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Randomized Clinical Trial

The Effect of Scapular Stabilization Exercises on Alignment, Joint Position Sense, and Functional Stability of the Upper Limbs in Adolescent Girls with Upper Crossed Syndrome: A Randomized Controlled Trial

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Abstract

Background: Upper crossed syndrome (UCS) is a prevalent postural issue among adolescents, with a rapid increase in its occurrence. This study aimed to investigate the impact of scapular stabilization exercises on alignment, joint position sense, and functional stability of the upper limbs in adolescent girls with UCS.
Methods: This randomized, controlled trial, double-blind study was conducted in December 2022 at the Laboratory of Sport Science of Bu-Ali Sina University, Hamedan, Iran. The study included 48 adolescent girls with UCS. The participants were randomly assigned into either the experimental or the control group. The experimental group performed scapular stabilization exercises for eight weeks and the control group received no intervention. The outcome measures were kyphosis angle measured by a flexible ruler, forward head and rounded shoulder angles measured by photography and Kinovea software, shoulder joint position sense measured by a goniometer, and upper limb functional stability measured by the upper quarter Y-balance test. The assessments were done before and after the intervention.
Results: The results showed that the experimental group improved significantly more than the control group on all the outcome measures (P<0.05). The experimental group had a significant decrease in kyphosis (P=0.001, 95%CI=[3.05%, 7.27%]), forward head (P=0.001, 95%CI=[4.21%, 7.70%]), rounded shoulder (P=0.001, 95%CI=[5.01%, 8.40%]) angles, and in joint reposition error (P=0.001, 95%CI=[1.07%, 2.89%]). Also, there was a significant improvement in upper limb functional stability in the right (P=0.042, 95%CI=[-3.56%, -0.91%]) and left (P=0.032, 95%CI=[-4.31%, -0.20%]) directions, as compared with the control group.
Conclusion: The study results indicated that scapular stabilization exercises can improve alignment, joint position sense, and functional stability of the upper limbs in adolescent girls with UCS. Therefore, these exercises could be an effective intervention for preventing or treating UCS and its associated problems.

Keywords: Musculoskeletal abnormalities, Proprioception, Kyphosis, Forward Head Posture, Rounded Shoulder

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1. Introduction

In recent years, children and teenagers have increasingly adopted a sedentary lifestyle (1). Reduction in physical activities, rapid growth, and unfavorable lifestyle can result in weak trunk muscles and abnormalities related to the spine during the growth period (2).

Upper crossed syndrome (UCS), a common musculoskeletal abnormality in teenagers, is caused by lifestyle changes and characterized by muscle imbalance in the upper part of the body (3). This syndrome is also characterized by tightness in the upper trapezius, levator scapula, and major and minor pectoralis muscles. On the other hand, the deep flexors of the neck are weak, in contrast to the middle and lower trapezius and rhomboids, which are also weakened (4). This muscle imbalance leads to joint dysfunction in the atlantooccipital, cervicothoracic, and glenohumeral joints, resulting in changes such as misalignment of the head, increased thoracic kyphosis, rounded shoulders, rotation, abduction, and winging of the scapula (5).

These postural disorders in the upper quarter of the body disrupt the biomechanical connection between the skeletal components that support the head, neck, spine, and muscles. As a result, they not only affect body alignment but also contribute to postural fluctuations and reduced balance (6). The alignment and functional stability of the shoulder joint and shoulder girdle depend on the relationship between static and dynamic stabilizers created by joint position sense (7). The spine also plays a role in the somatosensory system (8), with the afferent information from the cervical facets being crucial for postural stability and sensory information from the thoracic region providing information about the upper limbs and determining static and dynamic stability of the body (4). Therefore, maintaining a healthy proprioception of the spine is necessary for optimal static and dynamic balance, as well as proper alignment of the spine (9).

Various methods, including braces, muscle taping, surgery, and corrective exercises, are used to treat UCS. Since teenagers are at the age of growth and their muscle structure can be formed and modified, corrective exercises have been recommended (1). The effectiveness of corrective exercises has been investigated for UCS correction, including exercises in water, thoracic extension exercises, and scapular stability exercises. The stabilizing muscles of the scapula, such as the rhomboid, middle and lower trapezius, and serratus anterior muscles, play a key role in maintaining the scapula in a position attached to the chest and controlling its movements (10). Therefore, it is believed that stability exercises that strengthen these muscles can effectively correct changes in alignment and other associated problems. However, few studies have investigated the effectiveness of scapular stability exercises specifically adolescents (1, 11, 12). Given its high prevalence, the purpose of the present study was to examine the impact of scapular stabilization exercises on alignment, joint position sense, and functional stability of the upper limbs in adolescent girls with UCS. This randomized controlled trial study hypothesizes that eight weeks of scapula stabilization training significantly affects these outcomes.

2. Methods

The protocol (IR.BASU.REC.1401.024) was approved by the local Ethics Committee, Bu Ali Sina University in Hamedan, Iran. This study was registered at the Iranian Clinical Trials Registration Organization website, with the unique trial number of IRCT20221215056827N1.

2.1. Study Design

This was a double-blind, randomized, and controlled trial study. The participants were informed about the research process and completed and signed the consent form before registration. Students were recruited by the researcher using school flyers in December 2022. All tests were taken in the Laboratory of Sports Science of Bu Ali Sina University, Hamedan, and the exercises were performed in its Sports Hall. The experimental group received eight weeks of corrective exercises while the control group did not receive any exercises.

2.2. Sample Size Calculation

The sample size was determined by G-Power software (version 3.1), using Mean±SD of CVA (exercise group=51.73±5.06, control group=48.07±3.25) from the study of Sayyadi and colleagues (13). The total sample size was 42 people (21 participants in each group), with the statistical test of t-test, an alpha of 0.05, and a power of 0.85. To account for possible participant drop out, 24 individuals were placed in each group.

2.3. Randomization and Allocation Concealment

The participants were randomly divided into two groups of scapula stabilization exercises and the control group. Randomization was performed using the Random Number Generator software, and the SNOSE technique was applied to ensure the allocation concealment and to randomize the participants into two groups. The randomization of participants was done in two stages; firstly, each participant chose a number between one and 48 using a random selection method; then 24 random numbers were selected between 1-48 using the Random Number Generator software; the participants were determined and selected in two groups accordingly (Figure 1).

2.4. Participants

In the present study, 48 girl students were included in the study based on the inclusion criteria. The inclusion criteria were: adolescent girls with UCS (forward head posture (FHP) greater than 44 degrees, rounded shoulders angle (FSA) greater than 49 degrees and thoracic kyphosis angle greater than 42 degrees) (12), aged between 12 and 15 years, and body mass index of 19-25. The exclusion criteria were: not completing the corrective exercise program or unwillingness to continue the exercise program, presence of any abnormalities related to the pelvis and lower

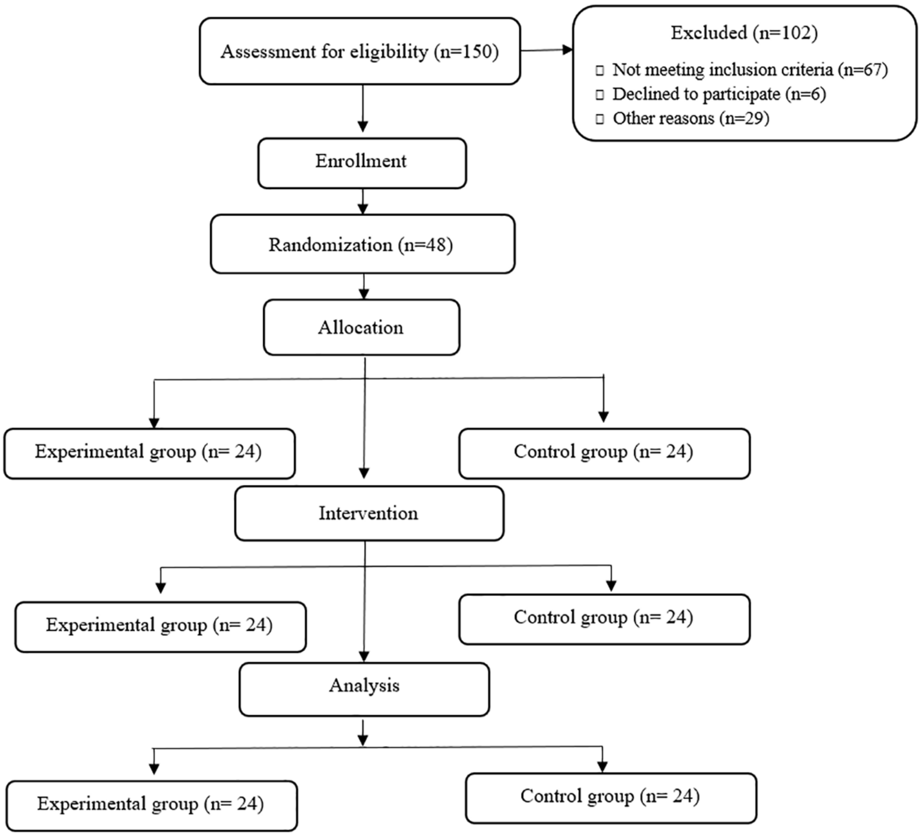

Figure 1: The figure shows the CONSORT flowchart of the study.

limbs, presence of pathological symptoms, history of fracture, surgery or joint diseases in the spine, shoulder girdle and pelvic girdle, any physical activity outside the program of corrective exercises that affects the results of the study.

2.5. Outcome Measures

2.5.1. Evaluation of forward head and round shoulder: Using photographing from the side view, the amount of FHP and FSA was measured (14). In previous studies, good ICC values for analysis with Kinovia software have been reported for FHP (98%) and FSA (80%) measurements (10). Using this method, three anatomical points including ear tragus, spinous process of C7 vertebra, and acromion process were determined and marked with markers. Then, the participant was asked to stand at a distance of 23 cm from the wall in such a way that his left arm was towards the wall.

A digital camera (Canon 80D) was placed on a tripod at a distance of 265 cm from the wall and at a height equal to the participant's shoulder. In this situation, the participant was told to bend forward three times, raise his hands above his head three times, and then stand comfortably and look at a point on the opposite wall, and the examiner took a picture of the side view of the body. Finally, the mentioned photos were transferred to the computer, and using Kinovea software, the angle of the line between the tragus of the ear and the C7 vertebra with the vertical line, as FHP , and the angle between C7 vertebra and the acromion process as FSA was registered (12).

2.5.2. Kyphosis valuation: A flexible ruler (manufactured by Qamat Pouyan Company) was used to measure the thoracic curvature of the participant's spine. ICC results indicated that this measurement method has 87% reliability (15). To measure with this method, the spinous process of T2 and T12 vertebrae were determined as the starting and ending points of thoracic kyphosis curve. Then, to calculate the kyphosis angle, after placing a flexible ruler on the vertebral column and drawing the measured arc on the paper, connect the desired points to each other and obtain the values of H and L, which include the height and depth of the kyphosis curve, respectively. It was determined by aligning the ruler on the back of the participant, and using formula 1, the kyphosis angle was calculated (16).

$$\theta = 4 \arctan(2H/L)$$

Formula 1: Trigonometric formula for calculating kyphosis curvature

2.5.3. Y Balance test (YBT-UQ): This test was used for the assessment of the upper limb functional stability and is performed in a closed kinetic chain (17, 18). YBT-UQ uses a kit with three rods attached to it in the anterior (ANT), posterior medial (PM) and posterior lateral (PL) directions. In order to perform the test, the participant was asked to be in the starting position on the palms and toes like the push-up position and keep her spine and lower limbs in one stretch. In this situation, the participant was asked to stretch his free hand as far as she could, while keeping the other hand, trunk and legs still, and then come back to where she started slowly and carefully. In order to compare with other people, the length of the upper limb was measured using a meter (from the acromion process to the tip of the middle finger) and then the reach values were normalized with the length of the upper limb. The participant reached out in three different directions, one after another, without taking a break or letting the free hand touch the ground. If the participant is unable to maintain three-point contact, or if the kit is out of reach, or if the kit is used on the ground for additional support, the test must be repeated. After familiarizing the participant, three repetitions were performed with both right and left hands, for all three directions, with 30 seconds of rest between each trial. For each direction, the average distance (absolute value in cm) was calculated and normalized based on the length of the upper limb (relative percentage) (17, 19). Finally, the YBT-UQ score was calculated as the average of the three-way reach values (normalized by hand length) for each of the two left and right sides (20).

2.5.4. Assessment of shoulder joint proprioception: Proprioception was measured using a goniometer. The reliability of this device was reported to be 97% (21). For the measurement, the participant was asked to sit on a chair, place the shoulder joint (dominant side) in 45 degrees of abduction and the elbow joint in 90 degrees of flexion. Then, the participant should take her hand from internal rotation to maximum external rotation. First, the created angle was recorded and then 50% of the desired angle was considered as the target angle. Next, the examiner took the shoulder and arm of the participant to the target angle and was asked to keep the mentioned position for a few seconds and remember it. Then, her arm was brought to the neutral position and she was asked to recreate the target angle three times with her eyes closed (11, 22). At the end, the average of three reconstructed angles was calculated and the difference between the number obtained and the target angle was recorded as the angle reconstruction error.

2.6. Intervention

In this study, the experimental group performed scapula stability exercises for eight weeks, while the control group did not receive any exercises. The experimental group trained for eight weeks, with three sessions per week, each lasting 50 minutes. At the beginning of the sessions, the participants warmed up for 10 minutes. At the end, 5 minutes were allocated for body recovery and cooling. These exercises were carried out in three levels: initial, improvement and maintenance. In designing these exercises in the first stage, the goal was stimulating and increasing the participants' knowledge of how to activate the desired muscles. Thus, the exercises focused on isometric muscle contractions, both separately and in different positions. In the improvement phase, the goal was to create tissue adaptations, and with the increase in the reading of the muscle fibers of the weakened muscles, the participant started to activate these muscles. The goal of stability exercises was to activate weak and inhibited muscles and to maintain the minimum activity of muscles that are stiff. In the maintenance phase, in order to maintain the changes made, the intensity of the exercises was increased, and the exercises were performed on an unstable surface such as a Physio-Ball in order to create more adaptations. In general, in the initial sessions, the exercises were performed without any equipment and with low intensity and in the following weeks, the intensity and difficulty of the exercises increased gradually (12, 23) (Table 1).

2.7. Statistical Analysis

All statistical analysis were performed using SPSS version 26. The Shapiro-Wilk test was used to assess the normality of data distribution in groups. The independent t-test was used to compare demographic information between groups. To investigate within-group differences in the pre-test and post-test in variables, paired t-test was used ($P<0.05$).

Table 1: Scapular stability exercises

Week	Exercise	Position	Repetition *Set
1/ initial phase	Educating contraction of stabilizer muscles /Static	Prone	3*15 S
	Contraction of scapula stabilizing muscles in T position/ Static	Prone	3*15 S
	Contraction of scapula stabilizing muscles in Y position/ Static	Prone	3*15 S
	Contraction of scapula stabilizing muscles in W position/ static	Prone	3*15 S
	Shoulder Flexion (Right and Left)	Lying on the side	3*8
	Shoulder External rotation (Right and Left)	Lying on the side	3*8
2/ initial phase	Educating contraction of stabilizer muscles /Static	Prone	3*20 S
	Contraction of scapula stabilizing muscles in T position/ Static	Prone	3*20 S
	Contraction of scapula stabilizing muscles in Y position/ Static	Prone	3*20 S
	Shoulder Abduction (Right and Left)	Lying on the side	3*10
	Shoulder External rotation (Right and Left)	Lying on the side	3*10
	Scapular Retraction/ Static	Sitting	3*20 S
3/ Improvement phase	I to T/ Dynamic	Prone	3*10
	T to Y/ Dynamic	Prone	3*10
	T to Y to W/ Dynamic	Prone	3*10
	Shoulder External rotation/ Dynamic	Prone	3*10
	Shoulder Flexion/ Dumbbell	Lying on the side	3*10
	Shoulder Horizontal Extension and Scapular Retraction	Sitting	3*12
4/ Improvement phase	I to T/ Dynamic	Prone	3*12
	T to Y/ Dynamic	Prone	3*12
	T to Y to W/ Dynamic	Prone	3*12
	Shoulder Abduction (Right and Left)	Lying on the side	3*12
	Shoulder Horizontal Extension and Scapular Retraction	Sitting	3*12
	Shoulder Extension and Scapular Retraction	Sitting	3*12
5/ Improvement phase	I to T/ Dynamic/ Dumbbell	Standing	3*8
	T to Y/ Dynamic/ Dumbbell	Standing	3*8
	T to Y to W/ Dynamic/ Dumbbell	Standing	3*8
	Shoulder Horizontal Extension and Scapular Retraction/ Thera band	Sitting	3*8
	Shoulder External rotation/ Dynamic/ Dumbbell	Lying on the side	3*8
6/ Improvement phase	T to Y/ Dynamic/ Dumbbell	Standing	3*12
	T to Y to W/ Dynamic/ Dumbbell	Standing	3*12
	Shoulder External rotation/ Dynamic/ Dumbbell	Lying on the side	3*12
	Shoulder Horizontal Extension and Scapular Retraction/Thera band	Sitting	3*12
	Brugger Exercise (Shoulder Horizontal Extension with extend elbow) / Thera band	Sitting	3*12
7/ Maintenance phase	I to T/ Dynamic	Prone/ On physio-ball	3*10
	T to Y to W/ Dynamic	Prone/ On physio-ball	3*10
	Shoulder External rotation/ Dynamic/ Dumbbell	Sitting	3*12
	Simultaneous abduction of arms up to 90 degrees	Standing	3*10
	Shoulder Oblique Flexion (Right and Left)/ Dynamic/ Dumbbell	Standing	3*10
8/ Maintenance phase	I to T/ Dynamic	Prone/ On physio-ball	3*12
	T to Y/ Dynamic	Prone/ On physio-ball	3*12
	T to Y to W/ Dynamic	Prone/ On physio-ball	3*12
	Simultaneous abduction of arms up to 90 degrees	Standing	3*12
	Shoulder Oblique Flexion (Right and Left)/ Dynamic/ Dumbbell	Standing	3*12

3. Results

3.1. Demographics

Descriptive information about the demographic characteristics of each group and the independent t-test results are presented in Table 2. The results showed that the demographic information was the same in the groups and there was no significant difference between the groups in the average age, height, weight and body mass index (P>0.05). Additionally, 40.8% of the participants were in the seventh class, 18.4% were in the eighth class, and 40.8% were in the ninth class.

Table 2: The results of an independent test to compare the demographic information of the subjects

Variable	Mean±SD		P*
	Experimental Group	Control Group	
Age (years)	14±0.97	13.96±0.80	0.873
Height (cm)	161.42±6.47	161.33±5.58	0.962
Weight (kg)	55.08±9.15	55.42±5.88	0.881
BMI (kg/m^2)	21.08±2.93	21.32±2.02	0.738

SD=Standard Deviation; BMI=Body Mass Index. *P value was taken from independent t-test.

3.2. Alignment

The results of paired t-test comparisons demonstrate that degrees of FHP (P=0.001), FSA (P=0.001), and kyphosis (P=0.001) decreased in the experimental group from pre-test to post-test (P<0.05). However, there was no significant changes in the control group (P>0.05; Table 3).

3.3. Y-Balance Test (cm)

The results of paired t-test comparisons showed that the functional stability in the directions of R/Total (P=0.042), R/ANT (P=0.039), L/Total (P=0.032), and L/PL (P=0.044) were significantly better in the post-test as compared with the pre-test in the experimental group after scapula stabilization intervention (P<0.05); but there were no significant result in directions of R/PL (P=0.769), R/PM (P=0.582), L/ANT (P=0.101), and L/PM (P=0.398) from pre-test to post-test in the experimental group. Also, paired comparisons of the control group showed that there was a significant decrease in functional stability from pre-test to post-test in directions of R/Total (P=0.001), R/ANT (P=0.010), R/PL (P=0.001), L/Total (P=0.001), L/ANT (P=0.014), and L/PM (P=0.009); However, no significant changes were observed in the directions

Table 3: The results of paired t-test to compare the alignment, functional stability, and proprioception

Variable	Experimental Group (Mean±SD)					Control Group (Mean±SD)				
	Pre-test	Post-test	Difference (95%CI)	P	Percent of Changes	Pre-test	Post-test	Difference (95%CI)	P	Percent of Changes
Alignment (degree)										
FHP	49.46±4.38	43.50±3.57	5.96 (4.21,7.70)	0.001*	%12.05↓	50.71±4.73	51.46±4.67	- 0.75 (-1.86,0.36)	0.178	%1.47↑
FSA	51.96±2.21	45.25±3.32	6.71 (5.01,8.40)	0.001*	%12.91↓	52.54±2.20	52.88±2.96	- 0.34 (-1.47,0.81)	0.553	%0.62↑
Kyphosis	49.66±5.44	44.50±5.67	5.16 (3.05,7.27)	0.001*	%10.39↓	49.08±5.58	50.56±7.36	- 1.48 (-3.17,0.22)	0.086	%3.01↑
Y-Balance Test (cm)										
Total / Right Hand	81.86±9.79	83.19±9.99	- 1.33 (-3.56,-0.91)	0.042*	%1.62↑	78.77±7.27	76.97±6.79	1.8 (1.03,2.56)	0.001*	%2.28↓
ANT / Right Hand	65.07±9.70	68.60±9.86	- 3.53 (-6.84,-0.19)	0.039*	%5.42↑	67.61±11.42	65.70±10.22	1.91 (0.50,3.31)	0.010*	%2.82↓
PM / Right Hand	100.90±13.45	101.75±15.81	- 0.85 (-4.98,3.28)	0.675	%0.84↑	92.02±9.13	90.87±8.80	1.15 (-0.55,2.86)	0.176	%1.24↓
PL / Right Hand	79.61±11.39	79.22±10.45	0.39 (-2.32,3.10)	0.769	%0.48↓	76.69±7.47	74.35±6.98	2.34 (1.19,3.47)	0.001*	%3.05↓
Total / Left Hand	82.28±9.74	84.54±7.48	- 2.26 (-4.31,-0.20)	0.032*	%2.74↑	74.16±6.17	72.65±5.79	1.51 (0.70,2.31)	0.001*	%2.03↓
ANT / Left Hand	66.80±12.30	69.73±10.35	- 2.93 (-6.47,0.61)	0.101	%4.38↑	62.56±7.91	60.81±7.48	1.75 (0.38,3.11)	0.014*	%2.79↓
PM / Left Hand	99.39±14.48	100.91±13.34	- 1.52 (-5.16,2.12)	0.398	%1.52↑	88.21±11.00	86.38±10.51	1.83 (0.50,3.16)	0.009*	%2.07↓
PL / Left Hand	80.64±10.05	82.97±8.95	- 2.33 (-4.59,-0.06)	0.044*	%2.88↑	71.71±6.62	70.76±7.11	0.95 (-0.33,2.22)	0.140	%1.32↓
Joint reposition error (degree)	7.12±3.82	5.14±3.19	1.98 (1.07,2.89)	0.001*	%27.80↓	7.08±3.45	6.56±3.11	0.52 (-0.24,1.29)	0.174	%7.34↓

SD: Standard Deviation; FHP: Forward Head Posture; FSA: Rounded Shoulders Angle; ANT: Anterior; PM: Posterior Medial; PL: Posterior Lateral; RH: Right Hand; LH: Left Hand of R/PM (P=0.176), L/PL (P=0.140) of the control group (Table 3).

3.4. Proprioception (degree)

The result of paired t-test comparisons showed that shoulder proprioception increased significantly from pre-test to post-test in the experimental group (P=0.001); However, there were no significant differences between pre- and post-test measurements in the control group (P=0.174; Table 3).

4. Discussion

The present study aimed to investigate the effect of scapula stabilization exercises on the alignment, sense of position, and functional stability of the upper limb in adolescent girls with UCS. The results of the research showed that in the experimental group, after performing the exercises, there was a significant improvement in FHP, FSA and kyphosis angles, functional stability, and sense of shoulder joint position.

According to the results, in the experimental group, the FHP angle decreased by 12.05%, FSA by 12.91%, and kyphosis by 10.39%. This is while the trend of changes in the control group was constant or increasing. Stabilization of the scapula by activating the middle and lower trapezius and serratus anterior improves the physical condition; thus, it can be said that the intervention has a positive effect on the alignment of the head, neck, and spine by strengthening the mentioned muscles (10). Also, stability exercises by activating the cervical stabilizing muscles are effective in returning stability to the cervical spine and ultimately leads to the stability of the mentioned region. The reason for the effect of the exercises on all postures that occurred in this abnormality (FHP, FSA, and kyphosis) can also be considered that, according to Janda approach, muscles are connected through myofascial tissue and increase or a decrease in the activity of one muscle affects other muscles in other areas as well (4). Therefore, in the present study, with the improvement of the supporting muscles of the shoulder, there were positive changes in each of the deformities of FHP, FSA, and kyphosis.

The statistical results related to functional stability showed a significant improvement and increase in the experimental group and a significant decrease in the control group. More precisely, the experimental group showed a significant improvement in their total score and ANT direction of the right hand, as well as their left total score and PL direction of the left hand. However, no significant changes were observed in the PM and PL directions of the right side and the ANT and PM directions of the left side of this group. Accordingly, the total functional stability has increased in both sides and there have been more changes in the non-dominant side. Although the values recorded for the non-dominant limb were slightly higher than the values recorded for the dominant limb, this difference is not significant. One possible explanation for the finding may be linked to the dominant hand's more extensive range of motion. Also, according to the results of the functional stability test, in both the experimental and control groups, as well as in both the dominant and non-dominant sides, the highest scores were obtained in the directions of PM, PL, and ANT, respectively. In this regard, previous studies also reached similar results (19, 24). Given the position of the reaching hand, it is clear that the person performs better in the posterior-medial direction which is on the reaching side. In the posterior-lateral direction, the person makes a moderate reach using the rotation of the body. But in the anterior direction, due to being further away from the hand and the inability of the person to use the body rotation, a lower reach score is obtained. In general, the stability and strength of a person's upper body may affect the potential to activate muscles in a more coordinated manner and produce more force (24). Therefore, it is obvious that by strengthening the stabilizing muscles of the scapula, the stability in this area increases and the participants have better functional stability in the YBT-UQ test. When performing this test, the upper limb is placed in a weight-bearing position and moves the center of mass towards itself, creating a greater need for proprioceptive information in the shoulder joint (19, 25). The compression of the soft tissues around the shoulder during weight bearing can change the shape of the local mechanical receptors, including the proportion receptors, and thus increase the sense of proprioception. Therefore, the results of the present study showed that there is a possible relationship between proprioception and motor control of the upper limb, which is consistent with the studies of Ager and colleagues and Guirelli and co-workers (26, 27).

The angle reconstruction error, which measures the shoulder joint position sense, decreased by 27% in the experimental group and by 7% in the control group. This shows that the experimental group improved their proprioception more than the control group. This study used the angle reconstruction test at the end range of the external rotation movement to measure the shoulder joint position sense. The rationale for this choice was that frequent rotation movements of the shoulder enhance perceptual learning, signal processing accuracy, and movement sense. Repeated rotational movements in rehabilitation may also create neuromuscular adaptations that counteract the factors that disturb shoulder stability (28). Moreover, posture awareness may improve the proprioception and movement control of the shoulder girdle (28). The training period may also induce neuromuscular adaptation and posture recovery, which improve the proprioceptive mechanisms. As the muscle activity level increases, the stimulation level of the muscle spindles and Golgi tendon organs also increases, which improves the sensory perception of the area (10). Since the shoulder joint health depends on the joint proprioception, the progressive abnormality in UCS may be due to the proprioceptive impairment of this joint. Therefore, the improvement of proprioception in the experimental group suggests that the stability exercises used in this study were effective. Scapular stability exercises aim to restore the position, movement control, stability and strength of the shoulder muscles, and to maintain and restore the proper position of the shoulder.

4.1. Limitations

There were a few limitations in this study including short duration of the intervention, and lack of follow-up. Future studies should address these limitations and examine the long-term effects and underlying mechanisms of scapular stabilization exercises on UCS. It is also recommended that future studies investigate the effects of these exercises on adolescent boys with UCS, as there may be gender differences in the response to the intervention. Despite these limitations, the findings of this study provide valuable insights into the potential benefits of scapular stabilization exercises for improving alignment and functional stability in adolescent girls with UCS. Further research is needed to confirm these findings and to explore the long-term effects of this intervention on these outcomes.

5. Conclusions

This study investigated the effect of scapular stabilization exercises on the alignment, joint position sense, and functional stability of the upper limbs in adolescent girls with UCS. The results showed that the experimental group, who performed scapular stabilization exercises for eight weeks, had significant improvements in all the outcome measures compared to the control group, who received no intervention. These findings suggested that scapular stabilization exercises can be an effective intervention for improving alignment, joint position sense, and functional stability of the upper limbs in adolescent girls with UCS. These improvements can have positive effects on the prevention and treatment of UCS and its associated problems, such as pain, dysfunction, and injury, in adolescent girls.

Authors' Contribution

Maryam Nemati: Substantial contributions to the conception of the work, analysis of data for the work, and drafting the work. Farzaneh Saki: Substantial contributions to the conception of the work, analysis of data for the work, drafting the work, and reviewing it critically for important intellectual content. Farzaneh Ramezani: Analysis of data for the work, reviewing it critically for important intellectual content. All authors have read and approved the final manuscript and agree to be accountable for all aspects of the work, such as the questions related to the accuracy or integrity of any part of the work.

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Ethical Approval

Ethics approval was obtained by the ethics committee of Bu Ali Sina University in Hamedan with the code of IR.BASU.REC.1401.024. Also, the clinical trial was accepted by the Iranian Clinical Trials Registration Organization with the code of IRCT20221215056827N1. Also, written informed consent was obtained from the participants.

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