Original Article

Effect of Systematic Corrective Exercises on the Static and Dynamic Balance of Patients with Pronation Distortion Syndrome: A Randomized Controlled Clinical Trial Study

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Abstract

Background: The purpose of this study was to determine the effect of systematic corrective exercises on the static and dynamic balance of students with pronation distortion syndrome. **Methods:** In this randomized controlled clinical trial study, 30 volunteers were selected and randomly divided into the control and experimental groups (15 subjects per group). The experimental group performed systematic corrective exercises for 12 weeks, while the control group performed the routine exercise. Static and dynamic balance was evaluated before and after the interventions. The data were analyzed using independent and paired t-tests ($P < 0.05$). **Results:** The results showed significant improvement ($P < 0.05$) in the static and dynamic balance in the experimental group, but not in the control group. A significant difference was evident between the experimental and control groups in terms of static and dynamic balances, in static balance including Flamingo balance test (42.26 ± 5.35 vs. 10.13 ± 1.92) stabilometr (1.23 ± 0.48 vs. 3.71 ± 1.02), and in dynamic balance including star excursion balance test (anterior direction 82.4 ± 6.2 vs. 66.7 ± 6.9, Posterior-internal direction 87.8 ± 4.7 vs. 69.6 ± 6.3, posterior-external direction 86.06 ± 6.93 vs. 67.2 ± 6.2), stabilometr (3.8 ± 0.6 vs. 11.18 ± 1.8) ($P < 0.05$ for all variables). **Conclusions:** It can be concluded that systematic corrective exercises improve static and dynamic balance in students with pronation distortion syndrome and it could be recommended as modalities for these people.

Keywords: *Balance, exercises, pronation*

Introduction

Lower limb pronation distortion syndrome is a common postural distortion of the lower extremity, involving the anterior part of the leg.[1] It may cause pain in the leg and disturbances in the tarsal part, in addition to distal and proximal parts.[1] In this deformity, the head of the talus and navicular bones are rotated inward and downward, and the body's center of gravity shifts inward, resulting in flat feet.[1] It is also associated with a bunion and increased pressure on the medial parts of the first and second metatarsophalangeal joints.[1] The characteristics of pronation distortion syndrome due to excessive foot pronation include inward rotation of the tibia, internal rotation of the thighs associated with flat feet, genu valgum (knock-knee), and increased lordosis in the case of hyperpronation.[2] In this deformity, peroneal muscle, gastrocnemius muscle, hamstrings, soleus muscle, iliotibial band, adductors, and psoas muscle are functionally tightened, while posterior and anterior tibialis, gluteus medius, gluteus maximus, vastus medialis, and hip external rotators are inhibited.[1,2] Also, potential joint dysfunctions include the first metatarsophalangeal, subtalar, sacroiliac, talocrural, and lumbar facet joints.[1,2] These subjects may experience injuries such as Achilles tendon injury, plantar fasciitis,[3] posterior tibialis tendinitis,[4] ankle sprain or instability,[5] patellar tendinopathy and patellofemoral pain syndrome (PFPS),[6] anterior cruciate ligament (ACL) injures, posterior tibial tendon dysfunction, and low-back pain.[1,2] Furthermore, people with this syndrome are at a higher risk of foot pain, knee pain, stress fractures, poor sports performance, and imbalance.[7] Movement disorders include restriction of dorsiflexion movement in the thoracohedral joint, weakness of the foot and ankle supinators, intrinsic muscles, and hip external rotator that are manifested by the restriction

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created in these individuals.[8] They also have less joint proprioception, which may cause instability and imbalance in the lower extremities are affected.[9,10] Therefore, people with pronation distortion syndrome experience a reduction in the balance, which may lead to increased lower limb injury in such individuals.[9,10]

Balance, as one of the most important sensory‑motor concepts, involves the complex coordination of sensory input and motor responses needed to preserve or change posture.[11] Balance is defined as the control of the body position in space for stability and control of the body's direction.[12] The balance control system involves a complex coordination of three control systems (i.e., visual, proprioception, and sensory‑motor).[13] It is known that postural deviations can have negative effects on the individual's appearance, reduce his/her mechanical performance, and increase the risk of muscle or nerve damage.[14]

Since the foot is maintained in a closed kinetic chain and relies on the integrated response of the pelvis, knees, and ankles, balance may be disturbed by disruption of sensory input, reduction of mechanical strength and stability of each joint, or the structure of lower limbs.[15] an abnormality in the foot's structure may affect the individual function in static and dynamic postures (body movements). Different functions of the legs, such as absorbing and distributing forces and providing stability, depend on the arches of the foot, including the medial longitudinal arch.[14] Systematic corrective exercises that include inhibitory, stretching, strengthening, and integrative exercises should focus on these regions.[2,8,10,16] systematic corrective exercises improve the muscle structure, neuromuscular coordination based on flexibility, strength, and proprioceptive function.[2,8,10,16]

In normal circumstances, ankle, hip, and stepping strategies are used to maintain balance regarding the severity of disorder.[17] Observation of muscle responses to internal or external disturbances is one of the most common methods for evaluating neural strategies that provide stability.[18] Any alteration or deviation in the base of support, including pronation distortion syndrome, may cause changes in muscle activity among these individuals; these changes can result in a shift of balance strategies to maintain a strong base of support. In a previous study, the group with normal feet exhibited better balance on unstable surfaces, compared with those with flat feet. The arches of the foot play a more important role in balance performance on unstable surfaces. These results show the effect of the anatomical structure of feet in maintaining body equilibrium.[19] Therefore, systematic corrective exercises have been proposed to minimize these changes and improve the symptoms of this syndrome. They have reported it that the kinematics of proximal joints may influence the kinematics of distal joints.[20] Strengthening of abductor muscles and external rotators of the hip leads to kinematic changes in the distal region of lower extremity.[21] Previous research shows that some corrective exercises are superior to other approaches for improving the condition of individuals with flat feet and pronation distortion syndrome.[9,10,22] Therefore, use of these exercises, along with other balance and postural control methods, is recommended.

Major attempts have been made to correct pronation of the foot using conventional interventions which directly target the foot, such as orthoses,[23] braces,[24] ankle exercises,[25] therapeutic footwear, and exercises for hip joint strength.[20] Inconsistent findings have been reported regarding the efficacy of corrective exercises in foot pronation and the effect of flat feet on other factors related to physical fitness.[26] Some studies have reported that people with flat or claw feet have weaker postural control in comparison with those with normal feet[26]; however, some studies have not confirmed such a relationship.[27] Also, several studies show that the corrective exercise program has no significant effects on the improvement of flat feet.[27]

However, the effectiveness of corrective exercises with a systematic approach to improvement of disorders and balance in patients with pronation distortion syndrome are not evaluated. These exercises may also reduce the cost of treatment and decrease the time spent on rehabilitation and treatment. Investigation of pronation distortion syndrome heavily relies on data about growing populations (male students aged 10 to 16 years). Since students at this age are at the peak of physical growth, they may better respond to the corrective exercises, so the present study was of great importance.

The novelty of the present study is the evaluation of patients with pronation distortion syndrome according to the New York test and balance with stabilometer device an emphasis on outcomes, including static and dynamic balance. Thus, the current study aimed to elucidate the effects of corrective exercises with a systematic approach on the balance of patients with pronation distortion syndrome. It was hypothesized that a 12‑week systematic corrective exercise program would significantly improve static and dynamic balance in patients with pronation distortion syndrome.

Methods

This study was a single‑blind (study sample) randomized controlled clinical trial carried out to examine the effect of corrective exercises on the balance control of students with pronation distortion syndrome. The present study was extracted from a Ph.D. thesis in pathology and corrective exercise approved with number 1373509, the code of ethics of IR. UI. REC.1396.037, and IRCT20190824044597N1 by the University of Isfahan, Isfahan, Iran.

Study sample

The statistical population of the study comprised male students aged 10 to 16 years. In the present study, the alpha level, beta level, and the effect size of the intervention programs were considered being 0.05, 0.2, and 0.8, respectively.[28] For this purpose, 30 students of 10 to 16-year-old boys with pronation distortion syndrome were selected based on a general assessment using the New York test[2] and a coherent assessment according to the inclusion and exclusion criteria among 1836 students via purposive sampling. The study sample was randomly assigned according to a computer-generated randomization list and was stratified by age and navicular drop score to either off into experimental and control groups, also, none of the study samples knew which group they were in (single-blind). The study population comprising 30 male students with pronation distortion syndrome, who were evaluated in Clinic Corrective Exercise Training Center (district one). The subjects were purposefully selected and randomly divided into experimental and control groups.

They homogenized the experimental and control groups were in terms of height, weight, age, length of lower extremity, body mass index (BMI), pronation status, and supporting leg [Table 1]. After coordinating with the orthopedist, it assessed corrective exercise specialists from April 2018 until June 2018. Then, information was presented to the selected samples and their parents about pronation deviation syndrome, study objectives, research methods, and requirements for corrective exercises. If they will take part in the study, they signed a written consent form. After signing the consent form and considering the research limitations, it divided them into two groups.

Exclusion and inclusion criteria: The study inclusion criteria included ages 10 to 16 years and the functional pronation distortion syndrome according to the diagnosis of an orthopedic doctor and a corrective movement specialist, both of whom were present for evaluation at the same time. Having the functional pronation syndrome was determined based on all the specifications, including functional flat feet without symptoms of pain, based on the heel-rise test, in which they placed the person on the edge of the steps on his toes, moving his heel upwards. If a dimple appeared on the sole, the subject suffered from the functional flat feet.[8] Navicular bone drop greater than 10 mm was confirmed using the Brody method.[7] second degree flat feet based on the Denis A footprint test by seeing the soles on the mirror box and talcum powder, the sign of which was the identical size of the central part and the front of the foot,[29] the genu valgum by measuring the distance between the two inner ankles (at least 4 cm),[30] the lumbar lordosis more than 35 degrees[31] using a flexible ruler (Kidoz) by Youdas the method,[32] and having a natural or corrected vision with glasses or lenses.

Having other acute or chronic debilitating diseases contradictory to exercise or the prohibition by a specialist physician for exercise, history of injury or lower limb surgery, the inner ear and atrial fibrillation diseases, and problems affecting balance in the nervous system, abnormal range of motion (ROM) of the lower extremity joints, and serious orthopedic problems such as having a hard (structural) flat foot, not knowingly completing the consent form and personal health questionnaire, presence or creation of pain during the study, lack of completing the pre-test and post-test tests, and not continuously attending the exercises (absence in the two consecutive sessions or absence in three sessions during the period) were considered as the exclusion criteria.

Exercise program

The subjects in the experimental group performed a systematic corrective exercise program for three months and the control group continued his routine activity. The corrective training program comprised two sections of training and practice: in the training section, they explained the correct way to perform the functional activities of daily living in a two hour theoretical class session. The training section included 21 exercises as listed below.
A. self-release on the Foam Roller: Included the muscles

Table 1: Demographic data of the subjects

Variable Group	Groups	Mean±SD	Leven, s Test *F*	Leven, s Test Sing	Kolmogorov-Smirnov (*Z*)	*P*
Age (year)	Experimental	12.6±1.7	0.178	0.67	0.548	0.924
	Control	12.66±1.8			0.677	0.749
Height (cm)	Experimental	165.3±6.5	2.245	0.14	0.567	0.904
	Control	166.4±9.5			0.439	0.991
Weight (kg)	Experimental	67.29±5.72	3.84	0.06	0.477	0.977
	Control	68.9±9.9			0.503	0.962
BMI (kg/m^2)	Experimental	24.55±1.63	3.474	0.07	0.685	0.736
	Control	24.71±5.21			0.487	0.972
Leg length (CM)	Experimental	81.6±4.22	1.876	0.18	0.443	0.99
	Control	82.4±6.88			0.765	0.602

BMI: Body mass index; SD: Standard deviation of peroneal, gastrocnemius, soleus, psoas, hip adductor, and short head of the biceps femoris, and iliotibial band for 30 seconds

B. Static stretching Exercises: were performed on the gastrocnemius and soleus muscles on an inclined surface, the tensor fasciae latae muscle, the short head of the biceps femoris, and the psoas muscle.

C. Resistance Exercises: To strengthen the sole eccentric muscles, including ankle dorsiflexion and inversion, adduction, extension, and external rotation of the thigh with green and blue Thera band resistance band (Sporting, China) and short leg exercises to strengthen the sole intrinsic muscles.

D. Integrative Exercise: Included the Star Excursion Balance Test (SEBT) on all planes, climbing stairs, and launching exercises.

In all exercises, the principles of practice were observed.[8] The corrective exercises were collected from different scientific references [Table 2].[2,8,16] The subjects in the experimental group entered the training program one day after the pre-test (3 training sessions per week for three months). The corrective exercises used for the experimental group included 36 sessions of 60 minute (10 minutes of initial warm-up, 10 minutes of inhibitory exercise, 35 minutes of stretching, strength, and integrative exercises, and 5 minutes of cooling).[2,8] At the same time, the control group continued its normal activities. The screening process and the corrective exercises were implemented in the Corrective Exercise Center of Hazrat Mahdi (as) in Kermanshah Province in the school year of 2017-2018. The individuals cooperated during the exercises and attended the center, and none of them withdrew from the study.

Outcome measurement

Before and after 12 weeks of systematic corrective exercises, the desired variables were evaluated in both groups.

Table 2: Summary of Systematic Corrective Exercise Program

Indicators Exercises	Exercises	Sets	Reps	Tempo	Rest	Duration	Notes
Inhibit Exercise (Self-Myofascial Release)	Gastrocnemius/soleus	1	1			30 sec	foam roll
	Biceps femoris (short head)	1	1			30 sec	foam roll
	Iliotyial Bond/Tensor fasciae latae	1	1			30 sec	foam roll
	Adductors/Hip flexor complex	1	1			30 sec	foam roll
	Peroneals	1	1			30 sec	foam roll
Lengthen Exercise (Static Stretching)	Gastrocnemius (Internal rotation of the foot)	1	1			30 sec	Stretching
	Soleus	1	1			30 sec	Stretching
	Biceps femoris (short head)	1	1			30 sec	Stretching
	Iliotyial Bond/Tensor fasciae latae (In standing position and external rotation of foot)	1	1			30 sec	Stretching
	Adductors/Hip flexor complex	1	1			30 sec	Stretching
	Peroneals	1	1			30 sec	Stretching
Activation exercises							
Isolated strengthening Exercises	Ankle dorsiflexion against resistance	1-2	10-15	4/2/2	0 sec		Anterior tibialis
	Plantarflexion and inverting against resistance	1-2	10-15	4/2/2	0 sec		Posterior tibialis
	Raise the heel of one foot	1-2	10-15	4/2/2	0 sec		Medial gastrocnemius
	Bending knee against resistance with internal rotation	1-2	10-15	4/2/2	0 sec		Medial hamstrings
	Towel scrunches and shorten the leg without flexation your fingers	1-2	10-15	4/2/2	0 sec		Flexor fingers and intrinsic muscles of the foot
	Abduction and external rotation of the hip against resistance cache	1-2	10-15	4/2/2	0 sec		Hip abductor and external rotator
Positional isometrics techniques	Supine position with knees bent at 90° against hand resistance	1	4	25, 50, 75, 100%	0 sec		Medial hamstring muscle
	Supine position with straight knees, plantar and inversion foot against hand resistance	1	4	25, 50, 75, 100%	0 sec		
	Supine position with straight knees against of the hand resistance dorsiflexion foot	1	4	25, 50, 75, 100%	0 sec		Anterior tibialis
Integrate exercises (Integrated dynamic movement)	Single-leg balannce reach (In several directions)	1-2	10-15	Slow	30 sec		Under Control (Maintain proper arch feet and knees are directly in line with the second and third fingers) (Integration)
	Step-ups	1-2	10-15	Slow	30 sec		
	Lunges	1-2	10-15	Slow	30 sec		
	Single-leg squat	1-2	10-15	Slow	30 sec		

Flamingo balance test: This test is conducted by placing the palms of the hands on the waist (upper part of the pelvis) with a horizontal flexion of the thighs and placing the toes against the knee of the opposite leg, while standing straight on the toes of the opposite foot. The stopwatch was started as the heel was raised from the floor. The stopwatch was stopped, and the time was recorded when the person lost balance, his hands came off the hips, or the non-supporting foot lost contact with the knee of the supporting leg. Based on a study by Johnson and Nelson, this test has a reliability coefficient of 87%, and its objectivity has been estimated at 99%. It was assumed that this test has adequate face validity.[33]

Star excursion balance test: To assess the dynamic balance of the subjects, three anterior, posteromedial, and posterolateral directions were used. The star excursion balance test is a suitable tool for evaluating dynamic balance. Hertler *et al*. reported the internal validity of this test twice separately within the ranges of 0.82-0.96 and 0.81-0.93, respectively. To perform the test, an eight-pointed star (angle of 45°) was drawn on the floor. To evaluate dynamic balance, only the anterior, posteromedial, and posterolateral directions were evaluated based on the distance traveled on foot in centimeters. In this test, the student stands on one foot (supporting leg) at the center of the star with hands placed on the waist, while reaching the non-supporting leg as far as possible in the mentioned directions. The test was repeated three times, and the best recorded time was considered as the person's final score.[34]

Stabilometer: A stabilometer device (force plate) (version 5.0.1-1; Danesh Salar Iranian, Tehran, Iran), which indirectly measures body sway in relation to forces attributed to shifts in the person's center of gravity, was used to measure balance more precisely. Repeatability of this tool in comparison with the Kistler force plate was reported to be 0.85 (ICC) for measuring the postural sway area.[35]

To measure static and dynamic balance, after starting the device and taking the necessary measures for the test, such as calibrating the device and giving necessary explanations about the test, each person stood on the device on a naked foot for 30 seconds and was asked to stare at a specific point on the wall which was selected relative to his height to avoid eye movements (as every movement of the head can lead to a shift in the center of gravity). Each person was tested three times to increase reliability, and the mean score was recorded for each person. The rest time between the two tests was two minutes. The mean total sway area from the center of gravity (2 cm), as presented on the computer screen, was recorded as the static balance of each subject.[36]

To measure dynamic balance, the student was asked to stand at a predetermined distance from the device (2 m). To perform the test, after the student was asked to comfortably walk at his own pace, he was asked to step on a point determined by the examiner and pass the stabilometer device with the supporting foot. Finally, dynamic balance was calculated by measuring the total sway area from the center of gravity (from the moment of heel contact until toe lift). All balance tests were performed on the dominant foot. Stability of the body posture was evaluated in laboratory conditions by recording involuntary body sways that are not visible to the eye. The data were collected and saved on a computer. Analysis was based on the calculation of force changes on the center of gravity over time on the horizontal plane.[37]

Data analysis

Continuous data have been presented as mean ± standard deviation (SD). Normality of continuous data was evaluated using Kolmogorov-Smirnov test, all variables had a normal distribution. Independent ttest was carried out to compare the baseline characteristics between the groups. The data were analyzed using paired samples ttest to identify within group differences. Independent samples Student's ttest was used to detect differences between groups. The data were analyzed SPSS software (version 22 IBM Corporation, Armonk, NY, USA). P value <0.05 was considered to be statistically significant.

Results

Thirty students in two equal groups enrolled in this study and were randomly assigned to the experimental and control groups (15 patients per group). The two study groups were not statistically different in age, height, weight, length of the lower extremity, and body mass index [Table 2].

The static balance score (flamingo balance and stabilometer tests) improved significantly ($P < 0.05$) in the experimental group, but not in the control group ($P > 0.05$). A significant difference ($P = 0.001$) in the flamingo balance and stabilometer test score was evident between the experimental and control groups [Table 3] and [Figure 1].

Dynamic balance score (star balance in all three directions and stabilometer tests) improved significantly ($P < 0.05$) in the experimental group, but, not in the control group ($P > 0.05$). A significant difference ($P = 0.001$) in the star balance test on all three directions, and stabilometer test score was evident between the experimental and control groups [Table 3] and [Figure 1].

Discussion

This study was accomplished with the aim to determine the effect of systematic corrective exercises on the static and dynamic balance of students with pronation distortion syndrome. Based on the findings, the experimental group showed better performance on static and dynamic balance tests after 12 weeks of corrective exercises, compared with the control group. They had a greater static and

Table 3: Changes in dynamic and static balance in experimental and control groups (*n*=30) before and after an 12 week corrective exercise

Variables	Groups	Pretest		Posttest		¥*P*	€*P*
		Mean	SD	Mean	SD		
Star excursion balance test (CM)							
Anterior direction	Experimental	62.8	6.8	82.4	6.2	0.0001*	0.001*
	Control	63.4	6.9	66.7	6.9	0.29	
Posterior-internal direction	Experimental	69.6	6.6	87.8	4.7	0.001*	0.001*
	Control	69.4	6.7	69.6	6.3	0.61	
posterior-external direction	Experimental	66.2	7.1	86.06	6.93	0.0001*	0.001*
	Control	66.9	6.6	67.2	6.2	0.21	
Stabilometr test (CM) dynamic	Experimental	10.6	1.9	3.8	0.6	0.001*	0.001*
	Control	11.19	1.8	11.18	1.8	0.08	
Flamingo balance test (Sec)	Experimental	10.2	2.04	42.26	5.35	0.001*	0.001*
	Control	9.73	2.18	10.13	1.92	0.08	
stabilometr test (CM) Static	Experimental	3.7	0.89	1.23	0.48	0.001*	0.001*
	Control	3.72	1.02	3.71	1.02	0.12	

Values are mean±SD, ¥*P* Value Indicates within-group differences (paired samples *t*-test), €*P* Value Indicates between group differences (independent samples *t*-test) *P<0/05

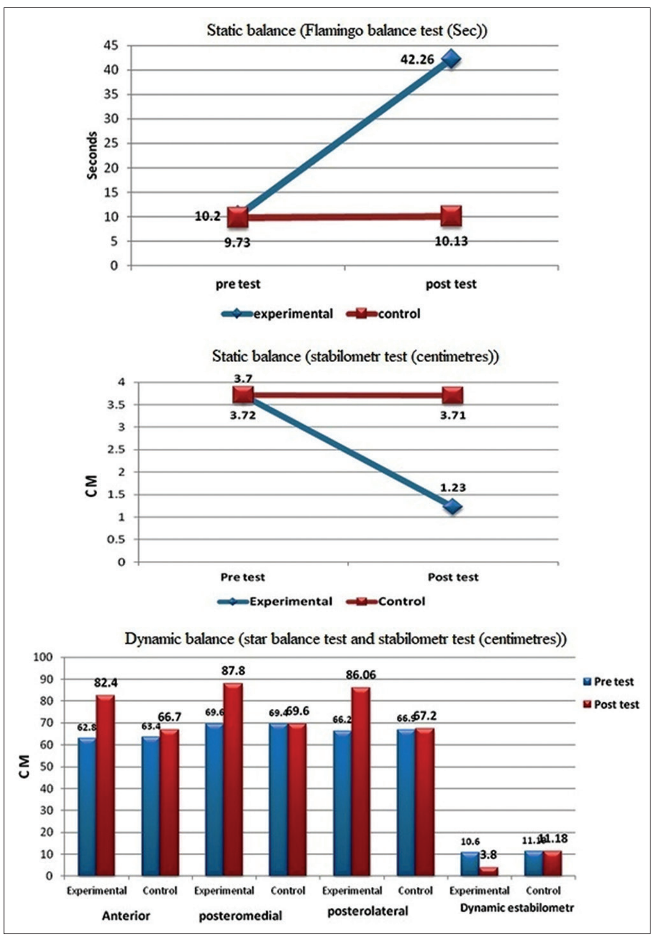

Figure 1: Changes in the scores of the variables of static and dynamic balance in two study groups in pretest and posttest

dynamic balance of the dominant leg showed the higher effectiveness and better outcomes of systematic corrective exercises, compared with the routine approach.

Difference in the mean posttest scores of static balance was significant between the groups (flamingo balance test: 32.13 sec; stabilometer test: 2.48 cm). Also, difference in the mean posttest scores of dynamic balance was significant (star balance test for anterior, posteromedial, and posterolateral directions: 87.67, 14.15, and 16.86 cm; stabilometer test: 7.31 cm). Difference in the mean posttest scores of posture was significant between the groups. On the navicular drop test, a 3-mm drop was observed, and the gap between the ankles was 4.91 cm (using calipers); also, the result of a flexible ruler test for lumbar lordosis was 13.11 degrees.

This finding shows the higher effectiveness of the systematic corrective exercises method compared to the usual activity; this is consistent with the results of studies by Mulligan *et al*. (2013),[38] Sulowska *et al*. (2016),[39] Goo *et al*. (2016),[40] Golchini *et al*. (2018)[10] and Najafi *et al*. (2018).[9] They reported that the static balance, dynamic balance, and posture of the subjects in the experimental and control groups before corrective exercises were not different, but this trend was reversed after performing the corrective exercises, and the experimental group subjects had a better static balance, dynamic balance and posture compared to the pretest stage and the control group.[9,10,38-40] The reason for this alignment may be the use of the corrective exercises in these studies[9,10] similar to the exercises applied in the present study. Najafi *et al*. used combined exercises in their study,[34] but the systematic exercises were used in the present study.[10]

Mulligan *et al*.[38] argued that plantar intrinsic muscle training supports medial longitudinal arch dynamics. Furthermore, Sulowska *et al*.[39] revealed that plantar short foot muscle exercises have beneficial effects on foot posture and functional movement patterns. Goo *et al*.[40]

also showed that an effective strategy for normal gait is to strengthen the gluteus maximus and perform exercises that correct pronation of the foot. Najafi *et al*.[9] showed that the involved muscles have different activities and tasks and that the time for ankle and thigh strategies differs between people with lower limb abnormalities and normal individuals. Golchini *et al*.[10] showed systematic corrective exercises improve ankle proprioception in patients with pronation distortion syndrome, and it may be recommended for these people. They showed that appropriate exercises and timely contraction of muscles in balance strategies, including the ankle strategy (as the first approach to balance recovery), can be improved to prevent balance disturbances and their consequences.[9,10]

Various studies have shown that regular corrective exercises can improve static and dynamic balance and reduce secondary abnormalities. Therefore, in order to improve and correct pronation deviation syndrome and balance in these people, design of a systematic corrective exercise program, by controlling factors such as exercise speed, strength, duration, intensity, and repetition, is necessary; in the present study, it applied this in the experimental group.[9,10,39,40] This finding did not match the findings of the studies carried out by Shih *et al*. (2012),[41] Pashnameh *et al*. (2014),[42] and Ghasemi Paindehi *et al*. (2016).[43] The discrepancy between the findings can be attributed to differences in exercise protocols with different approaches, study populations, and assessment tools.

Shih *et al*.[41] showed that movement patterns of joints in children with and without flat feet were similar and that there was no significant difference between these children; also, no kinematic adaptation was observed in the gait of children with flat feet. Pashnameh *et al*.[42] concluded that there was no significant relationship between flat feet and static and dynamic balance. Ghasemi Paindehi *et al*.[43] reported that the anthropometric features of the feet cannot be an effective measure of postural control and that other factors may affect the morphological features of the feet in postural control. Also, the significant relationship between the medial longitudinal arch and star balance test results might be related to the stable structure of the feet; therefore, anatomical structure of the feet affects dynamic balance, whereas anthropometric features do not induce such an effect.[43] The discrepancy between the results may be attributed to the corrective exercise program with different approaches or characteristics of the study populations.

Hertel *et al*.[15] reported that the star balance test requires neuromuscular control for proper joint position and muscle strength around the joint during the test. Biomechanical changes due to ankle pronation may affect the joint load, muscular mechanical efficiency, muscle feedback, and proprioception, causing changes in the somatic nervous control of lower extremity. Overall, activities of different muscles in feedback to postural disturbances are based on a common latency rule, involving shifts in the body's center-of-mass Welch *et al*.[44] Automatic postural responses are known as postural responses of the motor system for postural stability. These responses are formed in the cerebellum and occur involuntarily before voluntary movements; therefore, they cannot be corrected.[17] These automatic responses are characterized by three balance strategies: ankle strategy, pelvic strategy, and gait strategy; they are activated gradually to adjust the body center-of-mass.[17] The first balance strategy is the ankle strategy, which depends on the dorsiflexor and plantar flexor muscle groups around the ankle joint axis.[17] This strategy is typically used by the individual to control the body posture when balance-disturbing forces are not strong and the support base is firm.[17] When the person is standing or when there are small balance disturbances, the ankle joint moves to restore the body's center of mass.[45] In the event of forward balance loss, gastrocnemius, hamstring, and paraspinal muscles are activated, while in backward balance loss, anterior tibia, quadriceps, and abdominal muscles (distal to proximal) are activated.[45]

According to the results of the present study and previous research,[9,10,45,46] to explain the impact of corrective exercise training on balance and posture, it should be noted that stretching, contraction, and strengthening of muscles in the central body, thighs, knees, legs, ankles, and feet are postural reactions by the central nervous system before performing a balance test and moving the body; this can prevent postural disorders and regulate imbalance.[9,46] Therefore, strengthening of muscles in this area following the exercise program could improve the musculoskeletal system and coordination, which in turn reduced center of gravity displacement and sways.[9,10,45,46]

Corrective exercises increase the efficiency of the musculoskeletal system, which is involved in the proper movement of lumbar-pelvic joints along the kinetic chain during functional balance tests.[9] Also, the legs have controllable acceleration during movement, and the person shows greater muscular balance and functional performance. These effects lead to optimal performance and increased strength of the lower extremity, resulting in better muscular stability, and ultimately, the individual's higher score.[9,46] Therefore, in the static and dynamic balance tests with a stabilometer, the postural sway area is decreased; in other words, the stability is increased.

Limitations

In the present study, there were limitations in the control of nutrition, mood, and mental state of the subjects, because the samples were monitored only within the center of corrective exercise and for accurate execution of the corrective exercises. Besides, the study was performed only on 10- to 16-year-old male students.

Suggestions

It is suggested that the present study be conducted on larger samples. Moreover, samples including male and female students in different age groups should be practiced and evaluated. It is better to perform the same study on individuals at different and longer times.

Conclusions

Given the findings in the present study, systematic corrective exercises are likely to improve the static and dynamic balance in students with pronation deviation syndrome. Therefore, these exercises are recommended for this group of students.

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Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient (s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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