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RESEARCH ARTICLE

EFFICACY OF STAR EXCURSION TRAINING ON DYNAMIC BALANCE IN FLEXIBLE FLAT FOOT

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ABSTRACT

Purpose: The purpose of this study was to investigate the effect of Star excursion balance training on dynamic balance in flexible flat feet. **Methods:** A pre-post randomized experimental design was used. Thirty four physical therapy students were selected randomly and their age were ranged from 18_21 years, and body mass index ranged from 18.5-25 They were divided into two groups: Group A experimental group was received star excursion balance training for 10 min/session, 3 sessions/week, for 4 weeks, and during each session, the subjects were given with a period of 30 seconds rest, to perform the same exercises by changing the stance limb and the reaching limb. And short feet exercise 3 min each day for 4 weeks, three sets of 10 repetitions were performed each repetitions held for 5 sec and repeated for up to 3 min approximately 30 repetitions 45-second rest period between sets. Group B control group was received short feet exercise; Navicular drop test was used to assess feet posture.Biodex medical system was used to assess dynamic balance at level 6 and level 4 for both groups before and after intervention.**Results**::paired t test for group A there was a significance difference in dynamic balance at stability level 6 and 4, p value was 0.001 with higher percent of improvement at group A. **Conclusion:** Four weeks of star excursion balance training combined with short foot exercise can improve the dynamic balance at stability level 6 and 4 compared with those in the control group.

INTRODUCTION

Flat feet or pes planus is a complex disorder with diversity of symptoms and various degrees of deformity that is caused by structural loading changes along the medial part of the feet and planter arches **(1).** When the feet is put on the ground, its inner or middle side comes down to the floor rather than remaining raised **(4),** causing it to roll inwards (over pronation of the feet) **(5).** Pronation is a natural motion of the feet as it rolls inward after the feet makes contact with the ground**(6)**.

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The deformation into flatfeet occurs when the medial longitudinal arch (MLA) has descended as a result of the arch being excessively relaxed to the point where it cannot be maintained, causing the feet to be excessively pronated compared to normal feet, resulting in heel eversion and the weight load being shifted inward to compress the MLA (7). When the MLA has fallen or has been entirely removed, causing structural or functional deformation, the capacity to absorb shocks reduces and the sense of balance is lost, resulting in decreased stability while walking or running, resulting in walking problems and decreased endurance. (8)
The body balance maintained in the closed kinetic chain is dependent on the hip, knee, and ankle joints' tightly integrated feedback and movement strategies (9). As a result, decreased afferent feedback or deficits in the strength and mechanical stability of any joint or structure throughout the lower extremity kinetic chain might disturb body balance (10). Given that the feet is the most distal part of the lower extremities chain and constitutes a relatively modest base of support upon

which the body maintains balance, it is likely that even slight biomechanical changes in the support surface may impact postural-control strategies (11).Specifically, excessively pronated feet postures may influence peripheral (somatosensory) input via changes in joint mobility or surface contact area or, secondarily, through changes in muscular strategies to maintain a stable base of support (12). So Several studied were performed to improve the balance in flat feet as one leg dynamic balance training(13), also using of short feet short feet exercises (SFE) are sensory-motor training that activates the intrinsic muscles of the feet and actively forms the longitudinal arch and the horizontal arch (11).also using of kinesiotape to support medial longitudinal arch (14). SEBT (Star Excursion Balance Training) in patients with flexible flat feet may be beneficial in improving dynamic balance by enhancing control of body postures during movements through neuromuscular conditioning and neural adaptation of the Proprioceptors (15). However, there are less scientific evidences showing its effectiveness. As a result, the goal of this study is to see if a four-week SEBT program has any effect on dynamic balance in persons with flexible flat feet. As a result, the current study aims to enhance dynamic balance in flexible flatfeet, as measured by the overall stability index (OAI), anteroposterior stability index (APSI), and mediolateral stability index (MLSI).

METHODS

Design

Pre post randomized control design was utilize to assess the effect of SEBT on dynamic balance including 3 indices: OSI, AP-SI and ML-SI in flexible flat feet The Research Ethical Committee of the Faculty of Physical Therapy, Cairo University gave an acceptance for the study. The study was conducted between October 2020 and Mai 2021. The study had followed the Guidelines of the Declaration of Helsinki on the conduct of human research.

Randomization

Each participant signed a consent form after having clarified the existence, intent and advantages of the experiment, notified them of their right to reject or withdraw at any time, and the confidentiality of any data obtained. Upon randomization for thirty four students (by distribution of sealed envelopes), participants are selected. Participants were assigned into two groups, group A experimental and group B control.

Participants

The subjects of the present study were 34 university students (males 5, females 29) aged 18 to 21 years. The subjects that participated in the study were randomly assigned to an experimental group SEBT and SFE. Seventeen subjects in each group. The subjects' general characteristics are as shown in Table 1 and the experimental group's mean age, height, and weight were 19.82±1.13 years, 161.53±6.76 cm, and 62.18±11.24 kg respectively. The control group's mean age, height, and weight were 20.00±1.50 years, 163.65±3.46 cm, and 63.47±5.71 kg respectively. And those that were fracture, dislocation, neurological disorders fixed flat feet, unilateral flat feet or any one take medication affect the balance were excluded.

Assessment of flat feet using navicular drop test NDTs were conducted to measure changes in the height of the MLA. In the NDT, each subject was instructed to sit on a chair with the knee joint bent to 90° and align the second toe and the knee so that the subtalar joint was placed on the neutral position and under a non-weight bearing condition, the distance from the ground to the navicular tuberosity was measured and marked. Thereafter, the distance from the ground to the navicular tuberosity was measured in a standing position with the feet place at shoulder width and weight bearing by the two feet. Using a tape measurement, the difference in the height of the navicular tuberosity between the non-weight bearing(sitting position) position and the weight bearing (standing position) position was measured if the difference was more than 10 mm so the subject considered has flexible flat feet. (16)

Assessment of the dynamic balance using Biodex Balance System was used for all participants in the two tested groups. The system utilizes dynamic multi axial platform. This platform allows approximately degrees inclination in 360 degrees range and is interfaced with computer software. It measures the participant's ability to control the platform's angle of tilt, which is quantified as a variance from the center, as well as the degree of deflection over time at various stability levels. Stability levels allowed by the system ranged from one to eight. Stability level eight, allows the highest level of stability as it makes the platform to be the least tilted and is easier for the subject to maintain stability on. On the other hand, stability level one represents the least level of stability as it makes the platform to be the highest tilted and is more difficult for the subject to maintain stability. The participant's ability to control the platform's angle of tilt was measured by the system. The participant's performance was noted as a stability index. The stability index represents the variance of platform displacement in degrees from level. A high number is an indicative of a lot of motion, which indicates balance problem. The data regarding the balance of the tested participant were supplied from the system. These data include overall stability index (OSI), anteroposterior stability index (APSI), and mediolateral stability index (MLSI). Overall stability index (OSI) represents the participant's ability to control the balance in all directions, anteroposterior stability index (APSI) represents the participant's ability to control the balance in sagittal plane, and mediolateral stability index (MLSI) represents the participant's ability to control the balance in frontal plane. Before the testing procedures, the participant's weight, height and age were introduced into the system. All participants were tested on two stability levels, stability level 6 (more stable) and stability level four (less stable) for 20 seconds for each of these stability levels. Firstly, each participant has been received verbal explanation about the testing steps. The participant was asked to assume the test position (standing on both feet without feet wear) with arms were held at both sides. Then each participant was asked to center himself on the feet platform before starting the test. They asked to try to control his/her balance as much as possible during the testing procedures. Each participant was asked to perform two test trials before the actual testing procedures for the purpose of instrument familiarity prior to data collection. The participant was instructed that the platform was unstable just after the alarm. Each participant was instructed to maintain a level platform for the period of the test. Instructions were given for the participants to focus on a visual feedback screen directly in front of them and attempt to maintain the cursor, which represents the center of the platform, at the center of the bulls'-eye on the screen equated to a level platform. Finally, after conducting the two actual tests at the two testing stability levels, a printout report was obtained. This report included the information regarding the OSI, APSI and MLSI. The values of the two tests at both stability levels was recorded for each posture participant at the two tested groups **(8)**

Fig.1. Test position on Biodex balance assessment

Outcome Measures

Three indices at both stability level 6 and 4 are OSI, APSI and MLSI

Treatment

Group A: Star Excursion Balance Training (SEBT) group:

Prior to starting of the training program, the preparation for Star Excursion Balance training was performed, initially by selecting a flat and non-slippery surface. Then Four (4) strips of white athletic tapes of 6 feet in length were cut. In order to form the star grid shape on the floor, two strip were pasted in the form of "+" and the other two strips pasted across on the top in the form of "x". It has to be assured that the stripes pasted are arranged to each other from a center point at angle of 45 degrees with each other. This star shaped grid arrangement involves a series of single-leg squats with the stance limb and a dynamic maximal reach using the non-stance limb to touch a point as far as possible along eight designated lines radiating from a central point at an angle of 45°. To start with each training session the subjects were made to perform 3-minute of warm up followed by Star excursion balance training (SEBT) and conventional exercise training (SFE) continued with 2-minute of cool down, warm up and cool down included dynamic movements and static stretches. The subjects from the SEBT group performed the Star Excursion Balance training initially by standing in bilateral stance with bare feet on the middle of the star grid. The weight bearing leg is the stance limb and the unsupported leg is the reaching limb. Then the subjects were instructed to balance their body weight on the stance limb on the middle of the star grid where the strips of tapes are placed at an angle of 45 degrees. By keeping the hands on the pelvis, the subjects were made to reach a distance of 2 feet marked on the tape in all the 8 directional tape positions with the tip of toe of the reaching limb without shifting weight on the reaching limb. The 8 directional tape positions are anterior, anteromedial, medial, posteromedial, posterior, posterolateral, lateral, anterolateral. After each directional reach the subject returns the reaching limb to the start position at the middle of the grid, resuming a stable bilateral stance with 3 seconds of rest between each tape direction. The training with SEBT program was done with 12 rounds in clockwise and 12 rounds in counterclockwise reach. During each session, the subjects were given with a period of 30 seconds rest, to perform the same exercises by changing the stance limb and the reaching limb **(15)**.The training was administered for 4 weeks with the frequency of three sessions per week**. (3)**

SFE was implemented as sensory-motor training for balance improvement in the flatfeet. Before the intervention, the researcher demonstrated the short feet exercises while giving verbal instructions. Thereafter, each subject was instructed to sit on a height-adjustable chair and bend the hip joint, knee joints, and ankle joints to 90°. Thereafter, the subject was instructed to pull the head of the first metatarsal bone toward the heel without bending the toes the exercise performed 3 min each day for 4 weeks, three sets of 10 repetitions were performed each repetitions held for 5 sec and repeated for up to 3 min approximately 30 repetitions **(2),** 45-second rest period between sets **(19)**

Fig. 2. Application of Star excursion balance training

Statistical analysis

The total sample size (34 subjects) was calculated at α=0.05. Results are expressed as mean ± standard deviation.). Independent t-tests were conducted to compare the amounts of changes between the two groups and Paired t-tests were used to measure differences before and after experiment in each group. The computer program Statistical Social Science Package (SPSS) (25 windows version) has been used. The p value was considered <0.05 considered quite significant.

Results

There were no statistically significance difference (p > 0.05) between subjects in both groups concerning age, height, and weight The mean age, height and weight was presented at (table 1) for both groups.

Using paired t test Within group analysis For group A there was a significance difference post measurements for OSI, APSI and MLSI at both stability level 6 and 4 as the p value was <0.05, For group B there was no a significance difference post measurements for OSI, APSI and MLSI at both stability level 6 and 4 as p value was >0.05. In between group Comparison table 2 and 3 of Group A and Group B using un paired t test there was no significant difference in the pre measurements between both groups, and there was a significance difference in post measurements between both groups (p value <0.05) at the 3 indices at both stability levels, so group A is better than group B.

Table 1. General characteristic of the subjects

	Mean ± SD		t-value	p-value	SIG
	Group "A"	Group "B"			
Age: (years)	19.82±1.13	20.00±1.50	387.-	0.701	NS
Weight: (kg)	62.18±11.24	63.47±5.71	423.-	0.675	NS
Height: (cm)	161.53±6.76	163.65±3.46	1.14-	0.259	NS
BMI: (kg/m^2)	23.77±3.79	23.68±1.77	093.	0.927	NS

NS: no significant difference; SD: standard deviation; *p*-value: significance level; BMI: body mass index;

Table 2. Un paired T test for pre measurements for both groups at both stability level for the three stability indices

Stability indices	Level 6 stability			Level 4 stability		
	Group A	Group B	p-value	Group A	Group B	p-value
OSI	3.45±1.7	3.99±1.5	0.29	3.68±1.69	5.39±3.11	0.055
APSI	2.52±1.1	2.97±1.1	0.24	2.88±1.37	3.92±2.46	1.37
MLSI	2.5±1.02	2.85±1.1	0.38	2.5±1.09	3.72±2.2	0.058

OSI: overall stability index; MLSI: mediolateral stability index; APSI: anteroposterior stability index; *significant at the alpha level (p < 0.05).

Table 3. Un paired T test for post measurements for both groups at both stability level for the three stability indices

Stability indices	Level 6 stability			Level 4 stability		
	Group A	Group B	p- vale	Group A	Group B	p-value
OSI	1.61±0.32	3.5±1.3	0.001	1.55±0.39	4.66±2.76	0.001
APSI	1.27±0.25	3.3±0.9	0.001	1.34±0.35	3.52±2.06	0.001
MLSI	1.07±0.28	3±0.9	0.001	1.02 ±0.3	3.32±1.89	0.001

OSI: overall stability index; MLSI: mediolateral stability index; APSI: anteroposterior stability index; *significant at the alpha level (p < 0.05)

DISCUSSION

In the case of flatfeet, as the pronated state of the heel is maintained, the talus bone is moved to the inside of the sole leading to the disappearance of the medial longitudinal arch so that the ability to accommodate and distribute the weight is reduced compared to normal persons. minor biomechanical alterations in the support surface may influence postural-control strategies. When the arch starts collapsing, balance is disturbed at the feet, and therefore the balance throughout the entire body is also disturbed. **(10).** Our current study demonstrated that star excursion balance training (SEBT) administered for 4 weeks with the frequency of three sessions per week combined with short foot exercise has showed statistical significant result in group A on dynamic balance at stability level 6 and 4. This may be due to the effect of perturbation which is effective than resistance training in improve the postural control. The significant finding suggests that by performing star excursion balance training program, there is associated contribution of training strength, training ability of balance, training ability of dynamic performance and training compressive loading over the joint in improving the functional performance with good Static and dynamic balance, efficient and quick change in direction of movement, skill to quickly stops and resume the movements **(17)**

Our results agree with previously reported finding by Chaiwanichsiri *et al.*, 2005 (3) stating that 4 weeks of Star Excursion Balance training is more effective than the conventional therapy program in improving functional stability of the sprained ankle, The reason why dynamic balance ability was significantly improved in the group applied SEBT.This is considered attributable to the fact that the star excursion balance training involve closed kinetic chain motions of the stance leg, Concentric and eccentric muscle contractions, proprioception, as well as postural control simultaneously involved .While using another feet to reach specific directions, the proprioception and co-ordination are also trained in the non-injured side. These motions caused training effects in both sprained and normal ankles, as the improvement of single leg stance time after training not only demonstrated in the sprained ankle, but also detected in the non-injured side as well.. Detailed comparison studies SEBT and other dynamic balance rehabilitative exercises with more sufficient intervention periods are necessary.

Also Vijayakumar *et al.*, 2020 reported that Training with rapid stretching of a muscle (eccentric action) immediately followed by a concentric or shortening action of the same muscle produces more force than the force produced by a concentric action alone because of the stored elastic energy within the muscle The components of stopping, starting and changing direction in the training programs assists in developing postural control. Training the above components through Star Excursion Balance Training (SEBT) among subjects with flat feet may be effective by increasing the balance and control of body positions during movements by neuromuscular conditioning and neural adaptation of the Proprioceptors. But there are less scientific evidences in proving its effect (15). The lesser improvement in dynamic balance in SFE group agree with Rothermel *et al*., (2004)(18) reported that in a static stability test conducted on normal healthy adults, the center of pressure excursion velocity decreased substantially more in a traditional balance training group than an SFE balance training group and control group after 4 weeks. They stated that the traditional balance training group concentrated on maintaining balance only, whereas the SFE balance training group concentrated too much on maintaining the SFE positions, which interfered with their involuntary neurological activity. We therefore hypothesis that star excursion balance training (SEBT) program combined with short foot exercise is better than conventional exercises training program (SFE) alone, and may contribute in improving the dynamic balance among subjects with flexible flat feet.

Conclusion

It can be concluded that the SEBT is an effective rehabilitative exercises for dynamic balance improvement in the participants with flat feet at stability level six and four using the Biodex Balance System compared with those in the control group. Our study stresses the importance of improving the dynamic balance through efficient postural swaying strategies, rapid change of direction, quick stopping and resuming smooth and repetitive movements. Furthermore, this improvement in dynamic balance through SEBT can be a beneficial training program in demanding the physiological and neuromuscular system among subjects with flexible flat feet, in improving dynamic balance.

Therefore, conducting a planned SEBT program can be recommended for flexible flat feet to improve their dynamic balance.

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