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Research Article

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The Effect of Shoulder Stabilization Exercise and Core Stabilization Exercise on the Shoulder Height and Respiratory Function in Young Adults with Round Shoulder Posture

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| Abstract |

PURPOSE: The purpose of this study was to compare how the shoulder height and respiratory function are affected by applying shoulder stabilization exercises and core stabilization exercises that are effective for strengthening the trunk muscles and postural stability for adults with a round shoulder posture (RSP).

METHODS: The participants were 28 young adults with RSP. They were assigned randomly to two groups: shoulder stabilization exercise and core stabilization exercise. They performed the exercises for 30 minutes twice a week for four weeks. They measured the shoulder height and respiratory function before and after exercise.

RESULTS: No significant difference in shoulder height was found between the groups. A significant decrease in shoulder height was found in the shoulder stabilization exercise group after exercise. The core stabilization exercise group showed a significant decrease after exercise. In respiratory function, no significant difference was found between the groups. The forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1) were increased significantly in the shoulder stabilization exercise group before and after exercise. The FEV_1, FEV_1/FVC, and peak expiratory flow were significantly higher in the shoulder stabilization exercise group after exercise than in the core stabilization exercise group.

CONCLUSION: Shoulder stabilization exercise and core stabilization exercise improved the postural alignment and pulmonary function, and the exercises could be helpful in shoulder rehabilitation as well as the clinical part of the treatment of rounded shoulder posture.

Key Words: Core stabilization exercise, Respiratory function, Round shoulder posture, Shoulder height, Shoulder stabilization exercise

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Ⅰ. Introduction

A round shoulder posture (RSP) or forward shoulder posture (FSP) is defined as an increase in the distance between the inferior angle of the scapula and the spinous process of the vertebra. It is one of the common postural abnormalities in which the acromion moves anteriorly relative to the spinous process of the seventh cervical vertebra [1]. The RSP is a postural condition described as downward rotation, depression, anterior tilt, and medial rotation of the scapula [2] and is associated with poor postural habits, backpack carrying, repetitive overhead activities, computer use, mouth breathing, and long-term study time [1,3]. The cause of RSP is multifactorial, one of which is the shortening of the pectoralis minor muscle [4-6]. Shortening of the pectoralis minor muscle increases thoracic kyphosis, scapular position displacement [5,7], and shoulder diseases, such as shoulder impingement syndrome [7]. Many problems can occur if the head is not aligned with the vertical longitudinal axis of the body, such as in the RSP; the body malalignment, e.g., increased rounded shoulders and thoracic kyphosis, and additional damage, which is compensated for the altered position of the line of gravity, balance decrease [3], the spinal deformation and a change in the body center of gravity as compensation for the balance decrease, and increased lordosis of the cervical vertebrae due to a limited visual field [8]. The cervical and thoracic mobility changes, such as the RSP, impair normal respiratory mechanisms by reducing the diaphragm mobility [9], and respiratory values decrease as the forward shoulder posture increases [10].

Several methods, such as stretching and resistance exercise, a combination of stabilization and chin-tuck exercise, manual therapy, kinescoping, orthoses, and motor learning, are used to improve forward head and RSP (FHRSP) [11]. Shoulder stabilization exercises effectively recover from shoulder dysfunction [12], including stretching and muscle strengthening exercises [13]. Among the shoulder muscles, shortening of the pectoralis minor muscle is the only muscle of which relationship with scapular dyskinesis has been proved [14]. In addition, treatment of shortening of the pectoralis minor muscle among the shoulder muscles is essential for rehabilitating people with shoulder pathology and RSP [4]. In addition, shoulder stabilization exercises strengthen the scapular muscles [13], and the scapula plays an essential role in producing uniform and harmonious movements of the shoulder joint structure [1]. Therefore, changes in the normal position of the scapula and the function of the stabilizing muscles of the scapula can be important factors in developing abnormal biomechanics of the shoulder joint structure [15]. Scapular stabilization exercises can improve neck pain and posture by improving muscle activity and the quality of life [16]. Cervical stabilization exercises train the cervical deep stabilizing muscles and are increasingly used to improve coordination between the superficial and deep cervical muscles. These exercises ask patients to control their neutral alignment of the spine by activating and stabilizing muscles under various conditions [17], preventing cervical and shoulder pain, maximizing function, and avoiding additional injury [18]. Treating RSP can improve shoulder mechanics and reduce the risk of shoulder pathology or dysfunction [2], and shoulder stabilization exercises are widely used as a treatment for RSP [19,20].

Core stabilization can be defined as the ability to stabilize the posture and movement of the trunk above the pelvis with coordinated contraction of the abdominal muscles, the spinal and hip muscles, the diaphragm, the pelvic floor muscles, respectively, anteriorly, posteriorly, superiorly, and inferiorly [21]. Trunk stabilization exercise or core stabilization exercise has been defined as coactivating a specific muscle between the global and local muscles. Therefore, specific training that facilitates the function of these muscles is necessary for cooperative contraction [22]. Core stabilization exercises are recommended key exercise modalities to improve static and dynamic balance [21] and trunk stability in sports and rehabilitation [22].

In a previous study, shoulder stabilization exercises using a gym ball and pectoral muscle flexibility strengthening exercises using a foam roller were performed for eight weeks for young elite swimmers with RSP and forward head posture (FHP). A previous study reported that the forward head angle and forward shoulder translation before and after exercise decreased significantly in the exercise group [23]. An analysis of the respiratory function of adult men and women with an FHP showed that the forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1) were significantly lower in men and women in the FHP group than in the normal group. The activities of the sternocleidomastoid muscle and pectoralis minor of men in the FHP group, the muscle activities of the sternocleidomastoid muscle, pectoralis minor, and upper trapezius muscle of women in the FHP group were significantly lower than in the normal group [24]. In a previous study, complex exercises, including stretching exercises, cervical and shoulder stabilization exercises, and core stabilization exercises for adolescents with vertebral kyphosis were performed for 12 weeks [25]. The stabilization exercise group showed an improved forward head angle, Cobb's angle, and plantar pressure than the control group [25]. After performing cervical stabilization exercise including breathing exercise and including thoracic spine extension exercises respectively for four weeks for young adults with FHP, the FVC, FEV_1, peak expiratory flow (PEF), and FVC/vital capacity max (FVC/VCmax%) were significantly higher in the cervical stabilization exercise group with breathing exercises than thoracic extension exercises. Therefore, cervical stabilization exercise with breathing exercises improves the pulmonary function [26].

Although many studies have been conducted on postural alignment, muscle activation, and respiratory function in relation to the RSP, most studies applied shoulder stabilization exercises, such as stretching exercises, cervical and shoulder stabilization exercises, and shoulder muscle strengthening exercises only to the shoulder joint, or it has been applied as a complex exercise combined breathing or core stabilization exercises and shoulder stabilization exercises for adults with RSP. Therefore, the purpose of this study was to compare the effects of two types of stabilization exercises, which focus on different parts of the body, on shoulder height and respiratory function, by applying shoulder stabilization exercises that combine stretching exercises for the pectoralis minor related to the main causes of rounded shoulders and muscle strengthening exercises for cervical and shoulder joint muscles, and core stabilization exercises that are effective for strengthening the trunk muscles and postural stability for young adults with RSP.

Ⅱ. Methods

1. Participants

The subjects of this study were 28 young adults who satisfied the standard for RSP among students at N University located in Cheonan City, Republic of Korea. A priori sample size was calculated based on a previous study for strengthening exercise for RSP with an estimated effect size of 1.14, a two-tailed alpha level of .05, and a power of 80% according to independent T-test using G*Power V. 3.1.9.7 [27].

The inclusion criteria were RSP with a shoulder height of 2.54 cm (1 inch) or higher [6,28]. The exclusion criteria were those with musculoskeletal diseases, neurological diseases, cardiopulmonary diseases, and a history of surgery that could affect the experiment.

2. Apparatus

A body composition analyzer (Inbody720, Biospace Corp., Seoul) was used to identify the general characteristics of the participants. A digital vernier caliper (DC150-1, CAS, Seoul, Republic of Korea) was used to measure the shoulder height of the participant, and a spirometer (Pony Fx., COSMED, Rome, Italy) was used to measure the respiratory function of the participant.

3. Study Design

This study used a randomized and parallel group design. A person with RSP was selected by measuring the shoulder height and the general characteristics. Twenty-eight participants who fully understood the purpose and contents of the experiment and voluntarily signed the consent form participated in this study. The 28 subjects with RSP were assigned randomly to one of two groups: the shoulder stabilization exercise group and the core stabilization exercise group. The participants performed the shoulder and core stabilization exercises for 30 minutes twice a week for four weeks. Each group measured shoulder height and respiratory function before and after exercise.

1) Measurement methods

(1) Shoulder height measurement

A muscle length test was performed to confirm the shortening of the pectoralis minor muscle using digital vernier calipers ($ICC_{3,1}$ = .88–.93) [4,29]. When the pectoralis minor was normal length, the distance from the treatment table to the back of the acromion was 2.54 cm (1 inch), with the arms stretched side by side in a comfortable and relaxed supine position. The distance was longer than this distance when the pectoralis minor was shortened. The distance between the treatment table and the posterior border of the acromion was measured in the supine position to prevent humeral rotation and unwanted scapular movement [27,30]. The severity of the RSP increased as the distance increased [31].

(2) Respiratory function measurement

This study measured the FVC, FEV_1, FEV_1/FVC, and PEF using a spirometer to determine the respiratory function. The participants sat upright on a chair, placed their legs shoulder-width apart, flexed their hip joints 90°, and placed their feet vertically on the floor [32,33]. In addition, looking forward, they put the mouthpiece of the spirometer in their mouth and fixed their nose with a nose clip to prevent air leakage [34]. The respiratory function was measured by rapidly performing complete inhalation through a mouthpiece connected to a pulmonary function monitor under the supervision and instructions of the researcher. Exhalation was performed by exhaling as quickly, completely, and continuously as possible without hesitation [24,35]. The same researcher performed the measurements three consecutive times according to the criteria proposed by the American Thoracic Society. Among them, the most physiological respiratory function test value was used [34].

2) Exercise Programs

(1) Shoulder Stabilization Exercise Program

In this study, the shoulder stabilization exercise program consisted of 30 minutes, including five minutes of warm-up exercise, twenty minutes of main exercise, and five minutes of cool-down exercise. The warm-up and cool-down exercises involved stretching exercises on the pectoralis minor muscle. In the main exercise, shoulder stabilization exercises were performed (Table 1).

① Warm-up and Cool-Down Exercises

Pectoralis Minor Stretching

The participant was in a supine position with the knee flexion. Both lower extremities were rotated to the floor in the opposite direction to the upper extremity on the side of the muscles to be stretched by applying a stable distal tension to the rib so that the muscle stretched [6]. While maintaining this posture, the upper extremity was moved slowly over the head in a circular motion and stopped at the tightness points. The overhead upper extremity movement to stretch the pectoralis minor was facilitated by inferior tilting, elevation, and scapula retraction [6,36].

Table 1. Shoulder stabilization exercises

Exercise		Contents	Intensity	Time
Warm up	Stretching exercise on pectoralis minor muscle			5 min
Main	1st – 2nd week	1) Cervical stabilization exercise - Chin tuck exercise in the sitting position 2) Scapular stabilization exercise 1. Y to W exercise 2. L to Y exercise 3) Shoulder strengthening exercise with elastic band red color in female with elastic band green color in male 1. Shoulder retraction 2. Shoulder external rotation	10 sec 5 times 3 sets 5s rest between the times 10 s rest between the sets	20 min
	3rd – 4th week	1) Cervical stabilization exercise - Chin tuck exercise in the supine position 2) Scapular stabilization exercise 1. Y to W exercise 2. L to Y exercise 3) Shoulder strengthening exercise with elastic band green color in female with elastic band blue color in male 1. Shoulder retraction 2. Shoulder external rotation		
Cool down	Stretching exercise on pectoralis minor muscle			5 min

② Main Exercise

Shoulder stabilization exercises included cervical stabilization exercises, scapular stabilization exercises, and shoulder strengthening exercises. Each exercise was performed for three sets of five repetitions of 10 seconds, with five seconds rest within the exercise and 10 seconds rest between the sets.

Cervical Stabilization Exercise

The chin-tuck exercise was performed as a cervical stabilization exercise. The participant moved the chin completely backward and pushed it in. During the movement, cervical flexion was performed to avoid pulling the chin to the chest [16,23]. The chin-tuck exercise was performed in the sitting position on the chair in the first and second weeks and in the supine position in the third and fourth weeks to prevent adaptation by the participants.

Scapular Stabilization Exercise

· Y to W Exercise

It started in a position where both arms were flexed and abducted to 120° to form the letter 'Y' with the arms and body. The upper trapezius muscle was relaxed by raising and lowering the scapula with the thumb facing upward. The arms were then raised 10–12.5 cm (4–5 in). While maintaining the scapular retraction, the subject's arm formed the letter 'W' by moving it in elbow flexion and shoulder extension [16,23].

· L to W Exercise

The exercise started in a position where both arms were abducted to 90°, and the elbow joints were flexed 90° to form the letter ‘L.’ Subsequently, the scapula was retracted, and the arms were rotated externally to maintain shoulder abduction at 90° throughout the entire exercise. While maintaining the scapular retraction, both arms were raised above the head, and the elbow joints were fully extended to form the letter 'Y' [16,23].

Shoulder Strengthening Exercise

An elastic band (Theraband®, HYSNAL™ Synthetic Rubber Sheeting, Hygienic Corp., Akron, Ohio, USA) was used for shoulder muscle strengthening exercises. Each color of the elastic band used in this study represents a different resistance [37] and is divided according to increasing resistance as yellow, red, green, blue, and black colors [38]. The red, green, and blue colors were selected based on what was routinely used for performing various shoulder exercises [39]. To prevent adaptation of the participants, the red and green elastic bands were applied for females and males, respectively, in the first and second weeks, and the green and blue elastic bands were applied to females and males, respectively, in the third and fourth weeks [40].

· Scapular Retraction Exercise

The exercise started in a position where the shoulder joints abducted at 90° in the scapular plane, the elbow joints flexed at 90°, and the forearms horizontal. The participants held a part of the elastic band between the right and left hands and stretched the elastic band while the scapula was retracted. The shoulder and elbow joints were maintained in their original 90° position, and a controlled return to the starting position was then executed [37].

· Shoulder External Rotation

The exercise started where the upper arm was positioned at the shoulder joint abducted at 90°, the elbow joint flexed at 90°, and the forearm rotated vertically starting from a horizontal position and returned to the starting position. The elastic band was fixed at waist height in front of the participant at approximately the beginning of the exercise [37].

(2) Core Stabilization Exercise Program

In this study, the core stabilization exercise program was performed for 30 minutes, including five minutes of warm-up exercise, twenty minutes of main exercise, and five minutes of cool-down exercise, including five minutes of warm-up exercise, twenty minutes of main exercise, and five minutes of cool-down exercise. In the warm-up and cool-down exercises, stretching was performed on the trunk and thigh muscles. In the main exercise, core stabilization exercises were performed (Table 2).

Table 2. Core stabilization exercises

Exercise		Contents	Intensity	Time
Warm up		Stretching exercise on abdominal muscle, back muscle, iliopsoas muscle, quadriceps muscle, hamstrings muscle		5 min
Main	1^{st} – 2^{nd} week	Bridge exercise Quadruped with alternate arm and leg raises Diagonal abdominal curl-up exercise Back extension exercise	10 sec 5 times 3 sets 5s rest between the times 10 s rest between the sets	20 min
	3^{rd} – 4^{th} week	Bridge exercise using a foam roll Diagonal abdominal curl-up exercise using a foam roll Back extension exercise using a foam roll Quadruped with alternate arm and leg raises using a foam roll		
Cool down		Stretching exercise on abdominal muscle, back muscle, iliopsoas muscle, quadriceps muscle, hamstrings muscle		5 min

① Warm-up and Cool-Down Exercises

Stretching Exercise on Abdominal Muscles, Back Muscles, Iliopsoas Muscles, and Hamstring Muscles

For abdominal muscle stretching, the participants raised the upper body while pressing the floor with both hands next to the lower ribs in the prone position and maintained the posture [41]. For back muscle stretching, the participants moved their hands from the hip to the feet with cervical flexion after fully extending the knees and freely placing the feet or plantar flexed ankle joints in the long-sitting position and then maintained the posture [42]. For iliopsoas muscles stretching, the participants placed the opposite lower extremity of the side to stretch in a standing position in front and the side to stretch in the back, kept the hip joint extension of the side to stretch with both knee joints flexion, and maintained the posture. Both hands were placed on the pelvis to prevent anterior tilt of the pelvis [43]. For hamstring muscle stretching, the participants sat on the floor, extended one lower extremity in front of the pelvis, kept the knee straight, held their head up, straightened the back, and maintained the position until tightness was felt in the back of the thigh [44].

② Main Exercise

Core Stabilization Exercise

Core stabilization exercises included back bridge exercise, diagonal curl-up exercise, back extension exercise (Modified prone cobra exercise), and quadruped position exercises (Superman exercise). Adaptation of the participants was prevented by performing the exercises on a stable surface in the first and second weeks and on an unstable support surface using a foam roller in the third and fourth weeks. Each exercise was performed in three sets of five repetitions of 10 seconds, with five seconds rest within the exercise and 10 seconds rest between sets.

· Core Stabilization Exercise on a Stable Surface

The bridge exercise was performed in the supine position; both hands were placed on the floor with the forearms supinated, the hip and knee joints flexed, feet placed on the floor, and the pelvis lifted [45].

The diagonal curl-up exercise was performed in the supine position; both hands were placed next to the body, the hip and knee joints flexed 90°, the feet placed on the floor, the end of the fingers stretched toward the knee joints, and the trunk lifted to the acromion by lifting the head and shoulders alternately stretched their arms diagonally [46,47].

The back extension exercise was performed in a prone posture, with the palms of the hands facing up to the ceiling with the forearms supinated, arms placed on both sides, upper and lower body lifted, the spine extended, and the end of the fingers reaching toward toes with the scapular depression and retraction [22,48]. The quadruped position exercise was performed in the quadruped position with both hands and knees on the floor; the upper and lower extremities were lifted alternately [22,45].

· Core sTabilization Exercise on an Unstable Surface

Core stabilization exercises were performed using a foam roller for an unstable surface, which is a commonly used tool in physical therapy for rehabilitation. The foam roller is ideal as an unstable support surface because of its small contact area with the floor and is particularly useful for exercises requiring direct body contact [49]. The foam roller has been reported to allow greater activation of the abdominal muscles than other tools because of its smaller contact area [50]. In the bridge exercise and diagonal curl-up exercise, the foam roller was placed horizontally under the feet [49]. In the back extension exercise, the foam roller was placed horizontally, slightly above the patella [51]. In the quadruped position exercise, the foam roller was placed horizontally under the tibial tuberosity [22,51].

4. Statistical Analysis

The data were analyzed using SPSS (Statistical Package for the Social Sciences) version 23.0 (IBM, SPSS Inc., Chicago, IL., USA). The Kolmogorov–Smirnov test was used to verify normality, and the Levene F-test was used to verify homogeneity. An independent T-test was used to compare the changes in shoulder height and respiratory function between the two groups, and a paired t-test was used to compare the changes in shoulder height and respiratory function within each group. The statistical significance level was set to $\alpha = .05$.

Ⅲ. Results

1. General Characteristics of the Participants

The participants were 28 young adults with RSP (Shoulder height = 5.30 ± 1.05 cm). Table 3 lists the general characteristics of the participants.

2. Comparison of the Change in Shoulder Height

A comparison of the changes in shoulder height between the groups according to the exercise type revealed no significant difference. On the other hand, a comparison of the changes in shoulder height within the group before and after exercise revealed a significant decrease in the shoulder stabilization exercise group ($p < .05$) and core stabilization exercise group ($p < .05$) (Table 4).

3. Comparison of the Change in Respiratory Function

As a result of comparing changes in respiratory function between groups according to exercise type, there was no significant difference. A comparison of the changes in respiratory function within the group before and after exercise revealed significant increases in FVC and FEV_1 in the shoulder stabilization exercise group ($p < .05$) but no significant difference in the FEV_1/FVC and PEF. There were significant increases in FEV_1, FEV_1/FVC, and PEF

Table 3. General characteristics of the subjects (n=28)

Variable	Shoulder stabilization (n=14)	Core stabilization (n=14)	F	p
Gender (F/M)	7/7	6/8	-	-
Age (years)	19.50 ± 1.51	19.43 ± 1.56	.008	.928
Weight (kg)	67.05 ± 14.40	67.98 ± 15.38	2.377	.135
Height (cm)	168.42 ± 7.21	168.2 ± 10.00	.339	.566
BMI (kg/m^2)	23.46 ± 3.75	23.63 ± 3.54	.015	.903
Shoulder height (cm)	5.54 ± 1.20	5.07 ± .87	1.825	.188

Expressed as the mean ± standard deviation
BMI, body mass index

Table 4. Comparison of the shoulder height between the two groups

Variable	Group	Pre-test	Post-test	Change	t	p
Shoulder height (cm)	Shoulder stabilization	5.54 ± 1.20	4.00 ± .88	-1.54 ± .91	6.324	$.000^{\dagger}$
	Core stabilization	5.07 ± .87	3.96 ± .91	-1.11 ± .68	6.053	$.000^{\dagger}$
	t	1.170	.106	-1.410		
	P	.253	.917	.170		

Expressed as mean ± standard deviation
$^{*}p < .05$, Statistically significant difference between the two groups; $^{\dagger}< .05$, Statistically significant difference within the group

Table 5. Comparison of the respiratory function

Variable	Group	Pre-test	Post-test	Change	t	p
FVC (Litter)	Shoulder stabilization	3.41 ± 1.06	3.66 ± .91	.25 ± .27	-3.468	.004†
	Core stabilization	3.21 ± 1.24	3.49 ± .93	.28 ± .71	-1.489	.160
	t	.472	.489	.176		
	p	.641	.629	.862		
FEV_1 (L/sec)	Shoulder stabilization	2.90 ± 1.08	3.44 ± 1.02	.54 ± .77	-2.593	.022†
	Core stabilization	2.75 ± 1.02	3.47 ± .93	.72 ± .82	-3.281	.006†
	t	.378	-.100	.620		
	p	.709	.921	.541		
FEV_1/FVC (%)	Shoulder stabilization	82.43 ± 17.29	93.14 ± 9.49	10.71 ± 20.52	-1.954	.073
	Core stabilization	85.79 ± 11.38	95.21 ± 5.40	9.43 ± 12.46	-2.832	.014†
	t	-.607	-.710	-.200		
	p	.549	.484	.843		
PEF (L/sec)	Shoulder stabilization	4.36 ± 1.88	5.00 ± 1.81	.64 ± 1.62	-1.480	.163
	Core stabilization	4.13 ± 1.96	5.26 ± 1.93	1.12 ± 1.71	-2.465	.028†
	t	.318	-.358	.771		
	p	.753	.723	.448		

Expressed as the mean ± standard deviation

FVC: Forced Vital Capacity; FEV_1: Forced Expiratory Volume in 1 Second; PEF: Peak Expiratory Flow

*p < .05, Statistically significant difference between two groups; †< .05, Statistically significant difference within the group

in the core stabilization exercise group ($p < .05$) but no significant difference in FVC (Table 5).

Ⅳ. Discussion

RSP occurs in the horizontal plane, and scoliosis occurs in the sagittal plane [1]. Malalignment in the horizontal plane can cause changes in the sagittal plane, affecting pain, muscle activity, postural deformation, and physical function [16,52]. An incorrect posture negatively affects the respiratory function [53]. A comparison of the change in shoulder height in this study revealed no significant difference between the two groups but significant decreases in the shoulder stabilization and core stabilization exercise groups after exercise.

A previous study examined the activation of core muscles during isometric arm exercise in healthy adult females. As a result, both shoulder extension exercises increased the activation of the rectus abdominis muscle and external oblique muscle, and horizontal shoulder extension increased the activation of the longissimus muscle and multifidus muscle. These exercises induced trunk muscle contraction to develop endurance and strength characteristics [54]. Core stabilization exercise was performed five times a week for two weeks in healthy adults, and the activation of arm muscles and core muscles during shoulder adduction when weight was applied was analyzed. As a result, activation of the core and arm muscles, such as the upper trapezius muscle, pectoralis major muscle, and trapezius anterior muscle, were found. This is because core stabilization exercise altered the activation of three muscles in the cervical-thoracic-lumbar musculature, including intra-abdominal muscle generation through the oblique chain [55]. Poor posture is an incorrect relationship of various body parts that increases the burden on the support structure and reduces the balance of the body on the base of support [56]. The FHP alters the center of gravity of the body, which causes mechanical changes in relation to postural control in the trunk and other joints due to the body's efforts to adapt to these changes by changing the balance control mechanism [57]. Shoulder stabilization exercises focus on balance recovery to control inter-shoulder stabilizers [58], and core stabilization exercises focus on the intrinsic requirements of the core for flexibility, strength, endurance, and balance and on the core function related the role in function and dysfunction of the extremity [59].

Therefore, the lack of a significant difference in shoulder height between the two groups in this study suggests that although the main purposes considered by shoulder stabilization exercise and core stabilization exercise are different, shoulder stabilization exercise affected core muscle activation, and core stabilization exercise affected shoulder muscle activation. This improved the postural correction of the participants in this study whose center of gravity was changed due to the incorrect posture.

In a previous study, complex exercises, including the pectoralis minor muscle and pectoralis major muscle scratching exercises and shoulder strengthening exercises, were performed for swimmers with FSP for six weeks [16]. They reported that the distance from the wall to the acromion was decreased significantly in the exercise group compared to the control group who performed swimming exercises, which was reported to be because of the effect of these exercises on posture [16]. Complex exercises that combined scapular stabilization, thoracic stabilization, and lower trapezius strengthening were performed for patients with neck pain and RSP and FHP for four weeks. They reported that the neck disability index was significantly lower, craniovertebral angle (CVA) significantly higher, and cranial rotational angle (CRA) significantly lower in the Complex exercise group than the control group. In contrast, the control group that performed exercise combined with scapular stabilization and thoracic stabilization exercises showed a significant increase in muscle thickness and contraction rate during muscle contraction. Furthermore, the pain index, neck disability index, CVA, and CRA were improved significantly in both groups before and after exercise, and the muscle thickness and contraction ratio increased significantly during contraction of the lower trapezius muscle in the exercise group [59]. The trapezius muscle plays a vital role in the movement of the scapula, particularly the lower trapezius muscle, which plays a key role in the stability of the scapula [60]. Cervical and scapular stabilization exercises were performed for adults with FHP for four weeks [61]. The study reported that CVA was significantly higher in the scapular stabilization exercise group than the cervical stabilization exercise group and that CVA was increased significantly and the CRA was decreased significantly in both groups because the stabilization exercise changed the muscle imbalance pattern and the scapular stabilization exercise improved the general movement of the upper body [61]. Shoulder strength and stretching exercises were performed for adults with RSP for four weeks. A previous study reported no significant difference between groups, but that balance was improved significantly in both groups [19].

Therefore, the significant decrease in shoulder height in the shoulder stabilization exercise group before and after exercise in this study was attributed to the shoulder stabilization exercise combined with the pectoralis minor muscle stretching exercise, cervical stabilization exercise, scapular stabilization exercise, and shoulder muscle strengthening exercise affecting the muscle strength of the shoulder region, including the lower trapezius muscle, which plays a crucial role in scapular stability, helping to improve muscle imbalance patterns, and improving the participant's posture by affecting the alignment of the cervical and shoulder area.

In a previous study, adults in their 20s with rounded shoulder and forward head postures performed plank exercises on a stable and unstable support surface for four weeks [62]. They reported that CVA and shoulder height were improved significantly in the unstable support surface group after exercise, and the exercise on the unstable support surface was effective in correcting CVA and RSP [62]. Complex exercises using shoulder and abdominal stabilization and shoulder stabilization sneakers exercises were performed for adults with FHP for five weeks. Significant differences were found in the left inferior angle and the location of the right root of the spine in the complex exercise group compared to the shoulder stabilization exercise group. There were significant differences in CVA, location of the spine, and both inferior angles in the complex exercise group before and after exercise, and significant differences in CVA in the shoulder stabilization exercise group. This is because compound exercises, including abdominal stabilization exercises, affected shoulder alignment [63]. An analysis of the correlation between the core muscle endurance and static balance in adults with FHP revealed strong positive correlations in trunk flexion, extension, right flexion, left flexion endurance, and static balance [64]. Female and male university students performed core balance exercises for 10 weeks [65]. They reported that static and dynamic balance were significantly improved [65]. An exercise program, including bridge exercise and quadruped with arm and leg extension using foam roller exercise, was performed for elderly people over 60 years for five weeks [66]. They showed that static and dynamic balance increased significantly [66]. Achieving core stability allows the development of postural and dynamic balance with equal force distribution to distal segments [21].

Therefore, the significant decrease in shoulder height in the core stabilization exercise group before and after exercise is because the core stabilization exercise using a stable surface and an unstable support surface in this study improved the shoulder alignment by influencing the upper spine alignment correction. At the same time, it also affected the improvement of core muscle endurance, positively affecting the improvement of balance ability.

A comparison of the changes in respiratory function in this study revealed no significant difference between the groups. On the other hand, there was a significant increase in the shoulder stabilization exercise group and the core stabilization exercise group after exercise.

A previous study reported chest movement and stretching exercises using elastic bands for healthy adults in their 20s [68]. They reported that the maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) increased significantly after exercise [67]. The effect of breathing on postural stability is associated with the effect of respiratory muscles (diaphragm and abdominal muscles) on trunk stability [68].

Hence, there was no significant difference between the groups because the shoulder stabilization group and core stabilization group had a similar increase in respiratory function between the two groups by affecting the activation and muscle strength of the respiratory muscles, which are the trunk muscles for respiratory on postural stability.

In a previous study, scapulothoracic exercise was performed on sedentary young women with FSP for eight weeks [69]. They reported that the distance from the acromion to the wall and thoracic kyphosis decreased significantly, and the length of the pectoralis minor muscle and MIP increased significantly. This is because the pectoral muscle stretching and scapular stabilization muscle strengthening exercise program reduced the forward head posture and strengthened the chest mobility and respiratory muscles [69]. Cervical stabilization exercises with feedback, in addition to daily electrical, physical therapy, and cervical isometric exercise, were performed for six weeks for patients with neck pain with FHP. The CVA, respiratory muscle strength (maximal inspiratory pressure, PIMax), and FEV_1 were increased significantly in the cervical stabilization exercise group. The decrease in FHP due to cervical stabilization exercise improved the motility of the thoracoabdominal region and the efficacy of the diaphragm by correcting the altered biomechanics of the cervical and thoracic vertebrae. Moreover, cervical stabilization exercise was integrated into managing patients with FHP, which could correct the defective mechanism leading to respiratory disorders [70]. Complex exercises for adults with FHP involved a combination of scapular stabilization and thoracic extension exercises. The CVA, cervical lateral flexion angle, FVC, and FEV_1 were significantly higher in the complex exercise group than in the control group. Stretching exercises with self-myofascial release resulted in a decrease in pain. In addition, the CVA, cervical range of motion except for extension, MIP, and MEP increased significantly in the complex exercise group after exercise, and the pain and neck disability index decreased significantly. This is because the combination of thoracic extension and cervical stabilization exercises improved pulmonary function by correcting the pulmonary muscle imbalance caused by FHP. Hence, exercise positively affects the alignment of the neck and back of the spine [71].

Therefore, the significant increase in respiratory function in the shoulder stabilization exercise group after exercise is because shoulder stabilization exercise positively improved posture by influencing the alignment of the upper spine by correcting the biomechanics of shoulder subjects with incorrect postures, such as thoracic kyphosis, and improved respiratory muscle strength and pulmonary function by improving mobility of the thoracic and abdominal regions.

Trunk stabilization exercise was performed for six weeks for healthy adults. Therefore, the FVC, FEV_1, and PEF were increased significantly in the trunk stabilization exercise group compared to the control group that performed common abdominal exercises. In addition, FVC, FEV_1, and PEF increased significantly in the trunk exercise group, and there was no significant difference in the control group between before and after exercise. This is because muscular chain stretching and breathing techniques, according to the trunk stabilization exercises, could induce more significant improvements in respiratory function, abdominal muscle endurance, and movement efficiency than common abdominal exercises [72]. An asthma education program and exercises, including breathing, were performed for asthma patients for six weeks. Therefore, the MIP and dynamic balance increased significantly in the core stabilization exercise group compared to the control group that performed only the asthma education program and breathing exercises. Furthermore, the dynamic balance, FEV_1, FVC, FEV_1/FVC, MEP, and MIP were increased significantly in the core stabilization exercise group, and FEV_1, FVC, and FEV_1/FVC were increased significantly in the control group after exercise. This is because core stabilization exercise affected the inhalation and exhalation muscle strength, and it was thought that the level of dynamic balance could be improved as MIP increased [21]. The muscle activity of trunk muscles was analyzed when trunk stabilization exercise was performed on a stable and unstable surface for adults in their 20s. The muscle activity was higher in the bilateral rectus abdominis, bilateral external oblique, and ipsilateral to the arm lifted for the erector spinae during curl-up exercise on an unstable support surface using a Bosu ball than on the stable surface [22]. The main function of core stabilization cannot be reached without diaphragm contraction, and core stabilization exercises help strengthen the diaphragm and reduce the use of accessory muscles for breathing [21]. Diaphragmatic breathing exercises minimize accessory muscle activity by activating the diaphragm during inspiration [72]. The exercise aimed to facilitate neuromuscular control, strength, and muscle endurance of key muscles to maintain dynamic stability of the spine and trunk. One trunk stability training approach involves using unstable surfaces, the benefit of which is increased muscle demand to maintain postural stability [22]. Stabilization exercise activates the trunk muscles to provide stability to the spine and abdominal wall [73], and neuromuscular stimulation of the abdominal wall improves pulmonary function by reducing the functional residual capacity [74].

Therefore, the significant increase in respiratory function in the core stabilization exercise group before and after exercise in this study was because the core stabilization exercise performed in this study helped activate the respiratory muscle strength and minimized the activity of auxiliary muscles. The exercise positively affected the muscle chain stretching and breathing mechanism. Exercising on an unstable support surface further helped activate the trunk muscles, improving pulmonary function through neuromuscular stimulation of core muscles for stability.

This study had some limitations. First, the number of participants was small. Second, the participants were only RSP, one of the musculoskeletal disorders, so it was difficult to identify the effect on related other diseases. Therefore, it will be necessary to study subjects according to the degree of postural abnormalities, such as RSP, FHP, and upper crossed syndrome, or examine the long-term effects of comparisons of shoulder stabilization exercises and core stabilization exercises for those with pain, functional abnormalities, and other problems in addition to the postural characteristics.

Ⅴ. Conclusion

This study compared the effects of shoulder stabilization exercises, including stretching, muscle strengthening, and core stabilization exercises, on the shoulder height and respiratory function in young adults with RSP. A comparison of the changes in shoulder height revealed no significant difference between the groups according to the exercise method. On the other hand, the shoulder height decreased significantly in both groups after exercise. A comparison of the changes in respiratory function showed no significant difference between the groups according to the exercise method. By contrast, the respiratory function was decreased significantly in both groups after exercise. This is because shoulder and core stabilization exercises improved the postural alignment and pulmonary function. These results will be helpful in shoulder rehabilitation and the clinical treatment of RSP.

References

[1] Tafreshi ES, Moghadam AN, Bakhshi, E., et al. Comparing scapular position and scapular dyskinesis in individuals with and without rounded shoulder posture. Physical Treatments-Specific Physical Therapy Journal. 2015;5(3): 127-36.

[2] Fani M, Ebrahimi S, Ghanbari A. Evaluation of scapular mobilization and comparison to pectoralis minor stretching in individuals with rounded shoulder posture: a randomized controlled trial. J Bodyw Mov Ther. 2020;24(4):367-72.

[3] Singla D, Veqar Z. Association between forward head, rounded shoulders, and increased thoracic kyphosis: a review of the literature. J Chiropr Med. 2017;16(3):220-9.

[4] Wong CK, Coleman D, Song J, et al. The effects of manual treatment on rounded-shoulder posture, and associated muscle strength. J Bodyw Mov Ther. 2010; 14(4):326-33.

[5] Borstad JD, Ludewig PM. The effect of long versus short pectoralis minor resting length on scapular kinematics in healthy individuals. J Orthop Sports Phys Ther. 2005;35(4):227-38.

[6] Sahrmann S. Diagnosis and Treatment of Movement Impairment Syndromes (1st ed.). USA. Mosby. 2002.

[7] Kang FJ, Chiu YC, Wu SC, et al. Kinesiology taping

with exercise does not provide additional improvement in round shoulder subjects with impingement syndrome: a single-blinded randomized controlled trial. Phys Ther Sport. 2019;40:99-106.

[8] Ball JM, Cagle P, Johnson, BE, et al. Spinal extension exercises prevent natural progression of kyphosis. Osteoporos Int. 2009;20(3):481-9.

[9] Zafar H, Albarrati A, Alghadir AH, et al. Effect of different head-neck postures on the respiratory function in healthy males. Biomed Res Int. 2018;(2018):1-5.

[10] Ghanbari A, Ghaffarinejad F, Mohammadi F, et al. Effect of forward shoulder posture on pulmonary capacities of women. Br J Sports Med. 2008;42(7):622-3.

[11] Shiravi S, Letafatkar A, Bertozzi L, et al. Efficacy of abdominal control feedback and scapula stabilization exercises in participants with forward head, round shoulder postures and neck movement impairment. Sports Health. 2019;11(3):272-9.

[12] Thakur D, Motimath B, Raghavendra M. Forward head posture correction versus shoulder stabilization exercises effect on scapular dyskinesia and shoulder proprioception in athletes an experimental study. International Journal of Physiotherapy. 2016;3(2):197-203.

[13] Ekstrom RA, Soderberg GL, Donatelli RA. Normalization procedures using maximum voluntary isometric contractions for the serratus anterior and trapezius muscles during surface EMG analysis. J Electromyogr Kinesiol. 2005: 15(4);418-28.

[14] Umehara J, Nakamura M, Nishishita S, et al. Scapular kinematic alterations during arm elevation with decrease in pectoralis minor stiffness after stretching in healthy individuals. J Shoulder Elbow Surg. 2018;27(7):1214-20.

[15] Magarey ME, Jones MA. Dynamic evaluation and early management of altered motor control around the shoulder complex. Man Ther. 2003;8(4):195-206.

[16] Fathollahnejad K, Letafatkar A, Hadadnezhad M. The effect of manual therapy and stabilizing exercises on forward head and rounded shoulder postures: a six-week intervention with a one-month follow-up study. BMC Musculoskelet Disord. 2019;20(1):1-8.

[17] Kuo YL, Lee TH, Tsai YJ. Evaluation of a cervical stabilization exercise program for pain, disability, and physical impairments in university violinists with nonspecific neck pain. Int J Environ Res Public Health. 2020;17(15):5430.

[18] Dusunceli Y, Ozturk C, Atamaz F, et al. Efficacy of neck stabilization exercises for neck pain: a randomized controlled study. Journal of Rehabilitation Medicine. 2009;41(8):626-31.

[19] Kim MK, Lee JC, Yoo KT. The effects of shoulder stabilization exercises and pectoralis minor stretching on balance and maximal shoulder muscle strength of healthy young adults with round shoulder posture. J Phys Ther Sci. 2018;30(3):373-80.

[20] Borstad JD, Ludewig PM. Comparison of three stretches for the pectoralis minor muscle. J Shoulder Elbow Surg. 2006;15(3):324-30.

[21] Develi E, Subasi F, Aslan GK, et al. The effects of core stabilization training on dynamic balance and pulmonary parameters in patients with asthma. J Back Musculoskelet Rehabil. 2021;34(4):639-48.

[22] Imai A, Kaneoka K, Okubo Y, et al. Trunk muscle activity during lumbar stabilization exercises on both a stable and unstable surface. J Orthop Sports Phys Ther. 2010; 40(6):369-75.

[23] Lynch SS, Thigpen CA, Mihalik JP, et al. The effects of an exercise intervention on forward head and rounded shoulder postures in elite swimmers. Br J Sports Med. 2010;44(5):376-81.

[24] Han J, Park S, Kim Y, et al. Effects of forward head posture on forced vital capacity and respiratory muscles activity. J Phys Ther Sci. 2016;28(1):128-31.

[25] Park YJ, Kim WM, Yu JH, et al. Effects of combined exercise program on spinal curvature and balance ability in adolescents with kyphosis. Children. 2022;9(12): 1999.1-7.

[26] Yu LJ, Gu Q, Kim TH. The effects of cervical stabilization exercises with breathing exercises on respiratory function in subjects with forward head posture. WSEAS Transactions on Systems and Control. 2021;16:486-92.

[27] Werasirirat P, Namsawang J, Muanjai P, et al. Effect of blood flow restriction training with strengthening exercises in individuals with rounded shoulder posture: a randomized controlled trial. Journal of Physical Education & Sport. 2023;23(5):1262-71.

[28] McClure P, Greenberg E, Kareha S. Evaluation and management of scapular dysfunction. Sports Med Arthrosc Rev. 2012;20(1):39-48.

[29] Lewis JS, Valentine RE. The pectoralis minor length test: a study of the intra-rater reliability and diagnostic accuracy in subjects with and without shoulder symptoms. BMC Musculoskelet Disord. 2007;8(1):1-10.

[30] Nijs J, Roussel N, Vermeulen K, et al. Scapular positioning in patients with shoulder pain: a study examining the reliability and clinical importance of 3 clinical tests. Arch Phys Med Rehabil. 2005;86(7):1349-55.

[31] Kim EK, Kim JS. Correlation between rounded shoulder posture, neck disability indices, and degree of forward head posture J Phys Ther Sci. 2016;28(10):2929-32.

[32] Kim SY, Hwang YI, Kim KS. The effects of thoracic mobilizing and stretching exercise on maximal inspiratory pressure and maximal expiratory pressure in healthy adults. PNF and Movement. 2022;20(1):9-17.

[33] Kang MS, Shim JH, Kang SY. Comparisons of diaphragm movement, pulmonary function, and pulmonary strength among exercise methods in children with cerebral palsy. Korean Society of Physical Medicine. 2018;13(1):121-8.

[34] Jung SI, Lee NK, Kang KW, et al. The effect of smartphone usage time on posture and respiratory function. J Phys Ther Sci. 2016;28(1):186-9.

[35] Messan F, Lawani MM, Mama D. FVC and FEV reference values for beninese individuals aged 17-20 years. Open Journal of Respiratory Diseases. 2019;9(2):48-59.

[36] Wong CK, Coleman D, Song J, et al. The effects of manual treatment on rounded-shoulder posture, and associated muscle strength. J Bodyw Mov Ther. 2010; 14(4):326-33.

[37] Kluemper M, Uhl T, Hazelrigg H. Effect of stretching and strengthening shoulder muscles on forward shoulder posture in competitive swimmers. J Sport Rehabil. 2006;15(1):58-70.

[38] Naderi A, Mousavi SH, Katzman WB, et al. Kinesiotaping as an adjunct to exercise therapy for symptomatic and asymptomatic swimmers: a randomized controlled trial. Science & Sports. 2022;37(5-6):492-e1-e11.

[39] Hürer C, Angın E, Tüzün EH. Effectiveness of clinical Pilates and home exercises in sagittal cervical disorientation: randomized controlled study. J Comp Eff Res. 2021;10(5):365-80.

[40] Manral D, Sethi J, Jain A, et al. Effect of core-shoulder stability exercises on shoulder performance among throwers with glenohumeral internal rotation deficit. Journal of Medical Pharmaceutical and Allied Sciences. 2023;12(3):5814-19.

[41] Musiyenko OV, Mykhats LV, Budynkevych SN, et al. Determination of the functional state of the body using non-traditional research methods when performing the static exercise: “prone press ups, static top position” (Cobra). Health, Sport, Rehabilitation. 2020;6(1):41-8.

[42] Seif HE, Alenazi A, Hassan SM, et al. The effect of stretching hamstring, gastrocnemius, iliopsoas and back muscles on pain and functional activities in patients with chronic low back pain: a randomized clinical trial. Open Journal of Therapy and Rehabilitation. 2015;3(4):139-45.

[43] Kim KS, Jeon IC. Effectiveness of iliopsoas self-stretching on hip extension angle, gluteus maximus activity, and pelvic compensations during prone hip extension in subjects with iliopsoas shortness. The Journal of Korean Physical Therapy. 2018;30(1):23-8.

[44] Fox M. Effect on hamstring flexibility of hamstring stretching compared to hamstring stretching and sacroiliac

joint manipulation. Clinical Chiropractic, 2006;9(1): 21-32.

[45] Junker D, Stöggl T. The training effects of foam rolling on core strength endurance, balance, muscle performance and range of motion: a randomized controlled trial. Journal of Sports Science & Medicine. 2019;18(2): 222-38.

[46] Andrade LS, Mochizuki L, Pires FO, et al. Application of pilates principles increases paraspinal muscle activation. J Bodyw Mov Ther. 2015;19(1):62-6.

[47] Narouei S, Barati AH, Akuzawa H, et al. Effects of core stabilization exercises on thickness and activity of trunk and hip muscles in subjects with nonspecific chronic low back pain. J Bodyw Mov Ther. 2020;24(4):138-46.

[48] Escalante G, Fine D, Ashworth K. Progressive exercise strategies to mitigate shoulder injuries among weight-training participants. Strength Cond J. 2021;43(1):72-85.

[49] Luque-Suárez A, Díaz-Mohedo E, Medina-Porqueres I, et al. Stabilization exercise for the management of low back pain. In: Norastech, AA. (Ed.) Low back pain. InTech: 2012:261-92.

[50] Hong YJ, Kwon OY, Yi CH, et al. Effects of the support surface condition on muscle activity of abdominalis and erector spinae during bridging exercises. Physical Therapy Korea. 2010;17(4):16-25.

[51] Zahiri A, Alizadeh S, Daneshjoo A, et al. Core muscle activation with foam rolling and static planks. Front Physiol. 2022;13:1-9.

[52] Ertekin E, Günaydın ÖE. Neck pain in rounded shoulder posture: Clinico-radiologic correlation by shear wave elastography. Int J Clin Pract. 2021;75(8):e14240-1-6.

[53] Kapreli E, Vourazanis E, Billis E, et al. Respiratory dysfunction in chronic neck pain patients. a pilot study. Cephalalgia. 2009;29(7):701-10.

[54] Tarnanen SP, Ylinen JJ, Siekkinen KM et al. Effect of isometric upper-extremity exercises on the activation of core stabilizing muscles. Arch Phys Med Rehabil. 2008;89(3):513-21.

[55] Park C, Yoon S, Yoon H, et al. Effects of core stabilization exercise on muscle activity during horizontal shoulder adduction with loads in healthy adults: a randomized controlled study. J Mech Med Biol. 2021;21(09):1-11.

[56] Kendall FP, McCreary EK, Provance PG, et al. (2005). Muscles: testing and function with posture and pain (5th ed). USA. Lippincott Williams & Wilkins. 2005.

[57] Lee JH. Effects of forward head posture on static and dynamic balance control. J Phys Ther Sci. 2016;28(1): 274-7.

[58] Ludewig PM, Cook TM. Alterations in shoulder kinematics and associated muscle activity in people with symptoms of shoulder impingement. Phys Ther. 2000; 80(3):276-91.

[59] Kibler WB, Press J, Sciascia A. The role of core stability in athletic function. Sports Medicine. 2006;36(3):189-98.

[59] Park SH, Lee MM. Effects of lower trapezius strengthening exercises on pain, dysfunction, posture alignment, muscle thickness and contraction rate in patients with neck pain; randomized controlled trial. Med Sci Monit: International Medical Journal of Experimental and Clinical Research. 2020;26:e920208-1-9.

[60] Cools AM, Declercq GA, Cambier DC, et al. Trapezius activity and intramuscular balance during isokinetic exercise in overhead athletes with impingement symptoms. 2Scand J Med Sci Sports. 2007;17(1):25-33.

[61] Kang JI, Choi HH, Jeong DK, et al. Effect of scapular stabilization exercise on neck alignment and muscle activity in patients with forward head posture. J Phys Ther Sci. 2018;30(6):804-8.

[62] Lee SH, Yu WJ, Lee DY. Effects of planck exercise on the cranio-vertebral angle, round shoulder posture and forward head posture. Indian J Public Health Res Dev. 2019;10(11):4678-83.

[63] Kim JH, Rhee MH. Change of craniovertebral angle and scapula alignment in adults with forward head posture by shoulder and abdominal stabilization exercise. PNF and Movement. 2021;19(2):251-60.

[64] Abhilash P, Priya S, Kheriwala MK. Correlation between static balance and core endurance among college student with forward head posture. International Journal of Science and Healthcare Research. 2021;6(3):244-50.

[65] Jo SH, Choi HJ, Cho HS, et al. Effect of core balance training on muscle tone and balance ability in adult men and women. Int J Environ Res Public Health. 2022;19(19):12190-1-11.

[66] Bird ML, Hill KD, Fell JW. A randomized controlled study investigating static and dynamic balance in older adults after training with Pilates. Arch Phys Med Rehabil. 2012;93(1):43-9.

[67] Kim SG, Oh SM, Lee JY, et al. Correlation between lung capacity, resporatory gas analysis and diaphragm movement distance according to forward head posture and round shoulder posture. The Journal of Natural Healing. 2022;7(1):37-47.

[68] Foskolou A, Emmanouil A, Boudolos K, et al. Abdominal breathing effect on postural stability and the respiratory muscles' activation during body stances used in fitness modalities. Biomechanics. 2022;2(3):478-93.

[69] Thongchote K, Threetepchanchai K, Chuwijit A, et al. Pilot study on the improvement effects of scapulothoracic exercises on the respiratory functions in sedentary young female adult with forward shoulder posture: a randomized control trial. Advances in Rehabilitation. 2023;37(1). 23-32.

[70] Pawaria S, Sudan DS, Kalra S, et al. Effectiveness of cervical stabilization exercises with feedback on respiratory status in chronic neck pain patients with forward head posture. International Journal of Physiotherapy. 2019;6(3):70-4.

[71] Kang NY, Kim K. Effects of a combination of scapular stabilization and thoracic extension exercises on respiration, pain, craniovertebral angle and cervical range of motion in elementary school teachers with a forward head posture: a randomized controlled trial. Korean Society of Physical Medicine 2022;7(2):9-40.

[72] Cavaggioni L, Ongaro L, Zannin E, et al. Effects of different core exercises on respiratory parameters and abdominal strength. J Phys Ther Sci. 2015;27(10): 3249-53.

[72] Borge CR, Hagen KB, Mengshoel AM, et al. Effects of controlled breathing exercises and respiratory muscle training in people with chronic obstructive pulmonary disease: results from evaluating the quality of evidence in systematic reviews. BMC Pulm Med. 2014;14(1):1-15.

[73] McGill SM, Karpowicz A. Exercises for spine stabilization: motion/motor patterns, stability progressions, and clinical technique. Arch Phys Med. 2009;90(1): 118-26.

[74] Gollee H, Hunt KJ, Fraser MH, et al. Abdominal stimulation for respiratory support in tetraplegia: a tutorial review. Journal of Automatic Control, 2008;18(2):85-92.