The Effect of Corrective Exercise on Spatiotemporal Components and Gait Patterns of Adolescents with Upper Cross Syndrome

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Abstract

The aim of this study was to investigate the effect of corrective excercise on the gait components of adolescents with upper crossed syndrome (UCS). A total of 30 teenage boys were selected as the targeted sample and divided into two groups randomly: control and experimental. The inclusion criteria were, having forward head, forward shoulder and kyphosis angles greater more than 50, 50 and 40 degrees respectively. Clinical evaluations and biomechanical investigations, including posture and gait analysis with a 3D-scanner and mocap system, were conducted before and after the eight-week training period. The results showed significant differences in step length (*P*=0.017), cadence (*P*=0.040) and symmetry (*P*=0.000) due to the implementation of corrective exercise. Furthermore, significant changes were observed in pelvic rotation (0.006), hip flexion at heel-contact (0.003), hip flexion and abduction (0.030), and peak knee flexion in stance phase (0.001), and knee flexion (0.000) and rotation (0.000) in swing pahse. These findings highlight the effectiveness of corrective exercises in improving posture and gait patterns in adolescents with UCS. Further research is needed to explore long-term effects and potential benefits for other populations.

Keywords: Corrective Exercise; Gait; Spatio-Temporal; Kinematics; Upper Crossed Syndrome

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Introduction

Having a healthy society is a crucial issue that needs to be addressed for all of us. Many factors, such as genetics, environment, and lifestyle, impact on human health. Technological advancements have made daily tasks easier but have also led to negative effects on it like lack of movement, sedentary life style, and weight gain. These factors and incorrect habits can cause physical abnormalities in both upper and lower limbs. Muscle imbalances from repetitive overhead activities can affect upper body posture, leading to shoulder pain (1). Children may also experience muscle imbalances due to prolonged incorrect body positions in school and an unhealthy lifestyle. This can result in a condition called UCS (2). Vladimir Janda explained that the scapula bone plays a significant role in this syndrome, causing changes in muscle stiffness and position (3). For correcting this kind of structural disorders, exercise, and rehabilitation programs should be designed in an organized and targeted manner. In recent years, various training approaches have been utilized to correct UCS and its associated disorders, including kyphosis, forward shoulder, and forward head. Haji Hosseini et al. conducted a study using three types of stretching, strength, and combined exercise programs to correct UCS (4). They showed that doing combined exercises was more effective in correcting forward head and kyphosis. Other researchers have used auxiliary tools such as whole-body vibration devices or environments like swimming pools to design exercises for correcting the UCS (5). Javazi *et al.* (6)and Ahmadi *et al.* (7) recorded the positive effects of each of these methods. Some researchers investigated the effectiveness of exercising other parts of the body in correcting the UCS. For example, Rostami et al. used three training processes of lower body, upper body, and combined to correct the UCS (8). They concluded that doing combined exercises was more effective in correcting this syndrome. Although at first glance, exercising other parts of the body may not seem very logical in correcting UCS, different parts of the spine are connected to each other by means of a system of seals; therefore, a change in one area may affect other areas in the form of chain reactions (9). In this form, the posterior pelvic tilt causes a decrease in lumbar lordosis angle, an increase in kyphosis angle and finally causes a forward head problem. Postural abnormalities are generally caused by weakness in the muscles that support the spine, disrupting static, dynamic, and upright balance (10). Kyphosis also disturbs balance and changes the position of the center of gravity.

Changes in position can affect different organs and joints in relation to each other (11) and can affect movement patterns and gait. Walking is important for moving from one place to another (12). The foot is directly affected by changes in position and movement of the upper body during walking (13). Compensatory movements occur when there are structural or functional abnormalities in nearby joints (14). Several studies have looked at how upper body disorders affect walking patterns (15-18). One study evaluated the effect of unknown scoliosis on the spatiotemporal factors of gait in adolescent girls(15). However, the researchers did not find the effect of scoliosis on the spatiotemporal gait indices. Another study compared the walking characteristics of students with lumbar hyperlordosis deformity with their healthy subjects and found that the lumbar hyperlordosis deformity caused changes in the center of mass during walking (16). Other study on people with thoracic kyphosis found that upper body strength training had a significant effect on walking parameters (17). Another study compared the gait kinematics of students with UCS abnormalities with their healthy subjects and found that UCS led to a decrease in hip joint movement, which affected other kinematic factors (18).

UCS is a common postural disorder that affects the upper body, including the neck, shoulders, and chest. Although there have been studies on the movement pattern of people with this syndrome, but they have not been conducted on children and teenagers. Additionally, the effect of organized corrective exercises on various components related to the gait pattern of people with UCS have not been observed in any study. Moreover, no distinct investigation expressed the effect of organized corrective exercises on various components of Gait pattern in people with UCS.

Materials and Methods

This study was approved by ethics commite of Islamic Azad Univrsity (IR.IAU.CTB.REC.1400.109) after obtatining the ethical code to select the samples of this study, 200 male adolescents who were in the age range of 11 to 15 years with upper extremity disorders were identified and introduced from rehabilitation and correctional movement centers in 2019. In order to determine the number of subjects, G Power 3.1 software and considering statistical power 0.8 and effect size of 0.5 and alpha level 0.05 were considered and the sample size obtaind as 30. Subjects were selected by convenient and purposeful simple sampling method and randomly and equally, divided into experimental and control groups. (The inclusion criteria of the study were as follows: having a forward head and forward shoulder deformity greater than 50 degrees and a kyphosis angle greater than 40 degrees. participants who had the presence of symptoms related to a history of fracture, surgery, or joint diseases of the spine, pain in the neck or upper limb, and inability to complete the exercise program were excluded from study. Additionally, having a history of injury in the last six months, surgery on the lower body, or any complication or defect that leads to disturbance in walking and maintaining balance were also considered as criteria for exiting the program due to their potential impact on gait analysis. To record the kyphosis angle, we used the spine analysis system manufactured by Rasa Pejohan Company in Iran. This tool quantitatively estimates upper limb abnormalities such as kyphosis by scanning the back surface and analyzing its topographic map. We also used reflective markers and HP COSMOS treadmill in conjunction with Optitrack V120 Duo 3D motion capture system made in USA with VGA resolution (480*640) for measuring subjects' gait kinematic factors. The accuracy of this system is less than 0.1 mm.

The process of data collection started with familiarizing all subjects with the purpose of study and filling the informed consent by participants. We recorded the demoghraphic charachteristics of the participants using a relevant questionnaire and measured subjects' weight and height by Digital scale and wall meter respectively. The steps of data collection included the analysis of the three angles of kyphosis, forward head and forward shoulder, and then upper body posture evaluations and gait analysis using the posture analysis system, motion capture and treadmill.

Table 1. Individual and demographic information of subjects

Variable	Experimental group	Control group	*P*-value
	Mean (SD)		
Age (years)	13.1 (1.5)	13.2 (2.1)	0.877
Height (cm)	153.1 (1.6)	153.1 (9.6)	0.155
Weight (kg)	40.9 (7.2)	45.9 (8.7)	0.060
BMI	17.3 (2.1)	18.2 (7.2)	0.235

Table 2. Mean and standard deviation of head forward, shoulder forward and kyphosis evaluations in pre-test and post-test in both control and experimental groups

Variable	Groups	Pre	Post	*P*-value (Within Groups)	*P*-value (Between Groups)
Forward Head (ang)	Experimental	54.8 (0.0)	49.5 (4.7)	0.001*	**0.037***
	Control	56.8 (5.6)	56.9 (0.8)	0.706	
Forward shoulder (ang)	Experimental	55.8 (6.5)	51.7 (6.0)	0.002*	**0.073**
	Control	57.7(2.4)	57.8 (1.4)	0.871	
Kyphosis (ang)	Experimental	45.1 (5.1)	39.9 (1.9)	0.000*	**0.012***
	Control	46.6(4.2)	47.7 (2.1)	0.814	

After conducting the posture evaluations, the subjects were prepared for gait analysis on the treadmill. Initially, a general warm-up was performed on the treadmill for 5 minutes at a desired rhythm to ensure uniform heating conditions for all participants. This step not only served to warm up the test but also aimed to bring the normal walking pattern of individuals closer to the gait pattern on the treadmill. Following this, reflective markers were attached to lower body organs using the cluster method. Next, subjects were asked to stand anatomically on the treadmill and in front of a motion capture device to take static data. Before data collection, seven rigid bodies (local coordinate device) resulting from cluster markers on pelvic, hip, leg, and left and right leg were defined in Motive software. The previously set desired speed of the treadmill was then initiated and subjects were instructed to walk at their normal pace while data acquisition took place for at least one minute with a data acquisition speed of 120 frames per second. This ensured that at least 10 full gait cycles of walking were recorded. To ensure accuracy and reliability, this process was repeated three times. Motion data acquisition was conducted to extract kinematic factors during the entire test. The motion information obtained from gait analysis was smoothed using 4th-order Gossin and Butterworth filters with a cutoff frequency of 16 Hz before undergoing inverse kinematics processing and being converted into joint angles. Following the pre-test, the experimental group underwent 8 weeks of corrective exercises related to UCS (Appendix 1). The exercises were performed daily for 60 minutes per session, consisting of 10 minutes warm-up, 45 minutes of selected exercise programs, and 5 minutes cool-down. The duration and number of repetitions were increased during the exercise.

Statistical analysis

In this research, descriptive statistics were used to present the mean and standard deviation, and inferential statistics were used to analyze the data. Shapiro-Wilk test was used to determine the normality of data distribution, while paired t-test, ANCOVA, and LSD post-hoc test was utilized to compare groups before and after the exercise protocol. A significance level of 0.05 considered in all tests. MATLAB (2020) statistical analysis toolbox was used for processing and examining statistical differences between results.

Results

Table 1 shows the demographic information of subjects. As it is evident, no statistically significant difference was observed between the demographic information of the two experimental and control groups (P>0.05).

Table two shows the changes of the three abnormalities of forward head, forward shoulder, and kyphosis, which are among the most important factors that cause UCS complications. As can be seen, performing corrective exercises reduces the head forward complication in the subjects of the experimental group by nearly 9%, which has led to a statistically significant difference (P=0.001). The evaluation of the forward shoulder showed that corrective exercises had an acceptable effect on the values of this complication, and the effect of corrective exercises was statistically significant (P=0.002). Kyphosis was another complication that was evaluated using the Posture analysis system. The results of this evaluation showed that corrective

Table 3. Statistical comparison of spatial-temporal factors of gait in two control and experimental groups in two stages of pre-test and post-test

Variable	Groups	*P*-value (Within Groups)	*P*-value (Between Groups After Intervention)
Step Length	Experimental	0.017*	0.556
	control	0.703	
Step Width	Experimental	0.253	0.749
	control	0.981	
Cadence	Experimental	0.040*	0.083
	control	0.540	
Speed	Experimental	0.144	0.004*
	control	0.205	
Symmetry	Experimental	0.078	0.127
	control	0.765	
Stance Phase	Experimental	0.000*	0.018*
	control	0.410	

Table 4. Mean (SD) and significant difference evaluation of kinematic factors of pelvic, hip, knee and ankle during gait in experimental and control groups

Variable	Groups	Pre	Post	*P*-value (Within Groups)	*P*-value (Between Groups)
Pelvic A-P Tilt ROM (Deg)	Experimental	3.0 (8.8)	4.1 (8.4)	0.123	0.089
	control	3.0 (8.5)	3.0 (7.6)	0.248	
Pelvic Lateral Tilt ROM (Deg)	Experimental	4.1 (6.8)	5.1 (1.6)	0.565	0.359
	control	4.1(5.6)	4.1 (4.6)	0.644	
Pelvic Rot ROM (Deg)	Experimental	7.0 (1.8)	8.1 (4.3)	0.006*	0.001*
	control	6.0(9.9)	7.1 (9.0)	0.517	
Hip Flx in Heel Contact (Deg)	Experimental	19.6 (8.9)	14.3 (9.6)	0.003*	0.045*
	control	20.4 (2.9)	20.6 (6.1)	0.490	
Peak Hip Hyper Ext (Deg)	Experimental	-9.5 (1.3)	-10.3 (8.9)	0.271	0.369
	control	-9.5(4.4)	-9.5 (2.0)	0.357	
Hip Flx -Ext ROM (Deg)	Experimental	39.4 (2.4)	36.3 (1.4)	0.030*	0.045*
	control	37.3(6.2)	38.3 (9.7)	0.329	
Hip Abd -Add ROM (Deg)	Experimental	11.2 (9.5)	14.1 (7.8)	0.000*	0.000*
	control	10.2 (7.6)	10.3 (8.2)	0.737	
Hip Rot ROM (Deg)	Experimental	13.3 (8.3)	14.3 (6.6)	0.254	0.571
	control	13.2(6.4)	13.3 (9.3)	0.522	
Knee Flx in Heel Contact (Deg)	Experimental	0.2 (11)	-0.3 (8.4)	0.143	0.276
	control	0.2(5.5)	0.2 (4.4)	0.517	
Peak Knee Flx in Stance (Deg)	Experimental	9.6 (3.2)	19.6 (9.3)	0.001*	0.002*
	control	11.5 (9.3)	11.5 (7.4)	0.482	
Peak Knee Flx in Swing (Deg)	Experimental	54.5 (3.4)	60.4 (4.4)	0.001*	0.001*
	control	51.6 (0.1)	51.8 (9.2)	0.373	
Knee Flx -Ext ROM (Deg)	Experimental	53.5 (5.7)	61.4 (2.9)	0.000*	0.005*
	control	51.5(6.1)	51.6 (0.1)	0.341	
Knee Val -Var ROM (Deg)	Experimental	9.4 (8.2)	11.2 (1.2)	0.083	0.181
	control	9.3 (6.1)	9.2 (8.9)	0.535	
Knee Rot ROM (Deg)	Experimental	55.8 (6.5)	51.7 (6.0)	0.000*	0.000
	control	16.2 (7.6)	21.2 (8.9)	0.560	
Ankle Ang in Heel Contact (Deg)	Experimental	-4.5 (2.3)	-0.7 (6.2)	0.074	0.414
	control	-2.4(6.6)	-2.4 (4.5)	0.467	
Peak Plantar (Deg)	Experimental	-12.4 (6.1)	-15.5 (4.7)	0.194	0.626
	control	-14.3 (1.3)	-14.4 (5.0)	0.404	

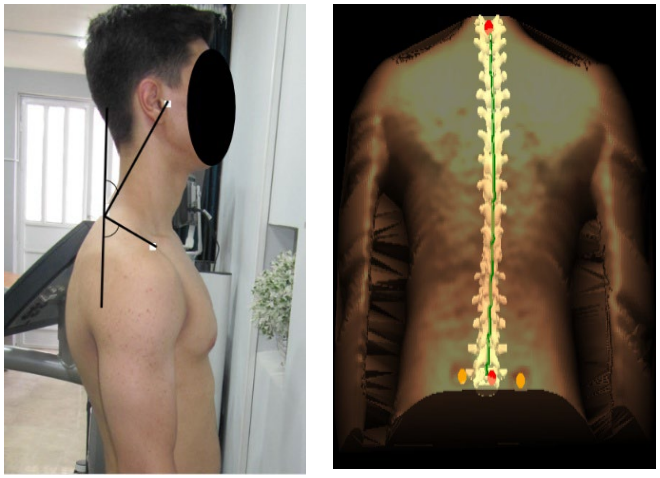

Figure 1: The output of the posture analysis system to calculate the kyphosis angle (right) and marking to calculate the forward head and forward shoulder angle with the optical motion recording system (left))

Figure 2: Static and dynamic data collection from subjects' gait on treadmill

exercises have led to a 5-degree reduction in the average kyphosis (*P*=0.000). In addition, this change has led to a statistically significant difference in the pre-test and post-test stages (*P*=0.012).

Figure 3 shows a selection of spatial-temporal factors of gait in two experimental and control groups. Step length is one of the important spatial-temporal factors that is related to height in normal gait conditions. The results of this graph indicate a seven percent increase in step length in the experimental group. According to table three, the changes made in the step length of the experimental group after the intervention were statistically significant (*P*<0.05). This is while no significant statistical difference was observed within the control group (*P*>0.05) and between the experimental and control groups in the post-test (*P*>0.05).

Another spatiotemporal factor related to the ability to control balance in many cases is step width. As it is obvious, the step width values of the subjects in all stages and groups are close to 15 cm and no statistically significant difference is observed between the comparisons made for the step width (*P*>0.5). Cadence or stepping frequency is another spatiotemporal factor investigated in this research. Figure 3 shows that the subjects' stepping frequency or cadence of the normal gait pattern. The decrease in cadence values in the experimental group can be related to the increase in step length of the mentioned group.

Table 3 shows the statistical comparison for this component, according to which a statistically significant difference is observed before and after the training period in the experimental group (*P*<0.05). In this research, the subjects' preferred speed was used to perform gait analysis. The results of graph one show that the experimental group, unlike the control group, preferred a higher walking speed in the post-test stage (*P*>0.05). Although this increase in speed did not lead to a statistically significant difference within the group, according to table three, a statistically significant difference is observed between the experimental and control groups in the post-test stage (*P*<0.05). The percentage of different phases of cycle gait was one of the other spatiotemporal factors investigated in this study. It is worth mentioning that the subjects of the experimental group showed a decrease of one and a half percent in this component after the training intervention, however, no statistically significant difference was observed in the pre-test and post-test (*P*<0.05). Stepping symmetry is the last spatiotemporal component that has been investigated in this research. In the present study, two factors of step length and left and right step time model were used to check the symmetry of stepping. Figure 3 shows the values of this parameter. Although the presence of symmetry less than 90% is not considered favorable, it is quite evident that the experimental group left a more favorable gait symmetry in the second place of the test. This approximately 4% increase in stepping symmetry has led to a statistically significant intra-group difference in the experimental group and between groups in the post-test stage (*P*<0.05).

Figure 4, shows the kinematics of the lower body joints of the experiment tal group normalized according to the gait cycle in the pre-test and post-test stages. Table 4 also show the mean and standard deviation and the evaluation of the statistical difference in the two experimental and control groups. As can be seen in the graphs related to the pelvis, the amplitude of the oscillations of the anterior tilt of the pelvis before and after the intervention was not significantly different and no significant difference was observed.

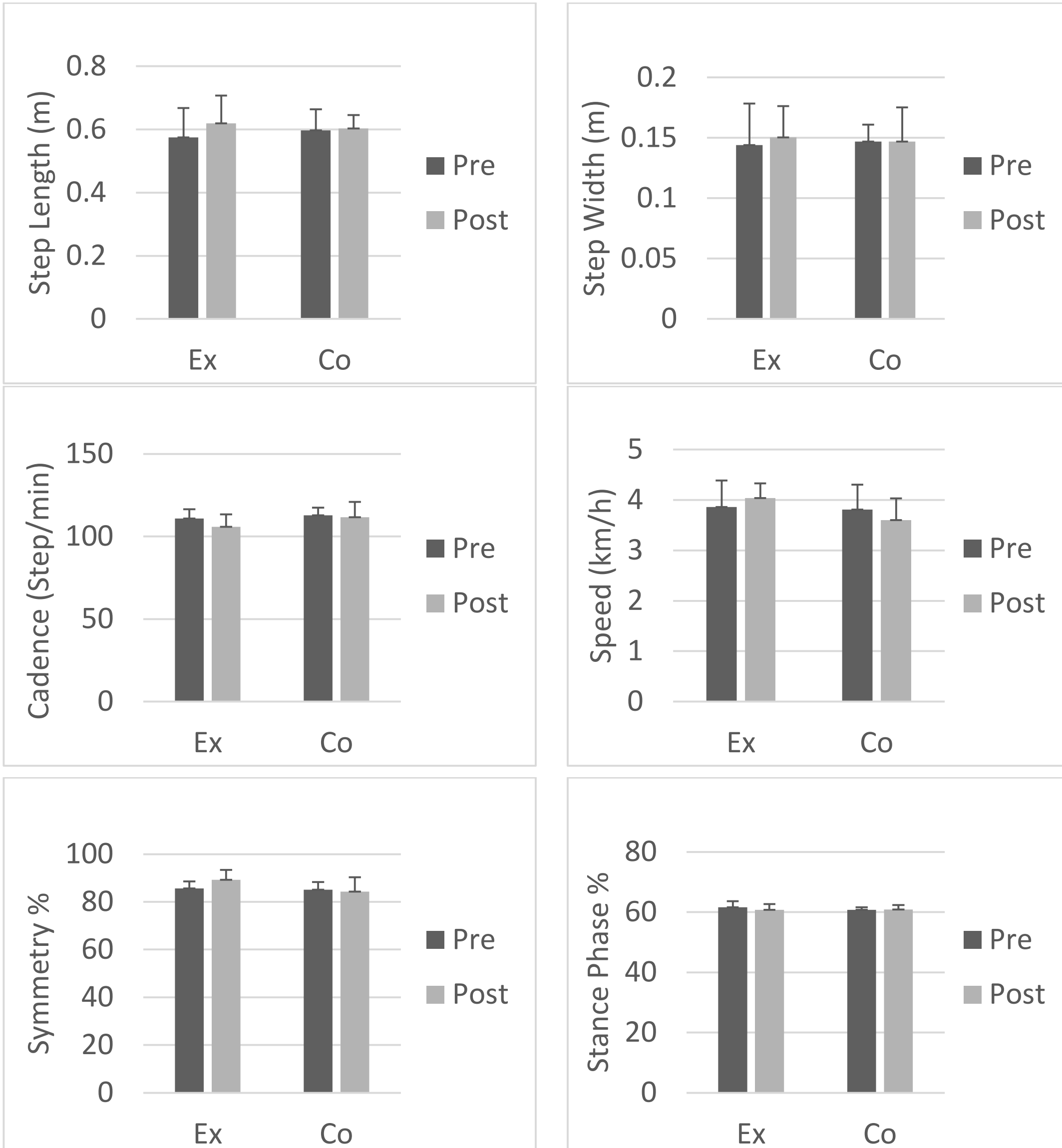

Figure 3. Mean (SD) of spatio-temporal factors of gait in two control and experimental groups in two stages of pre-test and post-test

In addition, the range of hip oscillations of the subjects in both stages was very similar to the normal gait pattern. Also, the amplitude of lateral pelvic tilt oscillations was relatively equal in two stages and no significant difference was observed between them. In relation to the amplitude of hip rotation fluctuations, there was a difference of about 18% between the experimental group in the pre-test and post-test, and these values led to a statistically significant difference between the two groups.

In relation to the hip joint, the average flexion at the moment of heel strike was very close. However, there was a statistically significant difference between the two stages ($P<0.05$). No statistically significant difference was observed regarding hip hyperextension ($P<0.05$). Also, the examination of the sagittal and frontal range of motion of the hip showed that there is a statistically significant difference in the pre-test and post-test ($P<0.05$) and between the experimental and control groups ($P<0.05$).

In relation to the movements of the knee joint during the gait cycle, statistically significant differences are observed in the maximum flexion in two phases of stance and swing and the range of motion of knee flexion ($P<0.05$). Also, in the range of motion of the knee rotation, statistically significant differences are observed between the two groups and the two stages of pre-test and post-test ($P<0.05$). The results of the statistical comparison of the components related to the wrist joint showed that no statistically significant difference was observed between the two control and experimental groups and in the two stages of the test ($P>0.05$).

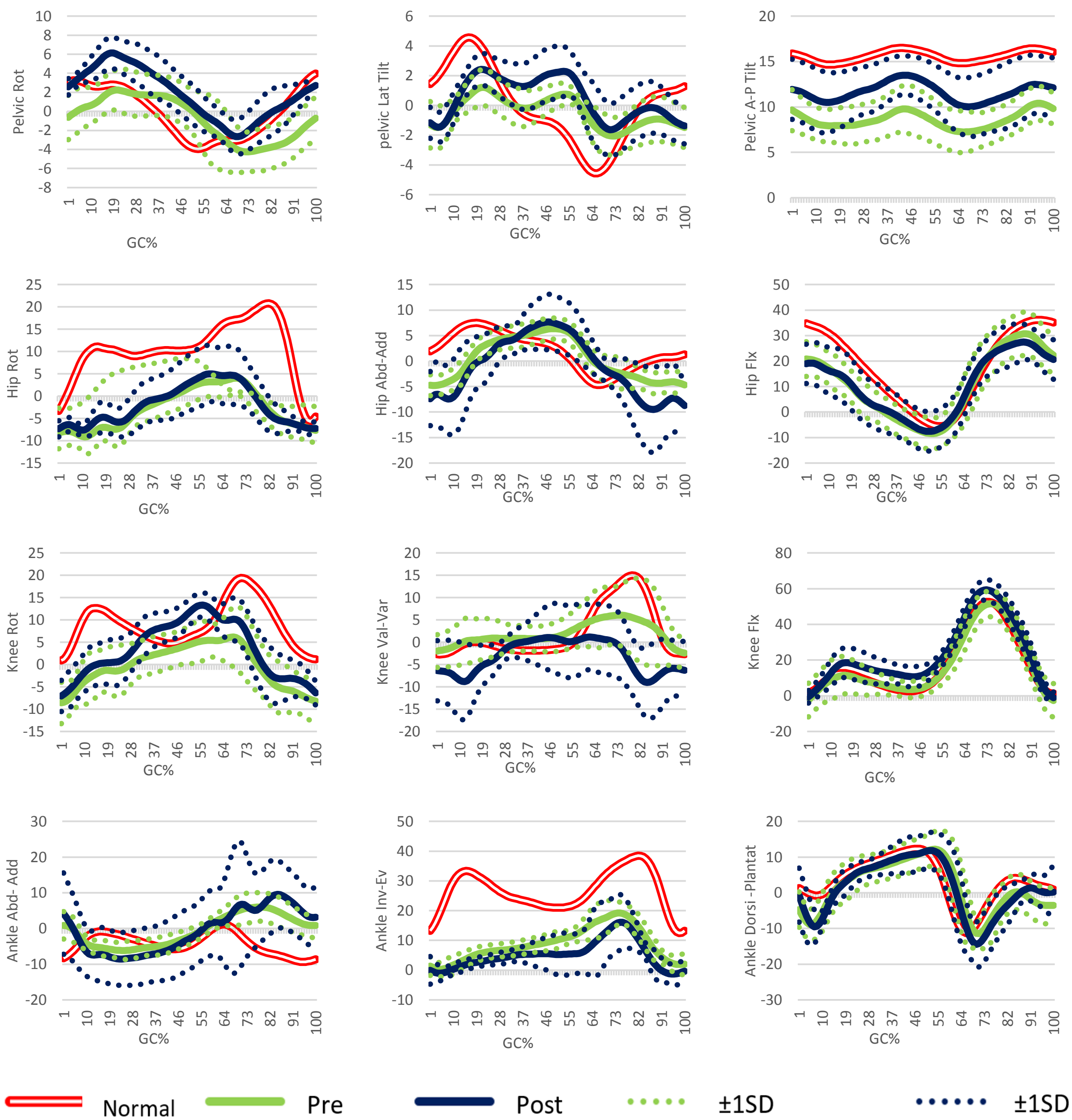

Figure 4: Kinematics of the hip, hip, knee and wrist joints of the subjects of the experimental group in three motion planes normalized according to the gait cycle. The continuous lines of the average movement pattern of the subjects and the dotted lines are positive and negative one mean (SD)

Discussion

The aim of this study was to investigate the effect of an eight-week training period of corrective exercise on the parameters related to the gait pattern of male adolescents with UCS. The body's chain structure and the potential for a compensatory mechanism resulting from the UCS necessitate the evaluation of spatiotemporal factors in gait, a quick and effective method for gait examination. Stride length, stride width, cadence, preferred speed, stance phase percentage, and stride symmetry were selected spatiotemporal factors that were investigated. In this regard, Kirtley (2006), stated that the length of a stride, which includes two consecutive steps, is in the range of 1.4 to 1.6 meters in men and 1.3 to 1.5 meters in women (18). These values are considered for the average of the society, and as a rule, the existence of differences in anthropometric characteristics (gender), especially in the length of the legs, which has a relatively direct relationship with height, can affect the step length factor.

Wellsandt *et al.* (19), considered the effect of body dimensions on the stride length factor and expressed the value of 0.8 height length as a criterion for estimating stride length. As a result, a person with 170 cm high should probably have a stride length of 68 cm. The results of the step length factor analysis in the pre-test and post-test showed that the step length of the experimental group in this study increased by about 7% after corrective exercises. Considering the relationship between height and stride length, the ideal stride length for the experimental group is more than 61 cm. This is while this group had a stride length of 57 cm in the pre-test stage, which reached nearly 62 cm after the corrective protocols. In a study that investigated the effect of corrective exercises on the gait parameters of kyphotic elderly people, found that doing these exercises has an effect on stride length.

Based on this, despite the differences between studied groups suffering from USC and Kyphosiss, it can be said that the results of s were consistent with each other. Sawant & Patil (16) investigated the effect of upper body strength training on the spatiotemporal parameters of stride length and stride in people with thoracic kyphosis. The results of this study were showed the positive effect of upper body corrective exercises on the stride length index.

In another study, Yazdani *et al*. (20) investigated the effect of idiopatic scoliosis on spatiotemporal gait factors of teenage girls and found that there is no significant difference between the stride length of the scoliosis group and the healthy group. These results were different from the findings of the present study. Although Yazdani *et al*., (20) did not investigate the effect of an exercise program and only compared two healthy and scoliosis groups, it seems that the lack of significant difference between the two impaired and healthy groups in step length is related to the nature of the complication (20). In other words, it can be said that the difference between the two healthy groups and those with scoliosis is in the left-right or mediolateral direction, but the step length component changes in the Forward-Backward direction. With the same argument, it can probably be said that in the present study, considering that the complication of the UCS leads to changes in the Forward-Backward direction of the upper limb, its modification can have an effect on the stride length, which is a component in the Forward-Backward direction.

Another spatiotemporal parameter that was evaluated in this study was stride width. Several studies emphasized the existence of a relationship between step width and dynamic balance. Young & Dingwell (2012), considered the increase in step width as a factor in increasing the value of the balance margin (an index related to dynamic balance) in the mediolateral direction (21). In addition, fundamental experiences in childhood and old age in this field also showed that by increasing the width of the step while walking, balance can be improved. The results of the present study showed that doing corrective exercises related to UCS did not have a significant effect on the stride width index. In other words, it seems considering that corrective exercises related to the UCS have been effective in the sagittal plane, the absence of a significant difference in the step width component that changes in the left-right direction can seem logical. Maki (21), by examining the variability of step width during walking, stated that increasing the variability of step width during gait can lead to a decrease in falls. In other words, it can probably be said that the increase in the variability of step with indicated a better quality of stepping. According to the results of the present study, the standard deviation of step width in the post-test is lower than in the pre-test. Based on this, it can be seen that the results of the present study do not confirm the findings of Maki considering the improvement of other indicators related to the quality of the gait after the implementation of the training protocol (21). Kirtley (18), stated the normal range for cadence values to be 110 to 115 steps per minute and speed to be between 1.3 to 1.6 meters per second in men. The results of the present study showed that despite the decrease in the frequency of stepping, the speed and stride length of the subjects increased. Usually, step length increase and step speed are considered as indicators of improving step quality, and if the speed increase rate is lower than the step length increase, step frequency decreases. This happened in the experimental group of the current study so that despite the increase in step length and step speed, step frequency decreased. This index is obtained by applying the effect of the length and duration of each step and comparing it between the left and right steps.

A change in one area of the body may affect other areas in the form of reactive chains (9). In the form of a chain reaction, the posterior rotation of the pelvis causes a decrease in the lumbar lordosis angle, an increase in the thoracic kyphosis angle, and finally the head forward position. Considering that the head and trunk make up more than half of the total body weight, changes in the position of the center of gravity of the head and trunk cause a change in the position of the center of gravity of the whole body. On the other hand, the imbalance of the head and body causes the improper placement of different organs and joints of the body in relation to each other (23). In relation to the movement pattern of the pelvis in the sagittal movement plane, no statistically significant difference is observed in the movement range and movement pattern of the pelvis tilt, before and after the exercise protocol (22). The results of the study show that the average anterior tilt in the post-test was accompanied by an increase, which indicated the corrective effect of the exercises on the UCS, which led to a change in the position of the center of mass of the upper body and increased the anterior tilt of the pelvis to the amount of the gait pattern (22). In relation to the effect of corrective exercises on gait pattern, we can also mention the range of motion of hip rotation. Accordingly, according to the results of the study, the range of motion of hip rotation has experienced an increase of nearly two degrees after applying the training protocol. This value is closer to the range of motion of the horizontal plane of the pelvis in the normal gait pattern. The reason for this problem can be attributed to the reduction of stiffness and shortening of the upper body as a result of the implementation of the training protocol, which has also affected the range of motion of the pelvis and improved the quality of walking. According to the results of the present study, in the comparison of hip joint kinematic factors, heel strike flexion and hip range of motion in sagittal planes were among the factors that decreased after the implementation of the training protocol, and this decrease was also significant. In this way, the increase in the anterior tilt of the pelvis due to the implementation of the training program has caused a decrease in the range of motion of flexion and the angle of flexion in the initial impact of the hip. Since the lower body has not been subjected to a specific training protocol, it should not be expected that changes outside of the compensatory mechanism and the influence of the upper body will occur in it. Hashemi Moghaddam *et al*. (15) showed in a study that the abnormality of lumbar lordosis leads to a change in the range of motion of the sagittal plane of the hip and ankle and the frontal plane of the knee. Despite the difference in skeletal deformity, these results were consistent with the findings of the present study regarding the difference in the movement of the sagittal plane of the hip. Knee flexion in the stance and swing phases of stepping is done in order to absorb the reaction force of the ground and increase the range of motion of the knee to create forward movement with acceleration. In this context, the results of the present study showed that after the implementation of the training protocol, both of these components increased. Although the movement pattern of the knee in the pre-test phase was more similar to the normal gait pattern, the increase of these two components in the post-test can indicate the improvement of the quality of the gait because, in the stance phase, Rano absorbs the force of the ground reaction more and prevents pressure on the upper limbs. Also, according to the increase in walking speed in the post-test stage, it can be seen that the increase in hip flexion in the swing phase had a direct effect on improving the walking speed. The results of the present study showed that there is a statistically significant difference in the range of dorsi-plantar flexion and wrist abduction-adduction after applying the training protocol. By comparing the gait pattern of healthy people and those suffering from the abnormality of UCS, concluded that there is no significant difference between the two groups in the movement of the sagittal plane of the wrist (17). The results of this study were different from the findings of the present study, despite the fact that the studied complication is the same, probably due to the difference in the target population.

Of the main limitations of the present study. It can be mentioned to the different life style of the subjects which all were students and engaged in various physical activity types. It means that pure physical isolation was not feasible to understand the absolute effect of training.

Conclusion

The findings indicated notable variations in step length, cadence, and symmetry as a result of incorporating corrective exercises. Additionally, significant alterations were noted in pelvic rotation, hip flexion at heel-contact, hip flexion and abduction range of motion, peak knee flexion in stance and swing knee flexion, and rotation range of motion following the integration of corrective exercises. These findings highlight the effectiveness of corrective exercises in improving posture and gait patterns in adolescents with UCS.

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Ethical considerations
This study was approved by the research ethics committee of Islamic Azad University, Central Tehran Breanch according to compliance with ethical standards in the research ministry of science, research and technology with the code IR.IAU.CTB.REC.1400.109

Practical application of the study
To prescribe the functional effect of corrective exercises for treating of the upper body cross syndrome especially in junior infants.

Conflict of interest
None.

Funding support
None.

Authors' contributions
Zohre Darabi: Initial design of study; Yahya Sokhanguii: Writing and paper revision. Farhad Tabtabe: Data analysis and writing and laboratory work. Ali Fatahi: Initial design of study, data analysis and writing and laboratory work.

References

1. Şimşek N, Keleş A, Ahmetoglu F, Akıncı L, Er K. 3D Micro-CT analysis of void and gap formation in curved root canals. European Endodontic Journal. 2017;2.
2. Wolf TG, Stiebritz M, Boemke N, Elsayed I, Paqué F, Wierichs RJ, et al. 3-dimensional analysis and literature review of the root canal morphology and physiological foramen geometry of 125 mandibular incisors by means of micro–computed tomography in a German population. Journal of endodontics. 2020;46(2):184-91.
3. Page P, Frank CC, Lardner R. Assessment and treatment of muscle imbalance. (No Title). 2010.
4. Haji He, Nooraste A, Shamsi Ma. Comparison Effect of Three Strengthening, Stretching and Comprehensive on Upper Crossed Syndrome (Ucs). 2014.
5. Sepehri S, Sheikhhoseini R, Piri H, Sayyadi P. The effect of various therapeutic exercises on forward head posture, rounded shoulder, and hyperkyphosis among people with upper crossed syndrome: a systematic review and meta-analysis. BMC Musculoskeletal Disorders. 2024;25(1):105.
6. Javazi F, Sedaghati P, Daneshmandi H. The effect of selected corrective exercises with physioball on the posture of female computer users with upper crossed syndrome. Journal of Sport Biomechanics. 2019;5(2):112-23.
7. Ahmadi H, Yalfani A, Gandomi F. The Effect of Eight-Week Corrective Exercises Carried out in Water on Pain, Neck Flexors Endurance and Upper Extremity Range of Motion in Patient with Upper Crossed Syndrome. Journal of Shahid Sadoughi University of Medical Sciences. 2019.
8. Rostamizalani F, Ahanjan S, Rowshani S, BagherianDehkordi S, Fallah A. Comparison of the effects of three corrective exercise methods on the quality of life and forward head of men with upper cross syndrome. Journal of Paramedical Sciences & Rehabilitation. 2019;8(1):26-36.
9. Daneshmandi H, Mogharabi Mozafari M. The effect of eight weeks of comprehensive corrective training on upper cross_syndrome. Journal of Research in Sports Medicine and Technology. 2014;12(7):75-86.
10. Kazemi A, Mahdavinejad R, Ghasemi G, Sadeghi M. Effects of an 8-week exercise with Physioball on the correction of thoracic kyphosis, balance and quality of life in addicted men after quitting drugs. Journal of research in rehabilitation sciences. 2013;9(2):328-37.
11. Damavandi M, Maskani A, Mohammadi M. The effect of comprehensive corrective exercises on the postural kyphosis and the three-dimensional (3D) positions of the head and trunk segment center of mass. 2015.
12. Neumann DA. Kinesiology of the musculoskeletal system. St Louis: Mosby. 2002:25-40.
13. Rosenbaum D, Becker HP. Plantar pressure distribution measurements. Technical background and clinical applications. Foot and ankle surgery. 1997;3(1):1-14.
14. Motooka T, Tanaka H, Ide S, Mawatari M, Hotokebuchi T. Foot pressure distribution in patients with gonarthrosis. The Foot. 2012;22(2):70-3.
15. Hashemi-Moghaddam K, Amir-Seyfaddini MR, Mohammadipour F. Kinematics of the Lower Extremity in Walking among Individuals with Hyperlordosis Waistline Malformation. Journal of Research in Rehabilitation Sciences. 2017;12(5):267-73.
16. Sawant V, Patil P. Effect of Upper Body Strength Training in Spatiotemporal Parameters of Gait In Individual with Thoracic Kyphosis. Indian Journal of Forensic Medicine & Toxicology. 2020;14(2).
17. Di Paolo S, Lopomo NF, Della Villa F, Paolini G, Figari G, Bragonzoni L, et al. Rehabilitation and return to sport assessment after anterior cruciate ligament injury: quantifying joint kinematics during complex high-speed tasks through wearable sensors. Sensors. 2021;21(7):2331.
18. Kirtley C. Clinical gait analysis: theory and practice: Elsevier Health Sciences; 2006.
19. Wellsandt E, Emory J, Golightly Y, Dudley A, Michaud K, Tao M, et al. Individual and cumulative measures of knee joint load associate with T2 relaxation times of knee cartilage in young, uninjured individuals: A pilot study. The Knee. 2021;32:19-29.
20. Yazdani S, Farahpour N, Habibi M, Saba MS. Spatiotemporal variables of gait in patients with adolescent idiopathic scoliosis and healthy individuals. Journal of Sport Biomechanics. 2016;2(3):5-14.
21. Maki BE. Gait changes in older adults: predictors of falls or indicators of fear? Journal of the American geriatrics society. 1997;45(3):313-20.
22. Eslami M, Damavandi M. Principles of biomechanics and movment analysis. Research Institute Physical Education and Sports Science; 2012.

Appendix 1. The exercises were designed for a period of 8 weeks. These exercises were performed daily for 60 minutes each session, including 10 minutes of warm-up, 45 minutes of selected exercise program and 5 minutes of cooling down, and the time and number of repetitions were increased during the training

	How to perform
1	Move the hands from the side to the top of the head and finally keep them stretched and straight for 5 seconds.
2	Shrugs up, shoulder roll from front to back, shoulder roll from back to front
3	Moving the shoulders away, we bend the head forward and down, with the help of the arms, we bring the shoulders together from the front. Bringing the shoulders closer, keeping the neck straight, the hands are in line with the body, and the chest is pushed forward.
4	Lying on the stomach and placing a pillow under the stomach, while the hands are locked behind the waist, we try to lift the head of the chest up and hold it.
5	Lying on the stomach, placing a pillow under the stomach, we hook the hands behind the head and in this position, we try to lift the head and chest up and hold it.
6	Lying on the stomach and placing a pillow under the stomach, we keep the hands stretched forward along the head and straight and lift the head and chest up.
7	hanging from the barfix bar (hands shoulder width apart)

Number of repetitions and pause time in stretching movements

Week	**Time**	**Repetition**
First	5 seconds	10
Second	5 seconds	20
Third	5 seconds	30
Fourth	10 seconds	10
the fifth	10 seconds	20
the sixth	10 seconds	30
the seventh	10 seconds	35
Eighth	10 seconds	40