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Review Article

Effects of Exercise Training Programs on Postural Control and Dynamic Balance in Individuals with Flat Feet and Cavus Feet: A Systematic Review and Meta-analysis

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ABSTRACT

Background: Considering the high prevalence of flat feet and cavus feet abnormalities among people and the adverse effects resulting from these complications on both balance and function, a systematic review on the effects of various exercise programs on postural control and dynamic balance of these individuals seems to be essential. Thus, the current systematic review and meta-analysis examined the effects of exercise training programs on postural control and dynamic balance among individuals with flat feet and cavus feet.
Methods: Relevant articles were identified through searches across the eight databases of PubMed, SCOPUS, LILACS, CINAHL, CENTRAL, Web of Science, PEDro, and Google Scholar. The search period ranged from the beginning of available date to November 2021. Manual searches and a complete investigation of the references of papers were also performed.
Results: The current systematic review and meta-analysis included 13 studies. Meta-analysis results indicated that the exercise programs had a significant effect on posture control (P=0.001) and dynamic balance (P=0.001) among individuals with flat feet and cavus feet. The effect size of Hedges's g of the exercise programs on postural control was 1.81 with a confidence interval of 95% (1.40-2.22). The effect size of Hedges's g of the exercise programs on dynamic balance was 1.32 with a 95% confidence interval (0.98-1.67).
Conclusion: The present systematic review found that exercise programs had a significant effect on the postural control and dynamic balance of individuals with flat feet and cavus feet abnormalities. Study results have revealed that to better correct abnormalities and thus further improve postural control and dynamic balance, the period of exercise program should be increased. Moreover, exercise programs should also focus on greater involvement of neuromuscular systems and direct effects on the central nervous system so that a greater effect on improving postural control and dynamic balance can be observed.

Background

The ability to control the body position in a space results from the complex interactions of musculoskeletal and neuromuscular systems, which is collectively known as postural control [1]. To maintain postural control, the person should maintain their body position in the space and generate proper force to maintain or correct the body position. Achieving this objective requires a complex relationship between neurosensory and musculoskeletal

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systems [2]. As postural control is maintained within a closed movement chain dependent on integrated feedback of movements of the hip, knee, and ankle joints, it may be disrupted in response to impairment in sending afferent sensory information or by disorders in the mechanical power and strength of each muscle or structure belonging to the lower limbs [3].

The feet constitute the lowest part of the body movement chain and provide a small range of support surface area for maintaining postural control [4]. The existence of abnormalities in the structure of the feet may affect a person's function in different positions [5]. Flat and cavus feet abnormalities may impair the peripheral inputs sent from proprioception [6]. Flat feet may be associated with excessive subtalar joint pronation. This abnormal compensatory pronation may cause instability and hyperactivity of the feet joints. Cavus feet, which is associated with excessive supination of the subtalar joint, may have adverse effects on postural control because of the deficient support surface the feet has to tolerate for the weight compared to normal feet [7].

It seems that changes in the sole structure causes changes in the joint mobility as well as alterations in the contact regions of the feet with the ground, thereby reducing the inputs upcoming from the somatosensory system [8]. Changes in the power and activity of the muscles around the ankle joint affect balance-keeping strategies as well as postural control and dynamic balance [9]. Studies examining the effect of feet abnormalities on postural control have found that individuals suffering from flat foot or cavus foot have weaker postural control compared to individuals with normal feet [10-13]. Other studies have reported that dynamic balance is weaker among individuals with flat and cavus feet compared to people with normal feet [12, 14].

Postural control is one of the essential factors required in performing daily activities, optimal implementation of sports activities, and preventing injury. It is believed that impairments in postural control lead to defective motor skills, occupational injuries, increased fluctuations of the body, and repeated injuries especially in the lower limbs [15, 16].

Concerning the high prevalence of flat and cavus feet abnormalities among people, the adverse effects of these complications on balance, the development of pain after undertaking daily activities and standing for long periods of time, along with changes in the plantar pressure pattern, the effect of exercises on the postural control and dynamic balance of these individuals should be examined so as to determine whether corrective exercises can improve the postural control and dynamic balance of these individuals. If corrective exercises have a positive effect on the postural control and dynamic balance of individuals with flat or cavus feet, they can be implemented as a very simple, comfortable, inexpensive, and non-invasive method (safe) to replace surgery in affected people. Because corrective exercises strengthen both the joints and ligaments and strengthen and stretch the muscles involved, they cause the line of gravity to be in its natural direction and the balance and posture of the body to be in a favorable position. Several original studies have been conducted on this issue. Therefore, a systematic review and meta-analysis study is needed on these studies to determine whether or not corrective exercises affect the postural control and dynamic balance of these individuals. To the best knowledge of the authors, no systematic review and meta-analysis to date has investigated the effects of exercise programs on postural control among individuals with flat or cavus foot. Thus, this systematic review and meta-analysis study investigated the effects of exercise programs on postural control and dynamic balance among individuals with flat feet and cavus feet.

Methods

This systematic review was performed according to the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines [17].

Search Strategy

Articles were identified through searches across eight databases, namely MEDLINE/PubMed, EMBASE/SCOPUS, LILACS, CINAHL, CENTRAL (Cochrane Central Register of Controlled Trials), Web of Science, PEDro, and Google Scholar. The search period covered the beginning of the available date up to November 2021. The keywords were originally chosen from MeSH terms and then slightly modified. The goal was to ensure that all eligible studies would be found. In addition, a manual search and complete investigation of the references of papers were also performed.

The mentioned databases were searched using the keywords: balance control; center of pressure; balance; postural stability; posture; postural balance; postural sway; stability; static balance; static stance; dynamic balance;* pronation foot* or flexible flat foot or rigid flat foot or flatfeet or pes planus;* supination foot* or cavus foot or pes cavus or arch height foot;* exercise training*or training; physical exercise; exercise program; exercise therapy; exercise; and exercise workout.

After collecting the search results, first the title and then the abstract of papers were studied. Those papers meeting the inclusion criteria were used in the review study; otherwise they were excluded. Based on the criteria and objectives of the research, 13 papers were chosen after the assessment stages. All papers were provided as full text.

Data Collection Process

In the first stage, the titles and abstracts of descriptive studies were screened with a focus on investigating the effects of exercise programs on postural control and dynamic balance among individuals with flat or cavus foot. Papers published in Persian and English were investigated. A research assistant independently inspected the abstracts of articles. In the second stage, the entire text was screened and explored for information regarding the effects of exercise programs on the postural control and dynamic balance of individuals with flat feet and cavus feet. Full-text screening was performed by a researcher. A senior researcher also checked the final list of the chosen papers to ensure all papers were in line with the research objective. A summary of descriptive information was prepared by the research assistant and then checked by the senior researcher. A sample table was employed (Table 1) for extracting the target population information, the effect of exercise programs on postural control and dynamic balance among individuals with flat feet and cavus feet, plus their results.

Inclusion Criteria

Inclusion criteria were: 1) Studies published in Persian and English language and peer reviewed; 2) All subjects were free from any orthopedic conditions that may affect balance; 3) Papers analyzing the effect of any type of corrective exercises on postural control and dynamic balance in individuals with flat feet or high-arched foot; 4) Original studies with randomized controlled trial design.

Papers were excluded whose statistical population consisted of individuals with conditions other than flat foot or cavus foot; in which the methodology had not been well specified; that had investigated the effects of other foot abnormalities (such as hallux valgus, mallet finger, etc.); and papers that had not investigated balance or had used other functional tests.

Quality of Evidence

Quality assessment scores for the selected studies were calculated using the Physiotherapy Evidence Database (PEDro) with a total score of 11. PEDro has some criteria for evaluating internal validity and presenting statistical analyses. The scoring system was as follows: studies scoring 7 to 11 were methodologically “high,” 5 to 6 were “fair,” and ≤4 were “poor” [18]. Evidence level was calculated based on previous studies [19, 20].

Data Extraction

Researchers (HZ and MAC) extracted study data on the following: first author name; sample size; exercise training protocol; participants’ characteristics; main outcome measures; instruments used for assessments; and main results of the study (Table 1).

Statistical Analyses

Heterogeneity was assessed using the I^2 index according to the following thresholds: 0%–30%=no heterogeneity; 30%–50%=low heterogeneity, 50%–75%=moderate heterogeneity, 75%–100%=high heterogeneity. The current study used random and fixed-effects models for between-study heterogeneity. A random effects model was used for a value of I^2>50% [21]. Hedges’ g effect size was also used to calculate effects of training (effect size) [17, 22]. Threshold values for assessing magnitudes of ES were <0.2, trivial; 0.2–0.6, small; 0.6–1.2, moderate; 1.2–2.0, large; 2.0–4.0, very large; and >4.0, nearly perfect [23]. The effect size is reported with a 95% confidence interval (CI) for all analysed measures. The significance level was set at P≤0.05. A symmetrical inverted funnel plot and Egger’s regression test of the intercept were used to examine publication bias [24].

Table 1: Physiotherapy Evidence Database (PEDro) Scale Ratings

Study	Eligibility Criteria	Random Allocation	Concealed Allocation	Groups Similar at Baseline	Blind Subject	Blind Therapist	Blind Assessor	Follow-up	Intention-to-Treat Analysis	Between-Group Comparisons	Point Measures and Variability	PEDro Score
Mehrian et al., 2016 [25]	1	1	1	0	0	0	0	0	1	1	1	6.11
Lee et al., 2016 [26]	1	1	1	1	1	0	0	0	1	1	1	8.11
Nikkhoamiri et al., 2019 [27]	1	1	1	1	0	0	0	0	1	1	1	7.11
Kim et al., 2020 [28]	1	1	1	1	1	0	0	0	1	1	1	8.11
Fakoor et al., 2013 [29]	1	1	1	0	0	0	0	0	1	1	1	6.11
Ghaderiyan et al., 2016 [30]	1	1	1	0	0	0	0	0	1	1	0	5.11
Nikkhoamiri et al., 2019 [31]	1	1	1	1	0	0	0	0	1	1	1	7.11
Rodriguez et al., 2020 [32]	1	1	1	1	0	0	0	0	1	1	1	7.11
Chehri et al., 2016 [33]	1	1	1	1	1	0	0	0	1	1	1	8.11
Golchini et al., 2020 [34]	1	1	1	1	0	0	0	0	1	1	1	7.11
Ghaderiyan et al., 2017 [35]	1	1	1	1	1	0	0	0	1	1	1	8.11
Listyorini et al., 2015 [36]	1	1	1	1	0	0	0	0	1	1	1	7.11
Kyung Kim et al., 2016 [37]	1	1	1	1	1	0	1	0	1	1	1	9.11

Comprehensive Meta-Analysis version 2.0 (Biostat Inc., Englewood, New Jersey) was used for statistical analysis.

Results

A total of 746 potentially eligible papers were retrieved from 8 databases. Ten additional records were identified through pearling reference lists. A total of 542 duplicate studies were excluded, and the remaining 214 potentially relevant abstracts were screened. Of these relevant abstracts, an additional 121 were excluded. The full text of the remaining 93 papers were retrieved for complete review. Another 80 papers were excluded, because they did not meet the eligibility criteria (Figure 1). Finally, 13 studies were included in the systematic review. The main characteristics of the selected studies are shown in Table 1.

Quality of Evidence

The overall quality of the papers under analysis by PEDro was higher than 7, signifying the high quality and reliability of the present study (Table 2).

Figure 2 displays the results of the meta-analysis for the effect of exercise programs on the postural control of individuals with flat feet and cavus feet. An I^2 index of 57.44% indicated heterogeneity across studies; as such, random effects model analysis was employed. The Hedges's g effect size for the exercise programs on postural control of 1.81 was obtained with a confidence interval of 95% (1.40-2.22). The results of meta-analysis indicated that exercise programs have had a significant effect on the postural control of individuals with flat feet and cavus feet (P=0.001). Furthermore, Egger's test across the studies was 0.71, suggesting no publication bias.

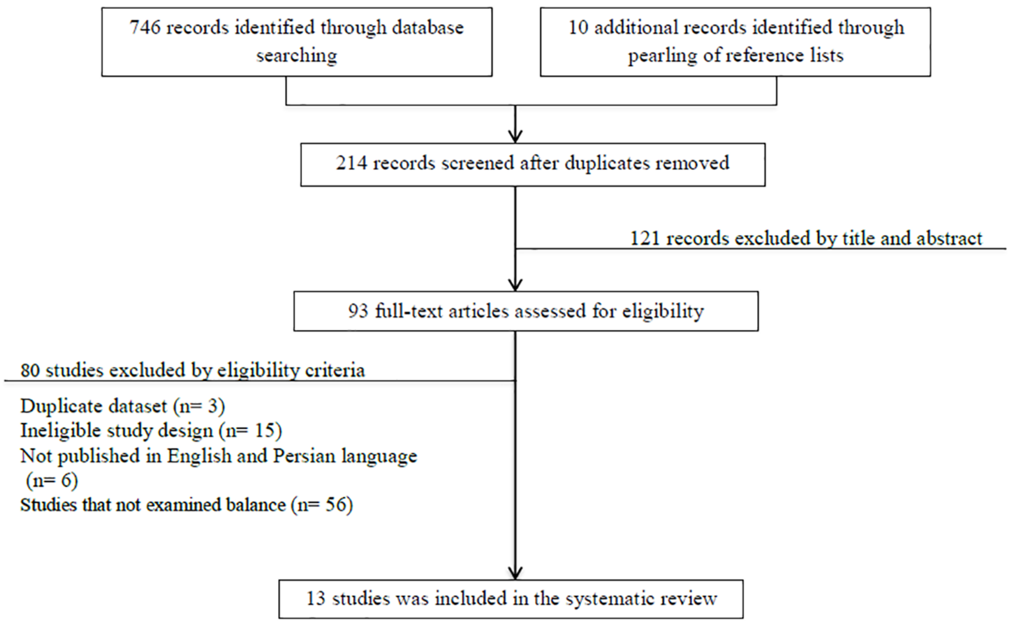

Figure 1: Flowchart for screening of articles

Table 2: Results of studies examined for effect of exercise training programs on postural control and dynamic balance among individuals with flat feet and cavus feet

Study	Sample Size and Exercise Training Protocol	Age range	Measurable variables	Measuring instruments	Main results
Mehrian et al., 2016 [25]	Control grouP=10 (No intervention) Experimental grouP=10 (Corrective exercises on cavus foot)	18-25 years	Static balance-Dynamic balance	One leg stance TTS balance test (time to stabilization)	The results showed an improvement in static and dynamic balance after eight weeks of corrective training.
Lee et al., 2016 [26]	Control grouP=8 (No intervention) Experimental group=8 (Strengthening Exercise on flat foot)	17-35 years	Plantar pressure Dynamic balance	Gaitview AFA-50 system Star Excursion Balance Test(SEBT)	- Combined exercises (strengthening exercises of the intrinsic muscles and tibialis posterior) had a significant effect on reducing plantar pressure and the height of the plantar arch and improving balance. - Combined exercises were more effective than strengthening exercises of the intrinsic muscles of the feet in people with flexible flat feet to reduce internal plantar pressure and improve dynamic balance.
Nikkhoamiri et al., 2019 [27]	Control grouP=15 (No intervention) Experimental grouP=15 (Comprehensive corrective exercises on flat foot)	9-10 years	Static balance Dynamic balance Navicular Drop	Foot Scan Machine Walking 20 meters Brody method R Scan System Vertical Jump 40 Yard Dash Test Visual Analogue Scale(VAS)	Corrective exercises are effective in improving balance and posture of the sole of the feet, so this study recommended that therapists use different exercises related to the trunk and lower limbs in the form of a corrective program to improve children's abnormalities.

Kim et al., 2020 [28]	Control grouP=15 (No intervention) Experimental group=15 (Short foot exercise using visual feedback on flat foot)	20-30 years	Static Balance Accuracy of knee joint movements	One leg stance test AI (accuracy index)	- When this type of exercise was performed, a significant difference was observed on static balance in pre- and post-tests in the flat foot group; no significant difference was observed in the normal foot group. - Both groups showed a significant difference in the accuracy of knee joint movements in pre- and post-tests. - Short foot exercises using visual feedback had a significant effect on improving the balance and accuracy of knee joint movements in people with flat feet.
Fakoor et al., 2013 [29]	Control grouP=15 (No intervention) Experimental grouP=35 (Corrective exercise on flat foot)	10-12 years	Static balance Postural stability	Biodex Balance System	- Corrective exercises can have a positive effect on improving flat feet and static balance in people with flat feet. - There was a significant difference between the pre-test and post-test of the experimental group in improving balance in the overall static balance index score. This difference was not observed in the control group. - In all three stability indices, balance was shown to have improved in the post-test compared to the pre-test.
Ghaderiyan et al., 2016 [30]	Control grouP=15 (No intervention) Experimental grouP=15 (Rope jumping training on cavus foot)	10-13 years	Postural control Static balance Dynamic balance	Foot Scan Balance RScan International Flamingo Balance Test Y Balance Test	Rope jumping can be a useful exercise to improve static and dynamic balance and postural control in individuals with cavus foot.
Nikkhoamiri et al., 2019 [31]	Control grouP=15 (No intervention) Experimental grouP=15 (Selected corrective exercises on flat foot)	9-13 years	Central pressure surface and static balance Change in sole pressure	Foot scan system Walking 20 meters R SCAN SYSTEM	Corrective programs had a significant effect on static balance with closed and open eyes and the level of the center of thumb pressure, first metatarsal bone, second metatarsal, third metatarsal and middle of the foot, and the inner part of the heel in the training group compared to the control group.
Rodriguez et al., 2020 [32]	Control grouP=18 (No intervention) Experimental grouP=18 (Therapeutic exercises on flat foot)	18-40 years	Foot Posture	Foot Posture Index (FPI)	- Performing corrective exercises resulted in a significant improvement in the treatment of excessive flat feet - No significant difference was seen in gender between the groups in relation to the foot posture index.
Chehri et al., 2016 [33]	Control grouP=15 (No intervention) Experimental grouP=15 (Balance training on flat foot)	11-15 years	Static balance Dynamic balance	Balance Error Scoring System Star Excursion Balance Test	The balance training protocol in this study had a significant effect on improving static and dynamic balance (in the post-test).
Golchini et al., 2020 [34]	Control grouP=15 (No intervention) Experimental grouP=15 (Corrective exercises on flat foot)	10-16 years	Postural swing Ground reaction force	Force plate	- Three months of corrective training had a significant effect on improving postural sway and ground reaction force. - After the intervention, the sways of postural control and ground reaction force were significantly less in the experimental group than in the control group. - Corrective training improved the activity of the body sway control system, which also reduced postural fluctuations and ground reaction force in people with pronation deviation syndrome.
Ghaderiyan et al., 2017 [35]	Control grouP=15 (No intervention) Experimental grouP=15 (Rope jumping training on flat foot)	10-13 years	Postural control Static balance Dynamic balance	Foot scan system Flamingo Balance Test Y Balance Test	Twelve weeks of rope training had a positive and significant effect on static balance, dynamic and postural control in people with flexible flat feet.
Listyorini et al., 2015 [36]	Control grouP=20 (No intervention) Experimental group=21 (Foot Muscle Strengthening on flat foot)	8-12 years	Dynamic balance	Star Excursion Balance Test	- Star excursion balance test for left and right feet showed a significantly better effect in the experimental group than the control group. - Strengthening leg muscles with or without elastic bands improved dynamic balance in children aged 8 to 12 years with flexible flat feet. - Exercises with elastic bands resulted in more significant improvement than exercises without elastic bands.
Kyung Kim et al., 2016 [37]	Short foot exercise group on flat foot=7 Arch support insoles group on flat foot=7	21-26 years	Navicular Drop Static Balance	NDT MatscanVersaTek System	- There was a significant increase in static balance test in both groups of foot shorts and floor support. - Short foot exercises had a greater effect on improving the internal longitudinal arch and dynamic balance for people with flexible flat feet than supporting the soles of the feet.

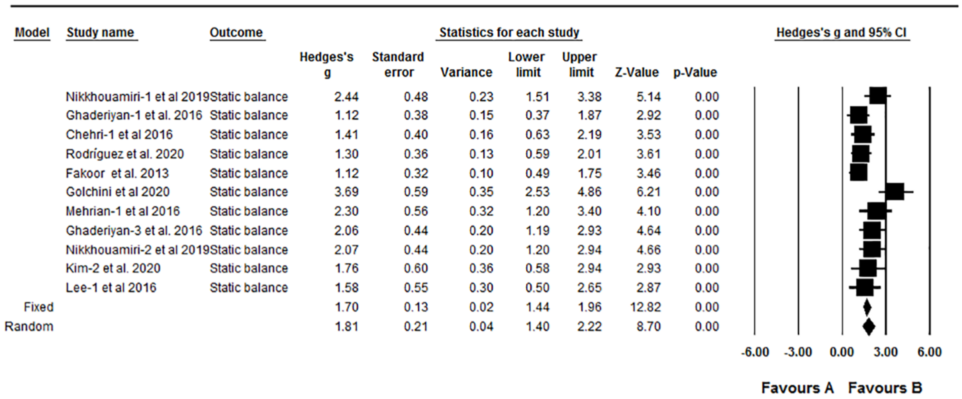

Figure 2: Results of meta-analysis for the effect of exercise programs on postural control of individuals with flat feet and cavus feet

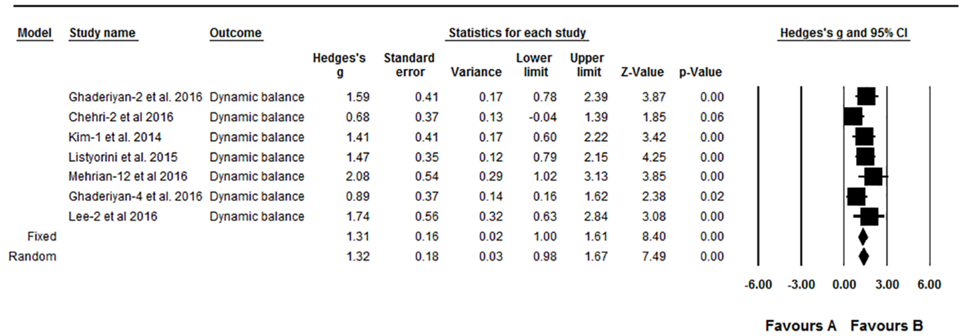

Figure 3: Results of meta-analysis for the effect of exercise programs on the dynamic balance of individuals with flat feet and cavus feet

Figure 3 depicts the effects of meta-analysis for the effect of exercise programs on the dynamic balance of individuals with flat feet and cavus feet. An I^2 index of 20.83% shows heterogeneity across the studies; thus the fixed effect meta-analysis model was utilized. The Hedges's g effect size for the exercise programs on the dynamic balance was 1.32 with a 95% confidence interval (0.98-1.67). The results of meta-analysis revealed that exercise programs have had a significant effect on the balance of individuals with flat feet and cavus feet (P=0.001). Furthermore, Egger's test across the studies was 0.11, suggesting no publication bias.

Discussion

The present study explored the effects of exercise programs on postural control and dynamic balance in individuals with flat feet and cavus feet. Some studies had evaluated both postural control and dynamic balance, while others had explored only postural control or dynamic balance. The present study has separately investigated each of these variables. The results showed that exercise programs had a significant effect on the postural control of individuals with flat feet and cavus feet. Thus, exercise programs could improve postural control among these people. The current results further indicated that exercise programs had a significant effect on the dynamic balance of individuals with flat feet and cavus feet; thus, exercise programs could ameliorate the dynamic balance of these individuals. The details related to the meta-analysis of each of the comparisons made are further discussed separately.

The Effect of Exercise Programs on Postural Control of Individuals with Flat and Cavus Feet

Overall, 11 studies were found that had explored the effect of exercise programs on the postural control of individuals with flat feet and cavus feet [25-27, 29-34, 37, 38]. The results of meta-analysis over these studies showed that exercise programs had a significant effect on the postural control of these people. The exercise protocols of these studies had been designed with the aim of improving correction of abnormalities and, in turn, enhancing the postural control of these people. Thus, it can be concluded that by correcting feet abnormalities, the postural control of these individuals can be improved. Furthermore, the effect size of studies on the postural control was different. This difference can be attributed to the number of sessions for exercise programs or the type of exercise programs that was considered for correcting the foot abnormalities and, in turn, improving the postural control.

The exercise study of Golchini et al. [34] with an effect size of 3.69 exerted the maximum influence across all exercise programs on postural control. This study implemented the exercise programs for 12 sessions, a larger number of sessions than in other studies. Thus, it seems that for correcting foot abnormalities, the number of exercise programs should be increased so that abnormalities are first corrected properly, and the postural control is further improved in these people. Golchini et al. [34] also considered two types of exercise programs, namely retraining and correcting abnormalities. In the retraining section, they had trained the person with the feedback of the correct method of performing their daily functional activities. In the exercise section, they presented comprehensive exercise protocols for correcting the foot abnormalities. Regarding how the comprehensive corrective exercise program could affect postural control, it should be explained that stretching, contraction, and strengthening of the muscles in the central region, thigh, calf, sole, and ankle would correct the postural predictive reaction from the central nerves, preventing postural control disorders and contributing to the balance organization [39]. Thus, strengthening the muscles of this region and functional muscular improvement in response to the exercise programs would improve the affected person's neuromuscular system and coordination [40]. This is followed, in turn, by diminished displacement of the gravity center out of the base of support and a reduction in postural fluctuations.

Postural control tests are performed in the standing position, where the person should maintain their body status in the space and generate a proper force to keep and correct their body position. Achieving this goal requires a complex relationship among the sensory, nervous, and musculoskeletal systems [1]. Thus, to maintain the desired gait with minimum postural fluctuations, the central and peripheral components of the nervous system should function desirably which other; the central nervous system should suitably process the peripheral inputs and choose the most suitable muscular response for postural control and body position [41]. Because postural control is maintained within a closed movement chain and depends on the integrated feedback of the movements of the hip, knee, and ankle joints, impairment in any of these segments or disruption in the mechanical power and strength of any of these joints would impair the sending of afferent sensory information to the central nervous system, thereby impairing postural control [5]. Hence, in foot abnormalities, the segments and joints should receive attention in addition to neuromuscular coordination exercises. This latter part is important, because in addition to correcting the abnormalities, improvement in postural control can also be observed in these people. For greater effectiveness of exercises, the length of the exercise periods should also be increased, so that the extent of influence of these exercises on correcting abnormalities and improving postural control would be enhanced.

The Effect of Exercise Programs on Dynamic Balance of People the Flat Feet and Cavus Feet

Overall, 7 studies investigated the effects of exercise programs on the dynamic balance of people with flat feet and cavus feet [25, 26, 28, 30, 33, 35, 36]. The meta-analysis results of these studies indicated that the exercise programs had a significant effect on the dynamic balance of the affected people. Static balance is established through feet joint ligaments and capsule, but dynamic balance is maintained mostly through intrinsic and extrinsic muscles [1]. Thus, one reason for increased dynamic balance can be improvement in the power of intrinsic and extrinsic muscles. Improving the function of these muscles would lead to the correction of abnormalities and, in turn, improve dynamic balance among these people. It is believed that exercises enhance neuromuscular coordination [42]. In particular, those exercise protocols with a goal of acentric and concentric contraction of muscles had a greater impact on neuromuscular coordination. It is clear that these exercises enhance sensory receptors and have a direct effect on brain activity [43]. Exercise protocols that aim to correct foot abnormalities cause the activation of motor neurons in a group of muscles and joints for performing an action and its adaptation within the environmental context [44]. They also enhance coordination and integration of motor units, co-contraction of agonist muscles, and increase inhibition of antagonist muscles. This eventually leads to improved neuromuscular responses and, hence, enhanced dynamic balance [45].

This review study had some limitations. This meta-analysis focused only on postural control and dynamic balance. Thus, the effect of exercise programs on other functional components should also be investigated to determine whether exercise programs could improve other functional variables as well in these people. Secondly, this meta-analysis study examined only the effects of exercise programs, while other rehabilitation interventions (i.e. kinesiotaping, orthoses, physiotherapy) were not evaluated. These types of exercise programs should also be examined and compared with other rehabilitation interventions to identify which interventional program has better and greater effects on improving postural control and dynamic balance.

Conclusion

The present review study found that exercise programs have a significant effect on the postural control and dynamic balance of individuals with flat feet and cavus feet abnormalities. Research results showed that to better correct abnormalities and thus achieve greater improvement in postural control as well as dynamic balance, the length of the exercise program periods should be increased. The exercise programs should also focus on greater involvement of the neuromuscular system and direct effects on the central nervous system, so that a greater influence would be observed on improving postural control and dynamic balance.

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Conflict of Interest: None declared.

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