sport Med*, 2004, 32(2): 484-493.
- 2) Decker MJ, Hintenneister RA, Faber KJ, et al: Serratus anterior muscle activity during selected rehabilitation exercise. *Am J Sport Med*, 1999, 27(6): 784-791.
- 3) Ng GYF, Zhang AQ, Li CK: Biofeedback exercise improved the EMG activity ratio of the medial and lateral vasti muscles in subjects with patellofemoral pain syndrome. *J Electromyogr Kinesiol*, 2008, 18(1): 128-133.
- 4) Park JS, Jeon HS, Kwon OY: A comparison of the shoulder stabilizer muscle activities during push-up plus between persons with and without winging scapular. *Journal of Korean Academy of University Trained Physical Therapists*, 2007, 14(2): 44-52.
- 5) Lear LJ, Gross MT: An electromyographical analysis of the scapular stabilizing synergists during a push-up progression. *J Orthop Sports Phys Ther*, 1998, 28(3): 146-157.
- 6) Dursun N, Dursun E, Kilic Z: Electromyographic biofeedback controlled exercise versus conservative care for patellofemoral pain syndrome. *Arch Phys Med Rehabil*, 2001, 82(12): 1692-1695.
- 7) Hardwick DH, Beebe JA, McDonnell MK, et al: A comparison of serratus anterior muscle activation during a wall slide exercise and other traditional exercises. *J Orthop Sports Phys Ther*, 2006, 36(12): 903-910.
- 8) Cools AM, Witvrouw EE, Declercq GA, et al: Scapular muscle recruitment pattern: Trapezius muscle latency with and without impingement symptoms. *Am J Sport Med*, 2003, 31(4): 542-549.