Research Paper

The Effect of Eight Weeks of Selected Corrective Games on the Balance, Proprioception, and Changes in the Arch of the Foot in Adolescent Girls With Pronation Distortion Syndrome

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ABSTRACT

Purpose: Pronation distortion syndrome is one of the most common physical abnormalities causing abnormalities in the lumbar pelvic and lower limb structures. This research was conducted to determine the effect of eight weeks of selected corrective games on balance, proprioception, and changes in the arch of the foot in adolescent girls with pronation distortion syndrome.

Methods: In this quasi-experimental study and clinical trial, 40 girls with pronation distortion syndrome with an age range of 7-12 years participated and were randomly divided into two equal control and experimental groups. The people of the experimental group played selected corrective games for 8 weeks (3 sessions per week, 60 minutes each session); however, the control group did their normal and daily activities. The modified star or Y balance test was used to measure the dynamic balance index, a goniometer to measure proprioception and measure navicular bone loss index using the method described by Brody (Brody) in the pre-test and post-test. To analyze the data, the combined repeated measure statistical test was used ($P<0.05$).

Results: The results of the present study showed a significant improvement in dynamic balance ($P<0.001$), proprioception ($P<0.001$), and a reduction in flat foot ($P<0.001$) after playing eight weeks of games. Correction in girls with pronation distortion syndrome.

Conclusion: Considering the favorable impact of corrective games and the greater compatibility of these programs with the physical-psychological characteristics of children, it is suggested to use corrective games for this age period.

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Highlights

• Corrective games training corrects abnormal balance strategies in adolescent girls with pronation distortion syndrome.

• Corrective games training increases the impulses sent from plantar mechanical receptors.

Plain Language Summary

Lower body pronation distortion syndrome is one of the common disorders in childhood and adolescence. People with this condition are at a higher risk of foot pain, knee pain, plantar fascia injury, stress fractures, poor athletic performance, and deficits in balance and proprioception. Since the occurrence of abnormalities in childhood and ignoring them can be a risk factor for their progression and occurrence in adulthood, improving and maintaining proper posture in children is of great importance. One of the methods currently used to correct postural abnormalities in advanced societies is games. In this method, it is possible to provide corrective movements in the form of games to individuals with postural abnormalities, especially children and adolescents. Considering children's interest in games and their enthusiasm for physical activity during games, it is easy to achieve corrective goals through this method.

1. Introduction

Lower body pronation distortion syndrome is one of the common disorders in childhood and adolescence. This syndrome is one of the most common abnormalities that may cause pain in the foot and may also lead to distortions in the skeletal structures of the tarsal, distal, and proximal parts of the foot [1]. People with this syndrome have a flat foot deformity, knee valgus, and internal rotation of the hip due to excessive foot pronation, which increases the lumbar lordosis in cases of hyper pronation [1]. In this abnormality, the muscles of the tibialis posterior, peroneals, soleus, iliotibial band, short head of the biceps femoris, hip adductors, and psoas become functionally short (overactive), while the gastrocnemius and soleus muscles, tibialis anterior, extensor hallucis longus, and the external rotators of the hip become inhibited [2]. These individuals are prone to predictable injury patterns, such as Achilles tendinitis, plantar fasciitis [3], medial tibial stress syndrome [4], posterior tibial tendon dysfunction, ankle sprains, instability [3, 5], and low back pain [1]. Furthermore, people with this condition are at a higher risk of foot pain, knee pain, plantar fascia injury, stress fractures, poor athletic performance, and deficits in balance and proprioception [3]. Balance is one of the controversial concepts of the sensory-motor system, and the human foot, with its small surface area, plays a crucial role in maintaining it. Therefore, the slightest changes in the range of support surface can affect posture control [6]. Abnormalities in the foot and plantar structure may affect the individual's performance in static, dynamic, and especially body movement situations [2].

Increased pronation of the foot affects sensory inputs through changes in joint mobility, contact surface area, changes in ligament status, and the occurrence of ligament laxity, or secondarily changes in muscle strategies to maintain a stable and secure support surface. And finally, it leads to a disturbance in the control of body posture. Increased foot pronation is also associated with some degree of ligamentous laxity [7]. And possible changes in soft tissues around the joint, such as ligaments, muscles, and tendons, are common, and mechanical receptors, sensory neurons, muscular spindle, Golgi tendon organs, and joint receptors are usually located among these soft tissues [3]. Proper physical fitness control depends on the biomechanics of the musculoskeletal system (including joint stability and structure) as well as proper neuromuscular control [8]. Muscles play a role in maintaining body balance through the joints, and it is clear that acting muscles in the trunk, thigh, knee, and ankle joints play a fundamental role in regulating body balance [8]. Asymmetric muscle strength disrupts proper body alignment and provides a basis for abnormal pressure on joints and other tissues. Musculoskeletal abnormalities are undesirable conditions that arise from environmental factors, lack of movement, and improper muscle and joint function [2]. Researchers have investigated the effect of foot structure on balance and confirmed the role of foot structure in controlling posture. For example, Cutt et al examined dynamic balance in people with foot abnormalities and measured dynamic balance using a star rotation balance test. The study showed that dynamic balance performance in people with foot abnormalities is weaker than in those with normal feet [9]. In a study conducted by Khoromtsov et al. the stability of 112 children aged

7-10 years with a flat foot was evaluated, and the results showed that children with a flat foot had less upright stability than those with a natural arch [10]. Since the occurrence of abnormalities in childhood and ignoring them can be a risk factor for their progression and occurrence in adulthood, improving and maintaining proper posture in children is of great importance. Therefore, identifying abnormalities and deviations in the lower and upper extremities before skeletal development can help to inhibit the secondary abnormalities and several complications which these deformations can create in human posture. Corrective exercises are a new branch of applied science in the sports society, which includes identification, education, prevention, and modification of abnormalities and movement behaviors of individuals [11].

Corrective exercises for a specific group are applied to correct specific physical abnormalities by using stretching and strength exercises to balance the opposing muscle groups of different areas of the body [12]. One of the methods currently used to correct postural abnormalities in advanced societies is games. In this method, it is possible to provide corrective movements in the form of games to individuals with postural abnormalities, especially children and adolescents. Considering children's interest in games and their enthusiasm for physical activity during games, it is easy to achieve corrective goals through this method. Studies have shown that corrective games have beneficial effects on correcting abnormalities in children and adolescents [13]. For example, in a study titled "comparison of the effects of a period of corrective exercises and games on changes in flat foot, balance, and depth proprioception in adolescent girls with flexible flat foot," Sadeghi et al found that both corrective game and corrective exercise programs had a significant effect on reducing flat foot and improving static and dynamic balance [11]. Considering the desirable effect of corrective games and their greater compatibility with the physical and psychological characteristics of children, it is recommended to use corrective games for this age group. In addition, limited studies have examined the effect of corrective games on pronation syndrome. Therefore, the present study was conducted to investigate the effect of eight weeks of selected corrective games on balance, proprioception, and changes in foot arch in adolescent girls with pronation syndrome.

2. Materials and Methods

The study population included girls aged 7-12 with pronation syndrome. To determine the sample size, G*Power software, version 3.1.9.2 was used. After entering the software environment, the analysis of variance (ANOVA), repeated measures, and F test option was selected from the test family section. The numerical values applied in the software environment included an effect size of 0.8, a significance level of 0.05, and a statistical power of 0.8. The software output indicated that the minimum number of participants required for this study was 30 (15 in each group). However, due to the special circumstances of the COVID-19 pandemic, 40 participants were selected (20 in each group) to prevent any disruption in the protocol and exercises in case of participant dropouts. The participants were selected purposefully and randomly (randomization of groups was done by writing the names of all participants on small pieces of paper and putting them in a bag, then pulling out the names from the bag. Any participant with an odd number was placed in the control group, and any participant with an even number was placed in the exercise group). Based on the inclusion criteria, they were divided into two groups (control: 20 participants, experimental group: 20 participants).

The inclusion criteria for participants in the study of the incidence of pronation distortion syndrome, according to the specialist's diagnosis of corrective movements, included having a flexible, painless, flat foot without any symptoms of pain, and measuring the navicular drop index using Brody's method, which was more than 10 mm [14], knee valgus, measured by the distance between two inner malleoli so that the distance between the two malleoli is more than 4 cm [2], age range of 7-12 years, no individual's affliction with other acute or chronic disabling diseases that conflict with exercise, and no prohibition from a specialist physician for doing exercises, no history of injury or surgery of the lower extremities, and no balance problems [2]. The exclusion criteria included pain or discomfort during the study, and not being present continuously in exercises (two consecutive absences or three absences during the course) [15]. Before entering the laboratory, all research stages were explained to the participants. Written informed consent was obtained from the parents of the subjects to participate in the study. Table 1 presents the demographic and anthropometric characteristics of the participants, including age, height, weight, and body mass index (weight in kilograms divided by height in meters squared). The present study was conducted in two stages, pre-test and post-test.

Measurement

Measurement of navicular drop

Brody's method was used to examine the structure of the flat foot by measuring the navicular drop. To measure the amount of navicular drop using the Brody method, the individual was first asked to sit on a chair and place their foot in a weightless position. Then, the individual's foot was placed in a natural position with the subtalar joint aligned so that the test probe placed the index finger on the prominent part of the talus bone and the thumb on the front and under the inner arch of the foot, and the individual slowly rotated their foot inward and outward until the index and thumb were aligned in one axis. In this position, first, the protrusion of the navicular bone was marked, and then the participant was asked to stand and in this position, the distance between the protrusion of the navicular bone and the ground level was measured (Figure 1). If the difference between these two positions is between 5 to 9 mm, the arch of the foot is considered normal, if the difference is greater than 10 mm, the foot is considered flat, and if the difference is less than 4 mm, the foot is considered hollow. The intraclass correlation coefficient range was reported to be from 0.73 to 0.96 for the reliability of the intratester and intertester when using this test [14].

Measurement method of proprioception

To measure the knee joint proprioception, a goniometer was used. The assessment of knee joint proprioception was performed using the "active test with an active reconstruction of the same limb" method. To make markers, each individual wears short sports pants so that no other covering is present on their lower limb. To facilitate goniometry, four markers are placed on the skin using double-sided adhesive, the greater trochanter of the femur, the distal end of the iliotibial band at the knee in the proximal area to the posterior knee crease at 90 degrees of knee flexion, the anterior side of the fibular neck in the upper part of the leg, and on the outer malleolus prominence of the ankle. First, the tester draws the test angle precisely on the wall next to the person without the test subject being noticed so that he can lift the test subject's foot to the desired range. According to Stilman, in this method, since the person reconstructs the same angle shown to them, and these two angles are compared, no error is created in the test results. For this purpose, the test subject sits on the edge of a flat surface in a way that the angles of their hip and knee joints are bent 90 degrees and their feet are hanging (resting position). Then, the tester passively lifts the test subject's foot to the target angle and asks them to remember it while keeping their active foot at that angle for 5 s. Then, the tester returns the test subject's foot to the resting position and asks them to actively reconstruct it without using visual cues and relying solely on proprioception [16].

Dynamic balance measurement method

To measure this variable, the star balance test or Y-balance test is used. The test is performed on both feet. The participant stands with one foot on the center of a board while the reaching foot is placed next to the board on the ground. The board has three directions, anterior, posteromedial, and posterolateral. When the participant balances on one foot, they reach with their free foot forward and diagonally backward in two directions. The reaching distance is recorded as their score. When reaching with the right foot, the test is performed in a clockwise direction, and when reaching with the left foot, it is performed counterclockwise. If an error occurs during the reach, the test is repeated. The test is performed three times in each direction, and the average of the three scores is calculated. The length of the leg in centimeters, which is the distance between the anterior superior iliac spine and the medial malleolus, is divided by 100, and the reaching distance is expressed as a percentage of leg length. The test is repeated three times, and the participant rests for 3 minutes between each repetition [17]. The higher the reaching score, the better the person's balance.

Figure 1. Measurement of navicular drop (while bearing weight)

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Table 2. A summary of the corrective games program

The Game	Description	The Process of Increasing Game Development	Goal
Kneeling game	Students are paired up based on their height and age and stand on the ground with their knees touching each other in a neutral position. As the game begins, each student tries to bend the other's leg by applying force. The winner is the student who can make contact with the other student's foot on the ground by bending their leg enough. The game is repeated 2 or 3 times, and the duration of the game varies depending on individual differences and the addition of extra challenges. The game requires a minimum of 2 players	To improve the game, big and small balls to placebetween the knees can be used.	Strengthening the gluteus maximus, gluteus minimus, and external thigh rotators.
The game of carrying the ball between the legs	Students are selected based on their height, weight, and age and are placed in a group. A ball is placed between the legs of two people. After placing the ball between their legs, they must cover the designated distance as quickly as possible while maintaining the ball between their legs. The group that reaches the finish line first is the winner. If the ball falls, the group members should pick it up and start the game from the same spot where the ball fell The game is repeated 10 times and the duration of each game is 20 minutes. The minimum number of players required is 2.	To improve the game, the type of ball can be changed from light to heavy.	Strengthening the gluteus maximus, gluteus minimus, and external thigh rotators.
Kneeling the game	A student sits on the ground while a coach stands in front of them and throws a ball toward the student's knees. The student must hit the ball so that it goes back to the coach's hands. Ten balls are thrown for each person, and the number of balls that reach the coach's hands is counted as a score. Number of repetitions: 10 times Duration: Variable depending on individual differences and additional factors Number of participants: At least 1 person	To improve the game, the subject can be asked to throw the ball into the basket, which is already placed in a certain place. To make the game more difficult, you can use heavier balls.	Strengthening the gluteus maximus, gluteus minimus, and external thigh rotators.
Pull and drop	For this game, several cubes or small balls are placed in front of the student, and the student's foot must be behind the cubes or the embedded ball and try to place the ball or cube in the place that is embedded on the wall. The number of repetitions is 10 to 12 times The duration of the game: Variable according to individual differences and the principle of overload Number of people: At Least 2 people	To improve the game, we can increase the distance of the cubes from the students or increase the distance to the place where they have to reach the balls and cubes.	Shortened muscle tension.
Get a side game	Students stand in a circle and cross their legs and arms. We put a small ball in the hand of the first person and ask him to pass the ball over his head to the next person by bending to the opposite side. When the ball reaches the first player again, he brings the ball to the sidekick in the opposite direction. The number of repetitions is 3 times. The duration of the game: Variable according to individual differences and the principle of overload. Number of people: At least 5 people.	To improve the game, students can be divided into two groups and the group that can spin the ball 2 or 3 times in less time wins the game.	Stretching of the tensor fasciae latae muscle and iliotibial band.
Powerful foot game	The outer side of the legs is in contact with each other and by applying force to the opponent's leg, they cause the ball to move in contact with his leg. Whoever moves the ball first loses the game. The number of repetitions is 3 times. The duration of the game varies according to individual differences and the principle of overload. Number of people: At least 2 people.	To improve the game, you can use bigger balls or increase the distance between the ball and the feet.	Strengthen supinator muscle large tibia.

The Game	Description	The Process of Increasing Game Development	Goal
Fabric game	We place a cloth between two students who are sitting on the floor. We ask them to put their feet on this cloth and gather the cloth under their feet when they hear the coach's whistle. Any student who pulls the cloth from under the opponent's feet faster is declared the winner of the game. The student should only use the muscles of the soles of the feet to gather the fabric and not interfere with the upper muscles. The number of repetitions is 3 times The duration of the game: Variable according to individual differences and the principle of overload. Number of people: At least 2 people.	To improve the game, you can use a thicker cloth or even a blanket. Or play this game in a group.	Strengthen muscles Depth of the soles and flexors of the fingers.
Pick and drop game	The student should sit on the floor. We put some napkins on the floor on the side of the foot that is on the floor. With the sound of the coach's whistle, pick up the handkerchiefs with his toes and place them in a predetermined place. The time taken to remove all napkins is recorded as a person's score. The number of repetitions is 5 to 7 times.	To improve the game, the distance between the places can be increased where the napkins are placed. Instead of napkins, heavier objects like balls can be used.	Strengthen muscles Depth of the soles, plantar flexors, and thigh flexors.
Bottle rolling game	We give each of the students a bottle or a ball and we place them in pairs at the beginning of the designated line and we ask them to roll the bottle with their soles and reach the end of the designated path after hearing the coach's whistle. Whoever completes the route first wins the game. It should be noted that the bottle does not separate from the soles of the feet along the way. The number of repetitions is 2 to 3 times. The duration of the game: Variable according to individual differences and the principle of overload. Number of people: At least 2 people.	To progress the game, heavier objects or a longer path can be used.	Strengthening the plantar flexor and deep foot muscles.
Walking game on paws	Students line up in line. Upon the coach's announcement, they tiptoe and upon the next announcement, they walk in the same position (on their toes). Whoever reaches the finish line faster than the others wins the game. Duration of the game: 3 minutes Number of players: 1 player	The game can be continued in a team and in an aid format, in which each student, after covering a distance, hands a stick to their teammate and their teammate continues the path. The team whose last member passes the finish line before the others, wins the game.	Strengthening the deep muscles of the soles of the feet and the plantar flexors of the foot.
One-leg hopping	We line up the students behind the starting line of the race. We ask them to lift one leg and take a hopscotch position, and upon hearing the coach's whistle, they hopscotch to the end of the designated path. The person who reaches the end of the path faster than others is declared the winner. Number of repetitions: 2-3 times Duration of the game: Variable depending on individual differences and the principle of overload. Number of players: At least 2	To progress the game, you can increase the path.	Strengthening the plantar flexor muscles, depth inside the soles of the feet, improving balance.
Snail walking game	In this game, the participants stand at the start line and, upon the tester's signal, they begin to move by bending their fingers and bringing the beginning and end of their feet close to each other. The person who completes the route faster than the others is the winner. Number of repetitions: 3 times Duration of the game: Variable depending on individual differences and the principle of overload. Number of participants: At least 2 people	To improve the game, you can make the walking path longer.	Strengthening the deep muscles of the soles of the feet and the plantar flexors of the foot.

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Table 3. Summary of the corrective games program

The Game	Important Points During the Game	Game Image
Kneeling game	1. It should be noted that the knees should be positioned facing each other at an appropriate angle. 2. It should be ensured that the participants with similar height conditions are selected for the game. 3. To prevent excessive force on the bones and surrounding tissues of the knee, a soft pad or object can be used to reduce the force applied to the knee.	
The game of carrying the ball between the legs	The examiner should remind the subject to apply equal pressure to the ball with both feet to maintain proper alignment in both feet. Using hands to hold the ball is considered a mistake.	
Kneeling the game	1. The ball must be kicked with the knee and other parts of the body must be fixed. 2. Lifting a hip or foot from the ground is considered wrong.	
Pull and drop	1. Loss of balance is considered a fault. 2. Maintain the correct alignment of the body while playing.	
Get a side game	1. Passing the ball to each other is allowed only in the mentioned way. 2. Using other parts of the body or other movements is considered a foul. 3. The game must be played in both directions.	
Powerful foot game	The examiner must make sure that the correct posture of the whole body does not get disturbed during the performance of this game and that the subjects observe the correct posture.	

The Game	Important Points During the Game	Game Image
Fabric game	It must be noted that the subjects pull the cloth by applying force through the fingers and plantar muscles and do not use the rest of the foot muscles.	
pick and drop game	The general posture of the subject should be normal.	
Bottle rolling game	The subjects must be warned to use the plantar muscles to transfer the bottle and to engage the other muscles of the footless.	
Walking game on toes	The examiner must warn the subject not to leave the paw position during the game.	
One-leg hopping game	The most important point in this game is to pay attention to safety precautions to prevent potential harm to the participants. Safety precautions: 1. Children should be reminded of the necessary precautions to prevent falling. 2. The game should be played on a soft surface to prevent any harm to the students in case of falling. 3. Children should be taught the correct way to lift their dangling feet to avoid joint injuries.	
Snail walking game	It should be noted that the subjects use only the plantar muscles to move forward.	

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Table 1. Demographic characteristics of the participants in the study (n=20)

Variables	Groups	Mean±SD	Sig.
Age (y)	Experimental	9.39±1.79	0.555
	Control	9.75±1.60	
Height (cm)	Experimental	138.50±5.24	0.725
	Control	139.08±3.31	
Weight (kg)	Experimental	37.17±4.08	0.132
	Control	39.33±3.98	
BMI (kg/m²)	Experimental	19.82±1.79	0.779
	Control	19.65±1.62	

BMI: Body mass index.

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Intervention

An experimental group performed exercises under a specific protocol for 8 weeks and 3 sessions per week, and each session lasted 60 minutes. The exercise program included warm-up, corrective games, and cool-down (Tables 2 and 3) [18]. The control group did not receive any exercise program during the 8-week period. After the end of the 8 weeks, various dependent variables were measured again using the same method as in the first stage (pre-test) in both control and experimental groups.

The data were analyzed using SPSS software, version 20. Shapiro-Wilk test was used to assess the normality of the data distribution, and the Leven test was used to examine the homogeneity of variances. Then, a parametric repeated measures test was used to compare the results between the two groups.

3. Results

Table 1 presents the demographic characteristics of the participants, including age, height, weight, and body mass index (weight divided by the square of height in meters) in both control and experimental groups. In Table 1, the results of the Shapiro-Wilk test showed that the data distribution is normal (P>0.05). Also, the results of Leven's test showed that the condition of homogeneity of variances is established (P>0.05). As a result, the combined repeated measure parametric test was used to compare the results between the two groups.

According to Table 4, the results of ANOVA with repeated measures showed the difference in the average dynamic balance of the right leg in the pre-test and post-test phases (η^2=0.402, P=0.001) and between the control and experimental groups (η^2=0.196, P=0.001) was significant. Also, the interaction effect of time and group (η^2=0.466, P=0.001) was significant at a 5% error level. Also, the difference in the average dynamic balance of the left leg in the pre-test and post-test phases (η^2=0.466, P=0.001) and between the control and experimental groups (η^2=0.184, P=0.001) was significant. Also, the interaction effect of time and group (η^2=0.544, P=0.001) was significant at a 5% error level. Also, the difference in the average proprioceptive sensation of the right foot in the pre-test and post-test phases (η^2=0.661, P=0.001) and between the control and experimental groups (η^2=0.386, P=0.001) was significantl. Also, the interaction effect of time and group (η^2=0.603, P=0.001) was significant at a 5% error level. Also, the difference in the average left foot proprioception in the pre-test and post-test stages (η^2=0.654, P=0.001) and between the control and experimental groups (η^2=0.331, P=0.001) was significant. Also, the interaction effect of time and group (η^2=0.667, P=0.001) was significant at a 5% error level. In addition, the difference in the average pronation of the right foot in the pre-test and post-test phases (η^2=0.718, P=0.001) and between the control and experimental groups (η^2=0.365, P=0.001) was significant. Also, the interaction effect of time and group (η^2=0.701, P=0.001) was significant at a 5% error level. Also, the difference in the average pronation of the left foot in the pre-test and post-test stages (η^2=0.652, P=0.001) and between the control and experimental groups (η^2=0.331, P=0.001) was significant. Also, the interaction effect of time and group (η^2=0.698, P=0.001) was significant at a 5% error level (Table 4).

Table 4. Comparison of intragroup and intergroup changes of the research variables in the experimental and control groups (ANOVA with repeated data)

Variables	The Source	Sum of Squares	df	Mean Square	F	P	Eta Squared
Dynamic balance of the right leg	Time	163.401	1	163.401	25.566	0.001*	0.402
	Group	201.613	1	201.613	9.276	0.001*	0.196
	Time*group	212.335	1	212.335	32.222	0.001*	0.466
Dynamic balance of the left leg	Time	201.824	1	201.824	33.180	0.001*	0.466
	Group	181.805	1	181.805	8.569	0.001*	0.184
	Time*group	286.024	1	286.024	45.378	0.001*	0.544
Right foot proprioception	Time	11.666	1	11.666	74.057	0.001*	0.661
	Group	19.159	1	19.159	23.827	0.001*	0.386
	Time*group	9.079	1	9.079	57.632	0.001*	0.603
Left foot proprioception	Time	15.967	1	15.967	71.905	0.001*	0.654
	Group	19.543	1	19.543	18.772	0.001*	0.331
	Time*group	16.873	1	16.873	75.985	0.001*	0.667
Pronation of the right foot	Time	140.185	1	140.185	96.905	0.001*	0.718
	Group	199.396	1	199.396	21.812	0.001*	0.365
	Time*group	128.778	1	128.778	89.020	0.001*	0.701
Left foot pronation	Time	119.651	1	119.651	71.307	0.001*	0.652
	Group	259.920	1	259.920	34.864	0.001*	0.331
	Time*group	147.425	1	147.425	87.925	0.001*	0.698

*Significant difference between groups (P<0.05).

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4. Discussion

This research was conducted to determine the effect of eight weeks of selected corrective games on balance, proprioception, and changes in the arch of the foot in adolescent girls with pronation distortion syndrome.

The results of the present study showed a significant improvement in dynamic balance in girls with pronation distortion syndrome after 8 weeks of corrective games exercise. Today, in advanced societies, corrective exercises in the form of games and rhythmic movements are considered, which are suitable and practical for school-aged children and have a recreational aspect so that people enthusiastically participate in games without any worries [13]. In this method, it is possible to present corrective movements in the form of games to people with height abnormalities, especially children and teenagers. The game allows students to have better control over their bodies and their self-confidence increases [19]. Children's physical education is associated with wordplay, and play is an essential factor in maintaining a child's health, growth, and all-around development [20]. Today, games are increasingly used to diagnose children and adolescents' problems and treat them [21]. Previous studies regarding the effect of corrective games on improving the balance of people with pronation distortion syndrome have been few, and only one study has investigated the effect of corrective games on balance reporting a significant improvement in balance [11].

In this research, under the title of comparing the effect of a training course and corrective games on changes in the arch of the foot, balance, and proprioception of adolescent girls with flexible flat foot, the results of the findings showed that both the corrective game program and exercises had a significant effect on reducing flat foot and improving static and dynamic balance. By examining the previous studies in the field of correcting the abnormality of pronation distortion syndrome in children, it has been determined that various interventions have been investigated for the therapeutic exercise of these people. Among these studies, we can mention the role of corrective exercises [22], corrective exercises with theraband and water resistance exercises [23], rope exercises [24], and exercises to strengthen the internal muscles of the soles of the feet [25], in children with flat foot. Consistent with the results of these studies, the results of the present research support the effectiveness of corrective games in improving balance in adolescent students with pronation distortion syndrome. According to the studies conducted, to establish a postural sway, a complex mutual relationship between sensory data and appropriate motor responses, such as the control of the motor system and efficient muscle power is necessary [26]. In the ankle joint, the supporting and opposing muscle groups that provide the strength of the joint include two muscle groups, flexors, extensors, and internal and external rotators of the ankle. Disruption in the functioning of this system causes the strength balance of these muscles to be disturbed, resulting in instability in the joint [2]. The activity of the invertor muscles (posterior tibialis) in people with hyper pronation and the activity of the External rotators is lower than in normal people, and in these people, the plantar flexion moment in the ankle is higher [2]. The main supporter of the foot arch in the static state is the ligaments, and at the same time, the anterior tibial muscle plays an effective role in the inversion movement of the ankle, which maintains the internal longitudinal arch of the foot [27]. Biomechanical changes caused by ankle pronation may affect joint loads, mechanical efficiency of muscles, feedback, and proprioceptive orientation, leading to changes in neuromuscular control of the lower limb [2]. In people with pronation distortion syndrome, the proprioception and movement sense of the muscles around the joint decreases [28]. The natural control of postural sway occurs in a bottom-up sequence, so that the activation of the lower muscle takes place 100 ms after a Pasture disorder. For example, during a forward swing, the postural muscles are activated in the following order, gastrocnemius muscle, muscles on the back of the thigh, muscles around the spine. Now, if in this sequence, the upper muscles contract first, the line of force used in the knee joint is shifted and the extension/flexion moments prevent long-term balance [2]. This irregularity in the order of muscle contraction can be caused by lower limb abnormalities, such as pronation distortion syndrome [2], which was used in the present study to create order and not delay the contraction of the muscles that should be activated. About how a regular corrective exercise program can affect posture and postural sway, it should be explained that the stretching, contraction, and strengthening of the muscles of the core area of the body, thighs, knees, legs, ankles, and the sole, before performing the test and moving the limb, creates a predictive reaction of the pasteur from the central nerves, which prevents pasteur disorders and participates in the organization of balance. Therefore, strengthening the muscles of this area as a result of the exercise program improves the neuromuscular system and coordination, and this issue results in the reduction of the center of gravity displacement outside the support surface and the reduction of postural sway [3].

In addition, in the present study, a significant improvement in proprioception was observed in girls with pronation distortion syndrome after 8 weeks of corrective game. The proprioception disorder causes peripheral and central changes in the central nervous system and ultimately leads to a disturbance in sensory-motor control, due to which the central nervous system will have less information to estimate the movements of the body's center of mass. As a result, postural stability decreases [29]. Ashton Miller et al. believe that in the case of proprioceptive improvement in the knee joint, since there is no proven reason that therapeutic exercise changes the number of peripheral receptors, we should look for possible central mechanisms for the explanation of how proprioceptive change was due to the corrective game. A possible mechanism for improved proprioception due to training is increased attention. Attention is a neuropsychological process by which the central nervous system affects the received information. Corrective exercises are likely to increase attention to proprioceptive signs by the brain first at the conscious level and after training, at the automatic level. According to them, another possible mechanism to justify the improvement of proprioception due to training can be the activation of pathways, the increase in the number of synapses and the increase in the corresponding sensory area, which is seen in plasticity. Also, studies have shown that the output of the muscle spindle can be increased voluntarily, which can increase the accuracy of the operation by changing the muscle tone [30]. Also, strengthening the muscles in this area as a result of the exercise program improves the neuromuscular system and coordination, and this leads to sensory improvement.

On the other hand, the results of the present study showed a significant decrease in the amount of navicular drop in girls with pronation distortion syndrome after 8 weeks of corrective games Regarding the reduction of flat foot, it seems that the recovery of muscle balance between shortened and weakened muscles is related to the designed corrective games. The protocol used regarding the deformity of flat foot includes fabric games (aimed at strengthening the deep muscles and flexors of the toes), vector bandaz game (strengthening the deep muscles of the sole, plantar flexor muscles, improving coordination), rolling the bottle game (strengthening the muscles) plantar flexor and profundus) hop-hop game (strengthening the plantar flexor muscles, depth inside the sole and improving balance), snail walking game (strengthening the deep plantar muscles), walking game on the toe (strengthening the plantar flexor and profundus muscles) sole [12]. It seems that according to the goals of the exercises designed in the current protocol, strengthening the weakened muscles, stretching and increasing the range of motion of the shortened muscles, involving the balance system and proprioception and body coordination, were ultimately effective in reducing the deformity of the soles of the feet.

Limitations and suggestions

There are limitations in this study, including the small size of the sample due to the COVID-19 pandemic, as well as the lack of investigation of the effect of corrective games on the electromyographic activity of selected muscles in people with pronation distortion syndrome. For future studies, it is suggested that muscle activity should be checked. It is also suggested to compare the effect of corrective games on the improvement and treatment of pronation distortion syndrome between girls and boys.

5. Conclusion

The results of the present study indicate that eight weeks of selected corrective games have a positive effect on improving balance and proprioception, reducing knee valgus angle and flat foot in girl students with genu valgum and flat foot. It seems that restoring the muscular balance between shortened and weakened muscles through corrective games designed to engage the balance and proprioception system, reduces knee and flat foot deformities, which are the main reasons for improving the musculoskeletal structure of students. Therefore, due to the benefits and enjoyable nature of corrective exercises for children, it is recommended to use them to reduce knee valgus and flat feet deformities.

Ethical Considerations

Compliance with ethical guidelines

The present study was a quasi-experimental and clinical trial that conducted in 2021 at Bu-Ali Sina University (Code: IR.BASU.REC.1400.031).

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Authors' contributions

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Conflict of interest

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