Original Article

THE EFFECTS OF SCAPULAR STABILIZATION EXERCISES ACCOMPANIED BY SPINE STABILIZATION EXERCISES USING AN UNSTABLE SURFACE ON MUSCLE ACTIVITIES AND WINGING DISTANCE FOR MEN AND WOMEN WITH SCAPULAR WINGING

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Abstract

Background: Scapular kinematics are important indicators of dyskinesis, often suggesting underlying shoulder pathology, but the influence of sex is unknown. The aim of this study was to compare the difference in muscle activity and winging distance between men and women with scapular winging in scapular stabilization exercises accompanied by spine stabilization exercises using an unstable surface.

Methods: This study included 30 subjects with scapular winging. The experimental group performed scapular stabilization exercises accompanied by spine stabilization exercises on an unstable surface, while the control group performed scapular stabilization exercises. Each group performed exercises for 40 minutes three times a week for four weeks. To investigate the intervention effects, the activity of the muscles around the shoulder and the winging distance were measured.

Results: The serratus anterior and lower trapezius activation levels in the experimental group were significantly greater in men than in women. The activation of the serratus anterior in the experimental group was significantly increased compared to the control group. The activation of the pectoralis major was significantly decreased in the experimental group compared to the control group.

Conclusions: As a result, scapular stabilization exercises accompanied by spine stabilization exercises on an unstable surface a greater effect seen than treatment with scapular stabilization exercise alone; thus, this combination treatment can be recommended as an effective exercise. The effect of the exercise on men in this experiment was greater than that on women; thus, the exercise methods can be recommended for use in men's health exercise programs.

Keywords: Scapular winging; Electromyography; Serratus anterior; Winging distance; Scapular stabilization exercise; Spine stabilization exercise.

1. Introduction

It is well known that biological differences exist between men and women and that those differences could play a major role in exposure to risk factors for work-related musculoskeletal disorders [1]. Few studies have assessed the influence of individual factors on the level and coordination of muscle activity exerted. Among individual factors, sex needs to be considered for clinical and biomechanical reasons. Epidemiological studies have shown that more women than men live with shoulder pain [2]. Characteristics of male and female anatomy, including segment masses and anthropometry, muscle activation patterns, and quantity of skeletal muscle mass, may contribute to different scapular movement patterns by sex when performing arm-raising tasks [3]. Scapular kinematics is an important indicator of dyskinesia and usually suggests underlying shoulder pathology, but the effect of sex is unclear.

Scapular winging, defined as a prominence of the entire medial border of the scapula, is mainly caused by insufficient activity of the serratus anterior muscle [4]. This muscle is associated with a normal scapulohumeral rhythm, scapular alignment, and functional movement and is one of the prime muscles used to rotate the scapula upward [5]. The serratus anterior contributes to scapular motion, such as posterior tilt, protraction, and upward rotation, in its role as a primary site of movement [6]. Weakness of this muscle is a major cause of glenohumeral joint impingement, scapular winging, and shoulder pain [4].

Additionally, excess upper trapezius activation or reduced activation of the lower trapezius and serratus anterior may contribute to pain, scapular dysfunction, and abnormal scapular motion and attempts to compensate for the weak serratus anterior [7]. Compensatory recruitment of the pectoralis major occurs in individuals with scapular winging during scapular protraction due to the weakened serratus anterior. This compensatory activation of the pectoralis major can result in scapulothoracic and glenohumeral joint pathology, such as decreased volume of the subacromial space, increased compressive force to the glenoid, and subacromial impingement [8]. Therefore, therapeutic exercise to restore the function of the scapular stabilizing muscle is an important part of the rehabilitation process [7].

Exercise may be an effective option for improving scapular muscle performance and correcting scapular position to reduce pain and other symptoms [9]. Many techniques and exercises have been created and modified to selectively activate the serratus anterior, such as tubing bandages, open and closed kinetic chain exercises, and the use of visual electromyography (EMG) biofeedback [8]. Several studies have shown that scapular stabilization exercise programs improve the position of the scapula and scapular muscle performance and control [10–12]. This method of improving winged scapular posture has been studied by many researchers. A previous study reported that the activation of trunk muscles may affect the scapular muscle activity by myofascial connections [7]. Therefore, the facilitation of the abdominal muscles is recommended to restore force couples of scapular muscle [7]. To further increase muscle activity during exercise, clinicians commonly instruct patients to perform the exercises on an unstable base of support. Biscarini et al. [13] reported that spine stabilization exercises performed on an unstable surface increased the activity of muscles around the shoulder.

Scapular stabilization exercises can enhance the stability and strength of the muscles surrounding the scapula [10–12]. Spine stabilization exercises can strengthen the serratus anterior and trapezius muscles while exercising the abdominal and back muscles [13, 14]. The combination of these two types of exercises can further improve winging scapular.

Therefore, this study aimed to examine the effect of scapular stabilization exercises accompanied by spine stabilization exercises using an unstable surface on muscle activity and winging distance for men and women with winging scapular.

2. Methods

2.1 Participants

This study included 30 subjects with scapular winging. The subjects were divided into an experimental group and a control group. Before participating, all subjects read and signed university-approved human subject consent forms. The study was approved by the Institutional Review Board of Daegu University (IRB No. 1040621-202107-HR-021). The inclusion criteria were as follows: winging scapular was determined if the distance between the medial edge of the scapula and the chest wall was more than 3 cm. The exclusion criteria were as follows: history of shoulder, back, or abdominal injury or surgery [7].

There were 7 males and 8 females in the experimental group. The average age of the subjects was 24.40±2.29 years old. The average height, weight, and BMI were 168.60±7.15㎝, 60.53±12.10㎏, and 21.12±2.73㎏/㎡, respectively. There were 7 males and 8 females in the control group. The average age of the subjects was 24.13±2.61 years old. The average height, weight, and BMI were 170.80±9.99㎝, 65.00±12.55㎏, and 22.16±3.15 ㎏/㎡, respectively. There was no significant difference between the two groups in terms of the general characteristics of the subjects studied.

2.2 Procedures

This study included 30 subjects with scapular winging. The subjects were randomly divided into an experimental group and a control group (15 participants in each group). The experimental group performed scapular stabilization exercises for 20 minutes and spine stabilization exercises for 20 minutes three times a week for four weeks. The control group performed scapular stabilization exercises for 40 minutes three times a week for four weeks. After the intervention period, the participants' muscle activity and winging distance were measured again.

2.3 Assessment

An electronic digital caliper (Orientools Industrial Co., Ltd., China) was used to measure the winging distance. Air cushion balance was used for the experimental group when performing the spine stabilization exercises. The EMG muscle activity measurements were performed while the participants held a dumbbell with their dominant hand and flexed their arms at 120°. The measurement method was done as described in a previous study. When the angle is set to 120°, the activity of the scapular muscle can be displayed [15]. To collect the muscle activity of the serratus anterior, upper trapezius, lower trapezius, and pectoralis major, the conduction and signal processing materials used in the study included the Telemyo system DTS and Myoresearch XP 1.08 software (Noraxon Inc., AZ, USA). The skin to which the electrodes were connected was shaved and wiped with disposable medical alcohol test paper to ensure that the skin was clean and smooth [4]. For the serratus anterior, the electrodes were placed at the lower angle of the scapula at a distance of 2 cm below the scapula. For the upper trapezius, the electrodes were placed 2 cm apart on the upper back halfway between the C7 spinous process and the acromion process. For the lower trapezius, the electrodes were placed 2 cm apart on an oblique angle, 5 cm down from the scapular spine and outside the medial border of the scapula. For the pectoralis major, the electrodes were placed on the chest wall at an oblique angle toward and approximately 2 cm below the clavicle, just medially to the axillary fold [16]. Two active electrodes were attached nearly 2 cm apart in the direction of the muscle fibers. Each pair of electrodes was arranged parallel to the underlying myofiber line. Electromyographic data was sampled at 1,000 Hz. The EMG signals were amplified and band-pass was filtered at 20–400 Hz. The root-mean-square (RMS) values of the EMG data were calculated to quantify the amplitude of the EMG signals.

To normalize EMG activity, the maximal voluntary isometric contraction (MVIC) activity of the tested muscles was measured. The MVIC value was calculated as the average RMS of the three measurements. The reference contraction data for 5 seconds was recorded. The participants performed three maximum voluntary isometric contraction tests on each muscle at the manual muscle test position. The middle 3 seconds of the 5-second contraction were used for data analysis. The average EMG activity was expressed as a percentage of the MVIC value. The mean root mean square of three trials for each muscle was calculated. A 3-min rest period was provided between trials [4]. The measurement method used has been described in a previous study [17]. For the upper trapezius, the subject performed 90 shoulder abductions with manual resistance to the head after the neck was first side-flexed to the same side, rotated to the other side, and extended in the sitting position without back support. For the lower trapezius, the subject was tested in the prone position. The subject's arm was placed diagonally overhead, in line with the lower fibers of the trapezius muscle during external rotation while applying resistance at the distal elbow joint. For the serratus anterior, the subject was seated with the shoulder rotated internally and abducted at 125° in the plane of the scapula. The researchers applied manual resistance to the proximal elbow of the subjects. For the pectoralis major, the shoulder was horizontally adducted to 90°, and resistance was applied to the upper part of the elbow with the subject in the standing position.

2.4 Intervention

2.4.1 Scapular stabilization exercises

The scapular stabilization exercises consisted of two two-week stages(Table 1). The first stage included upper trapezius, pectoralis major, and teres major stretching, wall slides, towel slides, supine serratus punches, scapular retraction, and Y formation. The second stage included upper trapezius, pectoralis major, and teres major stretching, side-lying wiper exercises, knee push-up plus exercises, forward leaning, chest presses, and dynamic hugs [18–20]. The stretching exercises were performed three times for 30 seconds each, and the other exercises were performed in three sets of 20 repetitions. All exercises were performed on both the left and right sides. Thirty-second rest intervals were allowed between the exercises.

Table 1. Scapular stabilization exercises procedures.

Exercises	Procedures
Trapezius stretching	Sitting up straight, slowly tilt your head to the side until you feel a gentle stretch along the side of your neck and shoulder.
Teres major stretching	Hold your left elbow with your right hand. Gently pull your elbow behind your head to feel a stretch in the shoulder or the back of the upper arm.
Pectoralis major stretching	Place your arm to the wall at 90° with your elbow bent. Lean forward to stretch.
Wall slide	Place your elbows against the wall. Your arms should be slightly apart with your thumbs facing out. Slide your arms up the wall while maintaining full contact with it using your forearms
Towel slide	Standing next to a table, perform the anterior slide using a towel. Return to the initial position and perform an arm extension with scapular retraction.
Supine serratus punches	Put your arm out at 90° and make a fist. Keeping your elbow locked out and straight, bring your shoulder up.
Scapular retraction	Fully extend your elbows in the prone position with your thumbs up and your arms raised. Abduct your shoulder at 120°.
Y formation	With your elbows fully extended in the prone position, slowly lift your arms off the floor, bringing them into the "y" formation.

Side-lying wiper exercise	Lay in a side-lying position with your extremity flexed and internally rotated at 90° and the elbow flexed at 90°. Support the distal humerus of the dominant arm with the palm of the opposite hand. From the starting position, move to a position of full lateral rotation.
Knee push-up plus	Get down on all fours with your spine making a neutral curve and your shoulder blades sinking in. Extend your shoulders to the front and squeeze your shoulder blades to bring yourself up. Keeping your arms extended, let gravity bring you back down to the starting position.
Forward learning	Prop yourself onto a ball with your elbows directly under your shoulders. Keep your back straight and body off the floor. Roll the ball back and forth.
Chest press	Wrap the band around your shoulder blades and bring the ends underneath your arms. Grasp the ends of the band at shoulder level. Extend your arms forward, straightening your elbows. Hold, and slowly return.
Dynamic hug	Wrap the band around your upper back and hold each end in your hands. Abduct your shoulders at about 60° and bend your elbows at about 45°. Keeping your shoulders elevated, push your arms forward and inward, then slowly return.

2.4.2 Spine stabilization exercises

The spine stabilization exercises also consisted of two two-week stages (Table 2). The first stage included abdominal bracing, alternate lower- extremity raising, bridge exercises, arm lifting, backward leg lifting (each performed three times for 10 seconds), hip abduction with knee flexion, and side-lying hip abduction (each performed in three sets of 10 repetitions). The second stage included knee flexor stretching, leg lifting, bridges with one-leg lifting, alternated arm and leg lifting (each performed three times for 10 seconds), hip abduction with knee extension, dead- bug exercises, and side-lying hip external rotation (each performed in three sets of 10 repetitions) [21]. All exercises were performed on both the left and right sides. Thirty-second rest intervals were allowed between the exercises.

Table 2. Spine stabilization exercises procedures

Exercises	Procedures
Abdominal bracing	Lie on your back with your knees bent and your feet flat on the floor. Tighten your abdomen and buttocks, pressing your lower back onto the floor.
Alternate rising lower extremity	Lie on your back with your knees bent. Tighten your stomach muscles and slowly raise the locked leg.
Hip abduction with knee flexion	Lie on your back with your knees bent. Pull one knee to the side, then bring your knees back together.
Bridge	Lie down on your back. Bend your legs and bring your feet in toward your bottom. Pushing through your feet, slowly lift your bottom.

Hip abduction	Lie on your right side. Lift your left leg as far as you can, keeping it straight. Put your legs back together.
Arm lifting	Get down on all fours. Raise one arm out in front of you while keeping your neck in a neutral position.
Backwards leg lifting	Get down on all fours. Raise one leg behind you while keeping your neck in a neutral position.
Knee flexors stretching	Bring your knee to your chest. Hold your knee tightly to your chest with both arms, then push your knee out against the resistance of your arms.
Leg lifting	From a supine position, raise your legs at 90°. Straighten one leg alternately.
Hip abduction with knee extension	From a supine position, raise your legs at 90°. Straighten one leg and abduct alternately.
Dead bug	Lift your hands so that your elbows are above your shoulders. Lift your legs so that your knees are directly over your hips. Slowly lower your right arm and left leg until they are just above the floor.
Bridge with one leg lifting	Lie down on your back and bend your legs. Lift one foot, extending the leg fully, and raise your hips, tightening your abdominals and buttock muscles to support the lift.
Hip external rotation	Lie on your side. Bend your knees at 90°. Bring your heels together in line with your bottom. Without rotating your back or pelvis, abduct your leg to open your knees as far as you can.
Alternated arm and leg lifting	Get down on all fours. Keep your knee locked and lift your leg from the floor, lifting your opposite arm at the same time.

3. Statistical analysis

Data normality was assessed using the Kolmogorov–Smirnov test. The paired t-test was used to evaluate differences before and after the intervention in each group and sex, and the independent t-test was used to determine differences between the two groups and between sex. The statistical analysis was performed using SPSS 20.0 for Windows. The level of statistical significance was set at $\alpha = .05$.

4. Results

In the experimental group and control group, there were statistically significant differences before and after the interventions in men and women. Serratus anterior and lower trapezius activation significantly increased, while upper trapezius, pectoralis major activation, and winging distance significantly decreased after the interventions for men and women ($p < .05$). After the interventions, the serratus anterior and lower trapezius activation levels in the experimental group were significantly greater in men than in women ($p < .05$). Conversely, there was no statistically significant difference in upper trapezius, pectoralis major activation, or winging distance between men and women ($p > .05$) (Table 3). In addition, there were statistically significant differences after the interventions between the experimental group and the control group. The activation of the serratus anterior in the experimental group was more significantly increased than in the control group. Furthermore, the activation of the pectoralis major was significant decreased in the experimental group compared to the control group (p < .05) (Table 4).

Table 3. Comparison for EMG activation of muscle and winging distance for men and women within the groups (N = 30).

	Group	Sex	Pre	Post	Different Value	t	*p*	Between Sex (t/p)
SA (%MVIC)	EG	Male	29.08±9.52$^{\alpha}$	47.78±10.50	18.70±5.50	-8.995	.000*	-2.192/.022*
		Female	24.91±8.91	38.55±9.08	13.64±2.65	-13.598	.000*	
	CG	Male	31.17±14.07	38.67±15.43	7.50±2.47	-8.015	.000*	.604/.758
		Female	23.83±10.90	32.18±11.24	8.35±2.93	-8.063	.000*	
LT (%MVIC)	EG	Male	19.86±7.68	28.59±8.64	8.86±5.31	-4.254	.036*	*.450/.048**
		Female	22.73±4.33	30.57±5.21	7.84±2.81	-7.371	.018*	
	CG	Male	17.10±7.25	22.33±8.18	5.22±3.00	-4.917	.001*	.983/.672
		Female	23.50±8.88	27.34±8.52	3.84±2.35	-4.314	.000*	
UT (%MVIC)	EG	Male	37.60±18.71	28.00±16.26	9.60±9.72	2.612	.040*	-.494/.269
		Female	30.70±12.08	22.99±9.67	7.71±4.47	4.877	.002*	
	CG	Male	29.54±13.49	23.82±12.05	5.71±3.62	4.172	.006*	.062/.880
		Female	25.05±6.52	19.22±5.41	5.83±3.39	4.859	.002*	
PM (%MVIC)	EG	Male	13.81±6.48	10.76±5.66	3.10±2.03	3.973	.007*	-.306/.500
		Female	9.54±4.72	6.85±3.17	2.69±2.48	3.059	.018*	
	CG	Male	10.63±3.45	7.45±3.09	3.18±1.56	5.407	.002*	-3.535/.050
		Female	5.48±4.59	4.51±4.14	.98±.79	3.497	.010*	
WD (mm)	EG	Male	33.26±0.93	30.41±0.94	2.85±0.28	29.202	.000*	.323/.298
		Female	34.19±1.10	31.38±1.19	2.81±0.19	39.570	.000*	
	CG	Male	33.54±1.73	31.75±1.52	1.80±0.36	13.924	.000*	1.301/.938
		Female	33.10±1.12	31.54±1.07	1.55±0.35	11.659	.000*	

SA: serratus anterior; LT: lower trapezius; UT: upper trapezius; PM: pectoralis major; WD: winging distance; EG: experimental group; CG: control group; $^{\alpha}$mean±standard deviation; $^{*}p < .05$.

Table 4. Comparison of different values on EMG activation of muscle and winging distance for men and women between the groups (N = 30).

	Sex	EG	CG	t	*p*
SA	Male	18.70±5.50$^{\alpha}$	7.50±2.47	4.915	.018*
(%MVIC	Female	13.64±2.65	8.35±2.93	3.644	.671
LT	Male	8.86±5.31	5.22±3.00	1.664	.070
(%MVIC	Female	7.84±2.81	3.84±2.35	2.888	.854
UT	Male	9.60±9.72	5.72±3.62	.990	.169
(%MVIC	Female	7.71±4.74	5.83±3.39	.949	.276
PM	Male	3.05±2.03	3.18±1.56	-.134	.465
(%MVIC	Female	3.05±2.45	0.98±0.79	1.858	.007*
WD	Male	2.85±0.28	1.80±0.36	6.514	.439
(%MVIC	Female	2.81±0.19	1.55±0.35	8.314	.116

SA: serratus anterior; LT: lower trapezius; UT: upper trapezius; PM: pectoralis major; WD: winging distance; EG: experimental group; CG: control group; $^{\alpha}$mean±standard deviation; $^{*}p < .05$.

5. Discussion

Scapular kinematics are important indicators of dyskinesis, often suggesting underlying shoulder pathology, but the influence of sex is unknown. The aim of this study was to compare the difference in muscle activity and winging distance between men and women with scapular winging in scapular stabilization exercises accompanied by spine stabilization exercises using an unstable surface.

Scapular winging is mainly caused by insufficient serratus anterior activity. This causes over activation of the upper trapezius and pectoralis major to compensate for a weak serratus anterior during shoulder flexion. To measure differences in muscle activity before and after the experiment, a wireless EMG system was used in this study. The EMG measurements were performed while each participant held a dumbbell with their dominant hand and flexed their arm at 120°. When the angle is set to 120°, the activity of the trapezius, pectoralis major, and especially serratus anterior can be displayed [15]. Thus, an arm flexion of 120° can be used as a measurement posture. Many studies have shown that the instability created by an unstable surface increases the demands on the neuromuscular system, thereby increasing muscle activity and improving the stability of the trunk and proximal joints [22, 23]. Biscarini et al. [13] found that spine stabilization exercises on an unstable surface yielded significantly higher EMG-measured serratus anterior, trapezius, and anterolateral abdominal muscle activity than the same exercises executed on a stable ground. Therefore, the goal of the exercise program was to increase serratus anterior and lower trapezius.

In the experimental group and control group, there were statistically significant differences before and after the interventions in men and women. For men and women, the serratus anterior and lower trapezius activation significantly increased, while the upper trapezius, pectoralis major activation, and winging distance significantly decreased after the interventions. Scapular stabilization exercises can enhance the stability and strength of the muscles surrounding the scapula [10–12] and prevent other muscle compensation due to serratus anterior weakness [24, 25]. Spine stabilization can increase the activities of the trunk and lower limbs muscles; these muscle activities may affect the scapular muscle activity by myofascial connections [13, 14]. Therefore, both the experimental group and the control group obviously increased the muscle activity of the serratus anterior and lower trapezius, as well as reduced the compensatory effect of the upper trapezius and pectoralis major during exercise. The winging distance was also reduced by the stabilization of the muscles around the scapula.

In this study, the serratus anterior and lower trapezius activation levels in the experimental group were significantly greater in men than in women. The experimental group performed spine stabilization exercises along with scapular stabilization exercises. Many actions in these closed kinetic-chain exercises can strengthen trunk muscles. It is well known that structural and biological differences exist between men and women. Sex hormones play a pivotal role in the physiologic differences between men and women. Testosterone affects men with a significant increase in bone and muscle growth, conferring a natural athletic advantage [26]. Manshadi et al. [27] found that men activate abdominal muscles more than women, demonstrating the sex dependency of abdominal muscle-activation strategies. Trunk stabilization is necessary to maintain effective load transfer to the extremities, coordinate distal and proximal movements, and regulate force or energy during integrated power-chain activity [28]. Trunk muscles affect the scapular muscle activity by myofascial connections [7]. Previous studies have shown that prior to upper limb flexion, strengthening the abdominal muscles is requisite for the restoration of the scapular force couple [29]. Therefore, when the arm is flexed, the activity of the serratus anterior and lower trapezius muscles in men was greater than that in women. In addition, Anders et al. [30] found that shoulder muscle activation in men could be described as being more precise than in women, which is consistent with our study.

In this study, there were statistically significant differences after the interventions between the experimental group and the control group. Compared with the control group, the experimental group activated more serratus anterior muscle and reduced the compensatory effect of the pectoralis major muscle. The experimental group in this study performed spine stabilization exercises based on the scapular stabilization exercises, which can enhance the stability and strength of the muscles surrounding the scapula [10–12]. Spine stabilization can increase the muscle activities of the trunk and lower limbs; the activities of these muscles may affect the scapular muscle activity by myofascial connections [7]. The shoulder joint has a large range of motion, and coordinated control of the shoulder muscles depends on the degree of scapular stability, which is based on the efforts of the trunk to stabilize during movement [31]. Previous studies have shown that prior to upper limb flexion, abdominal muscle contraction and extension exercises to strengthen the abdominal muscles are requisite for the restoration of the scapular force couple [29]. Because the experimental group not only strengthened the scapular muscles through scapular stabilization exercises but also activated the scapular muscles through spinal stabilization exercises, the experimental group had a higher effect on serratus anterior muscle activity. The activity of the anterior serratus muscle in the experimental group increased compared with that in the control group, which further reduced the compensatory activity of the pectoralis major muscle.

Certain limitations of this study should be noted. First, the experimental period was relatively short. Second, aside from the exercise time in the laboratory, the leisure sports activities of the subjects might have affected the experimental results; other exercise times could not be effectively controlled. Third, the study population included only students, not other professional groups. In the future, we hope to control other variables more effectively and increase the experimental population and time.

Conclusion

The aim of this study was to compare the difference in muscle activity and winging distance between men and women with scapular winging in scapular stabilization exercises accompanied by spine stabilization exercises using an unstable surface. The serratus anterior and lower trapezius activation levels in the experimental group were significantly greater in men than in women. The activation of the serratus anterior in the experimental group was significantly increased compared to the control group. Furthermore, the activation of the pectoralis major was significant decreased in the experimental group compared to the control group. As a result, with scapular stabilization exercises accompanied by spine stabilization exercises on an unstable surface, a greater effect can be seen than with scapular stabilization exercise alone; thus, this combination exercise program can be recommended as effective. The exercise effect on men in this experiment was greater than that on women, and thereby the exercise methods could be emphasized in the context of men’s health.

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