



Effect of a Course of Selected Corrective Exercises on Balance and Function of Female Adolescents with Flexible Flatfoot

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ABSTRACT

Aims: Postural abnormalities cause dysfunction. In this regard, lower extremity disorders such as flat-foot play a major role in creating lower extremity disorders. The present study evaluates the effect of a course of selected corrective exercise on the balance and performance of adolescent girls with a flat foot.

Instruments & Methods: Subjects in this study included 30 students within the age range of 9-10 years old with flat-foot deformities who were randomly selected and divided into two groups of corrective exercise (age: 11.60 ± 1.02 years, height: 148.46 ± 10.29 m, weight: 47.40 ± 11.69 kg and body mass index: 21.42 ± 11.92) and control (age: 11.40 ± 0.95 years, height: 148.46 ± 12.67 m, weight: 47.46 ± 12.28 kg and body mass index: 21.37 ± 4.28).

Findings: Demographic data were collected through a questionnaire and Navicular drop method was used to assess flat-foot deformity. Descriptive statistics were used to determine the frequencies, central indices, and dispersion in the form of tables and graphs, and multivariate analysis of covariance was used to investigate the intergroup differences in research variables. The results showed that corrective program had a significant effect on functional tests and static balance with open and closed eyes ($p < 0.01$).

Conclusion: This study showed that corrective exercises were effective in improving balance and function of the studied-participants. Hence, it is suggested that therapists use different exercises related to the trunk and lower extremities in the form of corrective program to improve female adolescents' deformities.

Keywords: Corrective Exercises, Balance, Flat foot, Female Adolescent, Function.

Introduction

Walking is considered as a very complex cycle since it is the most basic movement^[1]. One of the skeletal abnormalities that are directly associated with this basic movement is flat-foot, in which standard arches are not present in flat-foot and so body faces problem during walking because of not proper weight distribution, that lead in turn to a series of postural status disorder complications. The flat-foot is one of the changes that may lead to postural control disorder^[1], disorder in foot pressures^[2], different lower extremity injuries^[2], and changes in the foot and ankle joint mobility during contact with ground^[3]. Thus, as foot forms the lower part of this chain and provides

a small range of the surface support to maintain balance, biomechanical changes in the surface support range can affect balance control, and function consequently. Evidences suggest that when musculoskeletal abnormalities occur, the muscles and ligaments of the concave side show less activity-, but the muscles and ligaments of the convex side show more activity^[3]. Therefore, the activity of muscles change compared to normal people. Moreover, distortion of skeletal parts could be resulted in increased energy consumption and mechanical pressures^[4,5]. Various studies have also been conducted on the effect of foot postures on postural control and body function. With different

results. In the study that was conducted by Sandrey et al. (2008), no significant difference was found between flat-foot and normal foot in term of postural control and body function^[5]. In another study, Dobholkar et al. (2012) reported that people with flat-foot had a poorer function than those with normal foot in dynamic balance^[6]. On the other hand, Khodaveysi et al. (2012) in their research-, on female adolescents in order to measure dynamic balance using Biodex balance system, reported that at stable level, subjects with high arch foot had lower dynamic balance function than subjects with normal and flat feet, but at unstable level, the group with normal feet had better balance function than subjects with flat feet^[7]. In another study conducted by Bazund et al. (2014) to compare the dynamic balance of subjects with flat and claw foot abnormalities during walking, they reported that there is a significant difference among the subjects with flat foot and subjects with normal foot and subjects with pes cavus and subject with normal foot in the anterior-posterior direction^[8].

Given the high prevalence of flat foot malformations among adolescents^[9] and the negative effects of this complication on balance and function and also pain caused by doing daily activities and long standing, and since no domestic study has been conducted so far on the effect of these comprehensive corrective exercises on these factors among female adolescents with flat foot and as various studies have provided different results on the impact of exercise on correction of foot^[10], conducting further investigations and applying different exercise seem to be necessary. In addition, given the influence of proximal and distal chains on the anomaly, this study was conducted to investigate this issue.

Instruments and Method

The present study was a quasi-experimental

study. Thirty female students aged 10-13 years with flat foot were selected out of 50 students with purposeful sampling and were satisfied to participate in the study. They were randomly divided into control (n = 15) and experimental (n = 15) groups. After the initial justification of the research aims and procedures, written consent was obtained from the parents of the students. Flat foot variables were assessed using the Navicular drop method. Subjects with Navicular drop more than 10 were included in the present study. The height and weight of the subjects were also assessed so that two groups to be matched in terms of height and weight. After evaluating the balance and function of the experimental group, they received an exercise program for 6 weeks. After completion of the program, the subjects were re-evaluated.

Navicular bone drop measurement method Navicular drop was measured by the Brady method (4). In this method, the subject was initially placed on a chair in such a way that the foot was in a weightless position. The subject's foot was placed in subtalar position. Then, by touching the inner area of ankle and simultaneously with inversion and eversion movement, navicular bone function was determined and marked. The distance between the navicular bone head to the ground was measured and marked on the paper. The subject was asked to stand, and while she was bearing the weight, the distance between the navicular bone head to the ground was re-measured. Finally, by measuring the difference between the two measurements, the navicular bone drop level was determined^[11]. Subjects with a navicular drop greater than 10 mm were included into study as flat foot^[11], Intra-class Correlation Coefficient (ICC) range from 0.73 to 0.96 for inter-tester and intra-tester reliability was used by Cell et al. while doing this test^[12].

Static Balance Assessment

A foot scan machine was used to evaluate static balance. For this purpose, the subject was asked to stand with naked feet, so that the weight was evenly divided between the two feet on the foot scan machine and to stay in the same position for 20 seconds. After the test, she was asked to rest for 20 seconds, and then, do the same action with her closed eyes ^[13].

Dynamic Balance Assessment

To assess the dynamic balance, the subject was asked to start walking on a 20 m path after warming up. She was warned to avoid setting foot steps and to continue walking normally. It continued until the 3 correct trails from the right foot and 3 correct trials from left foot were stored in the foot scan machine. After the correctly recording the activity, it was completed ^[13].

Vertical Jump Test

This test, used to assess the explosive strength of the leg muscles-, for doing this test the subject stood next to the wall (it is better to stand without shoes), so that one hand was beside her body and other hand was stretched over his body comfortably. Then, she placed his plastered fingers on the scaled plane and the number was recorded. Then, without the rotation of shoulders, she jumped upwards and placed her plastered fingers again on the scaled plane at the highest possible point. This procedure was repeated twice and the best result was recorded. The difference between the two numbers for standing and jumping was considered the person's score ^[14].

40-yard Dash Test

This test assesses one's ability to drive forward or move all or part of the body in space in the shortest time possible. Speed was measured through a 36-meter- (42-yard) sprint test and recorded as meter/second. The 36-m sprint test was chosen as it is widely used for speed assessment and speed tests greater than 60

m do not correctly indicate the speed during the effect of skill and technique of running. In this test, the subject was placed behind the starting line and was running to the end of the line with the whistle sound ^[14].

Minute Walking Test

The 5-minute walking test measures the distance a participant can travel in a 5-minute period. The test was conducted on days when the subjects were mentally in good conditions. Test-retest reliability was reported (ICC = 0.60) in healthy subjects ^[15].

Visual Analogue Scale (VAS)

The VAS assesses pain on a one-dimensional scale with scores rated as "no pain" and "worst possible pain". This scale is a valid scale reporting the severity of pain reported by an individual. In this study, VAS was used to measure pain severity after completing a 5-minute walking test ^[15].

Exercise program

The exercise program of the present study was implemented for 6 weeks through three sessions per week. Exercise program included Thera-Band Hip Abduction exercises, Thera-Band Hip External Rotation, foot rolling, rotating both wrists toward each other, rolling up the fabric with the foot, heel raising with a chair, heel walking with a flat knee, slow walking (with foot pronation control), both legs squat (with foot pronation control), standing on one leg, fast walking (with foot pronation control), single-leg squat (with foot pronation control), turning both wrists toward each other (by placing the ball between two ankles), removing the small rings and placing them around a rod with fingertips, heel raising with the weight in two hands, standing on one leg (with weight in both hands) and walking on the sand (with foot pronation control). These 15 exercises were performed in a 6-week program, so that eight exercises were

included in each exercise week in program and they were performed by the subjects. All exercises were selected from valid sources [16-18] and included in the program with the help of instructors of corrective movements and professors of this field. The control group also did their daily activities during this period and did not participate in any exercise program. SPSS 18 software was used for calculating and statistical analysis of the raw data. Descriptive statistics were used to determine the frequencies, central indices, and dispersion in the form of Tables and Graphs, and Moreover ANOVA and MANCOVA tests were used to examine the inter-group differences in the research variables. In addition, the effect size was obtained by Eta test. Significance level was considered less than 0.05 in all statistical methods.

Findings

Mean and standard deviation of demographic characteristics of subjects including age, height, weight and BMI are given in Table 1. There was no significant difference between the groups in terms of all demographic variables ($p > 0.05$) the study groups were homogeneous in terms of the above-mentioned variables.

Table 3 shows the intergroup differences of all examined tests. It should be noted that the pre-test was considered as covariate in analysis of covariance test. In addition, for static balance variables with closed and opened eyes, covariance matrices of the dependent variables were evaluated by Box M test and the results showed that the hypothesis of homogeneity of covariance matrices were hold (box M = 30.614, $F=4.17$, and $sig=0.064$).

Table 1) Comparison of demographic characteristics of the studied subjects in both group

Variable	Group	Mean \pm SD	t	p.value
Age(year)	Control	11.40 \pm 0.95	0.970	0.341
	Experimental	11.60 \pm 1.02		
Height(m)	Control	148.46 \pm 12.67	0.747	0.765
	Experimental	148.00 \pm 10.29		
Weight(kg)	Control	47.46 \pm 12.28	0.451	0.326
	Experimental	47.40 \pm 11.69		
BMI(kg/m ²)	Control	21.37 \pm 4.28	0.225	0.420
	Experimental	21.42 \pm 11.92		
Drop Navicular	Control	13.73 \pm 1.16		
	Experimental	13.60 \pm 1.12		

Table 2) Results of descriptive statistics of the test of the studied subjects in both group

Variable	Group	Pretest SD ±Mean	Posttest SD ±Mean	
Vertical jump	Control	3.78 ±38.79	3.18 ± 37.74	
	Experimental	1.87 ± 37.21	1.96 ±40.38	
40-yard	Control	0.90 ±7.53	1.07 ± 7.67	
	Experimental	0.57 ±7.13	0.89 ± 3.45	
5-minute walking	Control	13.82 ± 390.53	16.28 ±394.86	
	Experimental	15.45 ± 387.73	17.05 ±411.33	
Pain	Control	0.79 ±4.73	0.63 ± 4.53	
	Experimental	0.48 ± 4.66	0.74 ±3.86	
Static balance with opened eyes	EO.COPx	control	0.81± 4.04	0.86 ± 4.10
		experimental	0.79 ± 3.85	0.86 ±3.14
	EO.COPy	control	0.36 ±2.63	0.32 ±2.68
		experimental	0.47 ±2.45	0.43 ± 2.16
	EO.Area	Control	3.29 ± 10.30	3.08 ± 10.48
		Experimental	3.08 ±9.23	2.97 ±6.70
	EO.TMV	Control	0.009 ±0.05	0.01 ± 0.05
		Experimental	0.01 ± 0.06	0.01 ±0.04
Static balance with closed eyes	EO.COPx	control	0.41 ±2.78	0.46 ±2.705
		Experimental	0.48 ±2.72	0.37 ±2.17
	EO.COPy	Control	0.35 ±1.75	0.36 ± 1.77
		Experimental	0.30 ±1.75	0.26 ± 1.44
	EO.Area	Control	1.03 ±4.61	1.07 ± 4.54
		Experimental	1.18 ± 4.55	0.84 ± 3.007
	EO.TMV	Control	0.006 ±0.003	0.009 ±0.03
		Experimental	0.009 ± 0.04	0.008 ± 0.03

Table 3) Results of covariance analysis of the tests in research dependent variables

Variable	Source	F	df	Sig	Eta
Vertical jump	Group	29.49	1	0.001	0.646
40-yard	Group	26.44.26	1	0.001	0.524
5-minute walking	Group	18.59	1	0.001	0.408
Pain	Group	6.787	1	0.01	0.201
Static balance with opened eyes	EO.COPx	11.995	1	0.002	0.333
	EO.COPy	15.387	1	0.001	0.391
	EO.Area	15.941	1	0.001	0.399
	EO.TMV	5.049	1	0.03	0.174
Static balance with closed eyes	EC.COPx	16.597	1	0.001	0.409
	EC.COPy	5.509	1	0.02	0.187
	EC.Area	18.562	1	0.001	0.436
	EC.TMV	6.148	1	0.02	0.204

Results of ANOVA test in post-test of control and experimental groups in variables of vertical jump (Eta = 0.646, $p = 0.001$, $F = 46.29$), 40-yard dash (Eta=0.552, $P = 0.001$, $F = 4.26$), 5-minutes walking (Eta = 0.408, $P = 0.001$, $F = 18.59$) and pain (Eta = 0.201, $P = 0.015$, $F = 6.78$) showed a significant difference. The results of MANCOVA test showed that there was a significant difference between at least one of static balance variables with open and closed eyes (Pillai Trace = 0.556, $F = 6.583$, $Sig = 0.001$, $\eta^2 = 0.556$). Finally, it was found that there was a significant difference between two groups in variables of displacement of center of pressure in anterior-posterior direction (COPx), internal-external (COPy), total area of movement of center of pressure (COP Area), and total mean velocity of center of pressure (TMV) during balance test in open and closed eyes.

Discussion and conclusion

The results of this study showed a significant effect of exercise program on function, pain and balance in girls with flexible flat foot. The results of the research with regard to improvement in balance are in line with the results of the studies conducted by Ghaderian et al. (2016), which reported the significant impact of rope jumping on improving the balance in people with flat feet [19], Fakoor and Daneshmani (2013), which reported the effect of a 6-week corrective program on improving flat foot and static balance in boys [20], Habibian et al. (2017), which reported an improvement in dynamic balance immediately after using medical shoes in subjects with flat foot [21], Lee et al. (2016), which reported the effect of strength exercises of intra-articular and tibialis posterior (inter-articular muscles) on improving foot pressure distribution

and dynamic balance ability of adults with a flexible flat foot [22].

Moreover, the results obtained on the balance are in line with the results of the research conducted by Kim and Jin Kim (2016), which showed an improvement in balance following exercise [23] and the results of the research conducted by Maligan et al. (2013) which examined the effect of intra-articular muscles of foot on internal longitudinal arch, morphology, and dynamic performance and referred to the positive effect of strength program on improving foot performance and heel arch [24]. Flat foot is associated with excessive projection of subtalar joint. Abnormal compensatory pronation may cause instability and excessive movement of the foot joints [25]. Therefore, flat foot may be unstable during weight bearing and disrupt the postural control [26]. Differences between flat foot and normal foot subjects in terms of postural control of dynamic balance can be due to two reasons: 1) differences in structure and biomechanics of the foot 2) differences in physiological characteristics such as differences in proprioceptive receptors, articular receptors or differences in muscle strategies. Disruption in mechanical receptors of the joints increases the latency period of the muscle response and prolongs the duration of the correction and rebuilding of the balance [27]. Since balance is maintained in the closed motor chain and relies on the coordination of feedback and motor strategies between the thigh, knee, and ankle, the balance can be impaired due to impairment in the mechanical strength and stability of any joint or lower extremity chain structure [28]. Flat and claw foot can influence the peripheral inputs through changes in irritability of joint or contact surface or changes in muscle strategies to maintain a stable level of support. In this regard, Dabholkar et al. (2012) reported that subjects with flat foot had a poorer

performance than those with normal foot in dynamic balance [29].

In addition, change in the strength and activity of the muscles around the ankle joint affect the balance maintaining strategies. As a result, balance, postural control, and performance are affected by foot structure, strength, and performance of the foot muscles. Properly maintaining of the foot arches requires static stability by capsule and ligaments of the joints as well as dynamic stability through the intrinsic and extrinsic muscles [30]. Flexible flat foot is often caused by weakness in the intrinsic and extrinsic muscles. Strengthening these muscles reverses this process and prevents the valgus and eversion the heel, which is associated with lack of pronation and reduced internal longitudinal arch [31]. Upon completion of the exercise protocol, it was shown that increased abductor and rotator hip muscles strength as part of the exercises had a positive effect on reducing and correcting foot pronation abnormalities. This study showed that there is a close relationship between foot projection and the weakness of external hip abductors and rotators that can cause foot flatness, which confirms the Janda's theory of pronation distortion syndrome, so attention should be paid to proximal part of lower extremities in correcting the flat foot.

In design of an effective corrective exercise program, those exercises should be used that strengthening the proximal muscles such as the external hip abductor and rotators and adductor stretches. These muscles are effective in controlling movement in all lower extremities in the transverse and frontal plane [32]. By increasing the strength of the external abductors and rotators and increasing the length of the abductors, the internal rotation motion and the closing of lower extremity to the midline of the body might

reduce, and this reduction is transmitted to the distal lower extremity (ankle). Finally, it can affect the area and correct and e the foot eversion and improves postural control indicators. As a result, these muscles play a major role in alignment of the lower extremities, because when the distal area of lower extremities is fixed, movement in one part affects other parts of the chain of movement ^[32], which in turn results in decreased pronation. Therefore, the present study also tried to use higher chain exercises such as central body area. In addition, in postural abnormalities, the performance of the proprioceptive senses disappears partially or completely. It has a negative effect on postural alignment, which exacerbates the present abnormality. A part of the improvement related to the results of functional tests in this study occurs due to correction of the foot condition and improvement of stiffness and weakness of the proximal joint muscles. In this study, the final stage of corrective exercises was coherence techniques. Coherence exercises were performed to retrain the motor system to return to a functional and synergetic motor pattern (keeping the foot straight in the frontal plane and lack of angled leg). Using multiple joint exercises can improve coordinated movement among the muscles involved by helping to neuromuscular control restoration ^[33].

In general, one of the reasons for an increase in balance and function following this exercise is to increase the strength of the lower extremity muscles of the subjects after participating in one course of exercise and to reduce subtalar joint compensatory pronation and to increase the stability of the foot structures. Increased strength in the first few weeks of exercise is thought to be nervous system adaptations ^[31]. Exercise may also increase balance by applying

stress on the musculoskeletal system ^[34, 35]. In addition to strength exercises, exercises related to proprioceptive sense may improve motor function by preparing motor neurons and increasing coordination and integration of motor units, co-contraction of corresponding muscles and finally by improving neuromuscular responses. After one course of exercise, the person prepares his or her sensory-motor system to provide appropriate responses for postural control based on the learning and neuromuscular coordination gained in the exercises.

Conclusion

Given the results obtained on the significant impact of applying corrective program on improving balance and function in female adolescents with flat foot, it seems that using these exercises are effective for better daily activities requires postural control. Hence, these exercises are recommended to improve the function of this target group.

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Ethical permission

This study approved by ethics committee of sport sciences research institute with ID number IR.SSRC.REC.1397.004

Conflicts of interests

The authors declare that they have no conflict of interest

Author's contributions

FNA was primary researcher author/ methodologist/assistant in statistical analyst and discussion section (50%) MA supervised all section of study (30%) ESHA&SHE were advisor of study all authors read the manuscript and approved it (20%).

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