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Assessment of Postural Stability in Children with Pronated Feet

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ABSTRACT

Background: Balance is required for normal daily living activities such as walking, running and stair climbing. The loss of balance response and increased incidence of falls are of concern to physical therapist. Therefore,it is necessary to consider the mechanics of the feet and how it affects postural stability. **Purpose:** Thepurposes ofthis study were to evaluate postural stability in children with pronated feet,toidentify the differences in postural stability between pronated feet and normal feet children,and to investigate the interrelationship between body weight and navicular drop. **Methods:** Twenty children with normal feet (control group) and twenty childrenwith pronated feet (study group) were participated in this study. All children aged from six to eleven years. Navicular Drop Test was used to determine pronated feet and Biodex Balance System was used to assess postural stability in both groups. **Findings:** MANOVA revealed no significant difference (p>0.05) in overall stability index and mediolateral stability index, with significant difference (p<0.05) in anteroposterioer stability index at stability level (8) between both groups. While all independent variables at stability level (4) has statistically significant difference (p<0.05) between both groups. The bivariate correlation showed non-significant correlation between body weight and navicular drop. **Conclusion:** Based on the previous findings, it may be concluded that there is balance affection in children with pronated feet that appear at difficult stability situation (level 4).

Key Words:Pronated foot, Postural stability, Biodex Balance System.

INTRODUCTION`

The foot is a highly unique and flexible structure, which is required to perform very diverse functions. It provides support, balance and stabilization during gait and weight bearing[1].Whilst, the structurally normal foot can adequately perform these tasks, deviations from its normal posture can place the foot under excessive stress[2].Foot arches help the foot to absorb shock during impact with the ground and they help store mechanical energy then release it to improve the efficiency of locomotion[3].If one or more of the foot's arches is not able to provide the necessary support, abnormal postural adaptations develop. Additional stress is then placed on all of the joints, ligaments, and muscles involved in helping to maintain upright posture[4].

A normal pronation involves calcaneal eversion, talar adduction, talar plantar flexion and tibiofibular medial rotation.In hyper pronation, an excessive amount of these motions occur. There is flattening of medial longitudinal arch causing hypermobility of the midfoot that may placegreater demands on the neuromuscular system to stabilize the foot and maintainupright stance andinterfere with the carefully coordinated movement during gait[4, 5].

Biomechanical alterations in the foot support surface may influence postural control strategies and increasing the soft tissue stress [6]. This biomechanically abnormal foot posture affects the normal transitions of the subtalar joint required during dynamic activities. The foot therefore loses the ability to maintain a rigid support in full weight bearing and the shock absorption ability is also affected[7].

Postural stability is defined as the ability to maintain or control the center of mass in relation to the base of support to prevent falls and complete the desired movements, which requires continuous adjustments of muscles activities and joints positioning [8, 9].The control of standing posture involves coordination of all of the segments of the body and control of foot center of pressure to keep the body center of mass within the base of support [10, 11].Postural control and dynamic balance are essential in activities of daily living such as walking, running and stair climbing and for optimal performance in sport activity. The loss of balance response and increased incidence of falls is of concern to therapist [12, 13].

Considering that the foot is the most distal segment in the lower extremity chain and represents a relatively small base of support upon which the body maintains balance particularly in single leg stance, it seems reasonable that even minor biomechanical alterations in the support surface may influence postural control strategies specifically, excessively supinated or pronated foot postures may influence peripheral (somatosensory) input via in joint mobility or surface contact area. Or secondarily to changes in muscular strategies for maintain a stable base of support[6].Accordingly, in an attempt to determine the effect of pronated feet on postural stability, this study was designed to evaluate postural stability in children with pronated feet, identify the differences in postural stability between pronated feet and normal feet children,and to investigate the interrelationship between body weight and navicular drop.

MATERIALS AND METHODS

Subjects

Upon approval of Cairo University's supreme council of postgraduate studies and research, ethical approval was granted from the University ethical committee prior to the commencement of the study. Forty children (18 boys and 22girls) with age ranged from six to eleven years participated in the study. Twenty children with normal feet assigned as control (group A), and twenty children with bilateral congenital pronated feet as study (group B). Informed consent was obtained from all subject's parents following a verbal and written explanation of the study. They were selected from Egyptian governmental primary schools at Greater Cairo area. Subjects were included if they had one meter or more, follow normal average of weight, and had no hip, knee, ankle and other foot deformities or any postural deformity by physical examination.Moreover, children in study (group B) had mild to moderate pronated feet posture according to the Brody method [14].Subjects were excluded ifthey had pronated feet secondary to neuromuscular causes or associated with other congenital anomalies, had repeated lower extremity injuries, had history of surgery to the lower extremity, or history of cerebral concussions, visual or vestibular disorders. Study was done in Faculty of Physical Therapy balance laboratory, Cairo University, Egypt.

Instrumentations

a. *A universal weight and height scale* was used to determine the children’s weight and height.

b. The navicular –drop test

It was used for assessing feet posture in both groups.A tape measurement was used for measuring navicular drop.

c. Biodex balance system

The Biodex balance system (Biodex Crop. Shirley, NY) was used to evaluate postural stability in both groups.The system consists of a movable balance platform which has been set at variable degrees of instability. This system has been interfaced with computer software monitored through the control panel screen and it has been supplied with cannon bubble jet printer to print the test results[15].

It included;*Support rails:*Adjustable from 25 inch to 36.5 inch above platform. The rails can be swung away from platform if desired.*Display:*Itsheighthas beenadjusted from 51 inch to 68 inch above the platform. Display Angle: Adjustable from vertical back up to 45 degrees. Display viewing area: 122mm x 92mm. display Accuracy: +/-1 degree of tilt.*Printer:*Bubble-jet printer, 80 columns, centronics parallel interface.

The foot platform allowed for approximately 20 degrees off surfaces tilt from horizontal in all direction. Platform diameter is 21.5 inches. It had a foot rid for determination of foot position, which important for centering process of the subject before testing[16].

Biodexbalancesystemhas been allowedforeightstabilitylevels,which has been ranged from stability level (1) to stability level (8).Stability level(8) wasthemoststable levelasitallowedthe highestlevelofstability bymakingtheplatformtobeleast easilytilted.Ontheotherhand,stability level(1)represented the least stable level and it has beenbecome more difficult forthe childtomaintainhis/her stability.The subject's ability to control the platform's angle of tilt has been measured by the system. Thestability indexrepresented thevariance of platform displacement in degreesfromlevel. A high number was an indicative of a lot of motion, which indicated balanceproblem.The data regardingthebalance ofthetested subject has been supplied to thesystem. These data included antero-posterior stability index (APSI), medio-lateral stability index (MLSI) andoverallstabilityindex (OSI)[16, 17].

The On the upper most part of the surface of the platform would appear angles from 0^o to 95^o with the lines which represented these angles. These lines were used to measure foot angle. The smallertheamountofsway,thelowerthenumericalvalueofthesei ndices.*Overall stabilityindex(OSI):*Representedthevarianceof footplatform displacement indegrees, from level,in all motionsduringthetest.Ahighnumberwasindicative ofalot ofmovementduringthistest,*Anterior/Posteriorstability index (APSI):*Represented the varianceof foot platform displacement, in degrees,fromlevel,formotioninthesagittalplane,*Medial/Lateralstabilityindex (MLSI)*:Represented the variance of footplatformdisplacement, in degrees fromlevel,formotioninthefrontalplane[17].

Procedure

Assessment for eligibility of subjects

Physical examination was done to select subjects according to inclusion and exclusion criteria.

Assessment of foot posture

Each child in both groups was evaluated for feet posture in a weight-bearing position by navicular drop test. The child was asked firstly to sit on stool with barefoot on the ground. The medial and lateral aspects of the talar dome have been palpated by the thumb and index fingers which have been placed just in front of the anterior aspect of the fibula and just anterior and inferior to the medial malleolus. Thenhe/she was asked to slowly invert and evert the hind-foot until the depressions that have been felt by the thumb and index finger of the clinician was equal.With the foot in this subtalar neutral position, the distance between the navicular tubercle and the floor has been measured in millimeters with a tape measurement.

Then the child was asked to stand barefoot on the ground, placing all weight on the foot being measured, while the other foot was rested lightly on the ground. Thenhe/she was asked to completely relax the foot into full weight bearing, and the resulting position of the navicular has been measured with the tape measurement in millimeter.

Finally the distance between the original height of the navicular and its final weight-bearing position has been recorded as the subject's navicular-drop score.The navicular drop has been measured two times, using the average measurement to classify the sample into one of two groups: a normal foot (between five and nine mm of navicular drop), a pronated foot (more than 10 mm of navicular drop) [14].

Assessmentof postural stability

The balance test was done for children of both groups on the Biodex balance system at stability level "8" (more stable) and "4" (less stable) for 20 seconds [18]. The assessment has been conducted for eachchild individually. The protocol of the work has been explained to the children before conducting this study.

Each child was tested without footwear and was asked to perform two test trials before specific test condition for the purpose of instrument familiarity prior to data collection [19]. She/he was asked firstly to assume the test position (standing on both feet) with arms was held at the sides and to try to control his/her balance as much as possible.Each child was asked to center herself/himself on the foot platform before starting the test.

The child's weight (Kg), height (m), and age (years) were introduced to the device. The stability level and testing time were determined.Then, the start key was pressed in the control panel to unlock the platform (which takes five seconds), with auditory alarm just before the beginning of the test.The child was instructed that the platform was unstable just after the alarm.Each child was instructed to maintain a level platform for the period of the test.For each test trial, child was attempted to keep the platform level for 20 seconds with double leg support [20].

Instructions were given for the children focus on a visual feedback screen directly in front of them & 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.At the end of each test a printout report was obtained. This report included information as regard OSI, APSI and MLSI.The mean values of two tests for each stability level (8) and (4) were calculated for each child individually in both groups.

DATA ANALYSIS

All statistical measures were performed through the statistical package for social studies (SPSS) version 19 for windows.Descriptive statistics: the mean value and standard deviation was calculated for each variable measured.One-way multivariate analysis of variance (MANOVA) was carried out to compare the OSI, APSI and MLSIat stability level (8) and (4) between both groups.Pearson product moment correlation coefficient was used to determine the correlations between body weight (Kg) and navicular drop (mm) for both groups.The level of significance for all statistical tests was set at $p < 0.05$

RESULTS

Baseline characteristics of the subjects are shown in **Table 1**. No significant differences existed between groups at age, height, and weight. While there were significant difference in the navicular-drop test between both groups. There was non-significant difference between the covariance among the tested dependent variables.

Table 1: Demographic characteristics of subjects

	Group (A) No.=20 $\bar{X}$ (SD)	Group (B) No.=20 $\bar{X}$ (SD)	MD	t-value	p-value
Age (years)	9.2 (1.6)	8.55 (1.84)	-0.65	-1.18	0.24
Weight (kg)	38.65 (9.27)	37.95 (9.7)	-0.7	-0.23	0.81
Height (cm)	137.15 (9.45)	136.4 (8.85)	-0.75	-0.25	0.79
Navicular drop (mm)	7.1 (1.37)	11.5 (1.27)	4.4	10.49	0.0001*

(*) Significant where alpha level of significance is set at $p < 0.05$.

Concerning the overall stability index at stability level (8), there was anon-significant difference between study and control groups (F=3.2, p=0.08). While at stability level (4), there was a significant difference between study and control groups (F=23.89, p=0.0001), (Table 2, Figure 1).

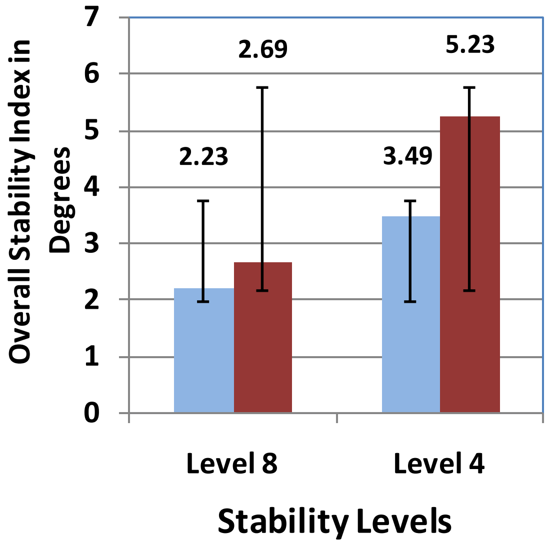


Fig. 1Mean values of overall stability index (degrees) for control group and study group.

Regarding the antero-posterior stability index at stability level (8), there was asignificant difference between study and control groups (F=6.11, p=0.01). Also at stability level (4), there was a significant difference between both groups (F=31.78, P=0.0001), (Table 2, Figure 2).

Considering the medio-lateral stability index at stability level (8), there was anon-significant difference between study and control groups (F=0.53, p=0.47). But at stability level (4), there was a significant difference between study and control groups (F=9.76, p = 0.003), (Table 2, Figure 3).

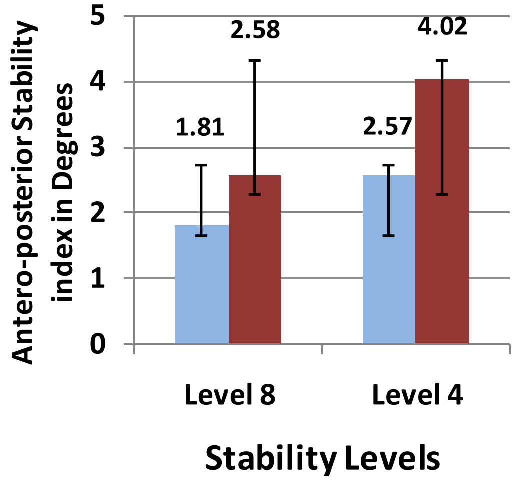
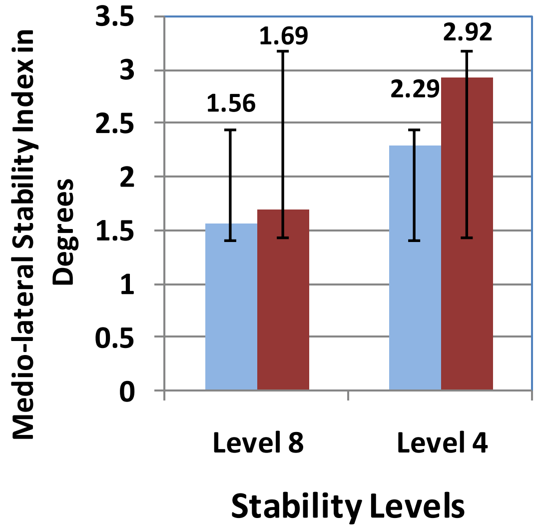


Fig. 2 Mean values of antero-posterior index (degrees) for control group and study group.



Finally, the bivariate correlation between body weight and navicular drop in both groups revealed that there was a non-significant inverse correlation in the control (group A) (r = -0.15, p = 0.52), while in the study (group B) there was a non-significant direct correlation (r = 0.19, p = 0.

Table 2:*MANOVA test for comparison between mean values of both control group (A) and study group (B) for overall stability index in degrees, antero-posterior stability index, andmedio-lateral stability index:*

	Overall stability index (degrees)		Antero-posterior stability index (degrees)		Medio-lateral stability index (degrees)	
	Level 8	Level 4	Level 8	Level 4	Level 8	Level 4
Group (A) No.=20 $\overline{X}$ ±SD	2.23 ± 0.81	3.49 ± 1.02	1.81 ± 0.94	2.57 ± 0.79	1.56 ± 057	2.29 ± 0.61
Group (B) No.=20 $\overline{X}$ ±SD	2.69 ± 0.8	5.23 ± 1.22	2.58 ± 1.01	4.02 ± 0.83	1.69 ± 0.59	2.92 ± 0.64
MD	0.46	1.74	0.77	1.45	0.13	0.63
F- value	3.2	23.89	6.11	31.78	0.53	9.76
p-value	0.08	0.0001*	0.01*	0.0001*	0.47	0.003*
Significance	NS	S	S	S	NS	S

(*) Significant where alpha level of significance is set at p< 0.0

DISCUSSION

The foot is a complex structurethat acts as an interface between the ground and the human body. It provides support, balance and stabilization during gait and weight bearing. Although the feet have common anatomical characteristics, their shapes and biomechanics differ greatly between subjects that may affectthe foot's function [21, 22].The anatomical variations in the foot itself, the environmental and hereditary factors[23]and therotational abnormalities of the lower extremity are parameters that determine a child's gait[24].Foot pronation is the most common foot disorders alteration in its function have series of biomechanical changes that produce a wide variety of signs and symptoms through the interrelated structures and systems of the body. As the pronated foot presents with multiple site fixations that could include the posterior subtalar joint, the calcaneotalonavicular complex, the cuboid, ankle joint and the first ray. Weight will be borne on the medial structures causesinternal rotation of the entire lower extremity.That interferes with the carefully coordinated movement during gait and causes problems throughout the musculoskeletal system[4 ,25].

As the stability of the foot decreases there is increased recruitment of motor units during stance. Demands are placed on the extrinsic and intrinsic dynamic stabilizers to stabilize the foot, which should have its own intrinsic stability but does not, so fatigue and insufficiency, and overuse injuries occur secondary to loss of shock absorption of the soft tissue structures and mal positioning of the joints, as well as oblique pull of the muscles. These create pathologic stresses, causingarthritis and pain [26].Excessive subtalar pronation creates an increase stress generated by the soleus, thereby causing a “bowing” of the tibia. Other anatomic considerations are genu varum, pes planus, external rotation of the hip, and leg length discrepancy [27].

The lower extremities are very well-supplied with proprioceptive nerve endings. Mechanoreceptors in the feet and ankle joints with the muscle spindles of the foot and lower leg muscles are responsible for the positive support reflexes and a variety of automatic reflexive reactions.The position receptors in the lower extremities, pelvis and spine must coordinate smoothly to maintain postural equilibrium. Inaccurate information sent by spindle sensors in chronically strained muscles [28]or aberrant joint mechanoreceptors in the feet [29]lead to local changes in motor pattern, that affect the ability of subject to respond effectively to perturbations [30, 31]and have difficulty in achieving or keeping optimal postural alignment, or problems with excessive postural sway.Poor foot position sense that hinder accommodation between the plantar surface of the foot and the support surface require postural adjustments more proximal to maintain upright posture and balance [32].

If one or more of the foot's arches are not able to provide the necessary support, or if there has been a breakdown of the plantar fascia, abnormal postural adaptations are created. Additional stress is then placed on the many joints, ligaments and muscles involved in helping to maintain upright posture[4, 5]. Also, the subjects with functional ankle instability took significantly longer to stabilize than individuals with stable ankles after a single-leg jump landing[33].

Postural control is controlled by neuromuscular mechanisms and maintained through combination of peripheral components and central processing systems. Any deficit in these systems or in the integration of information from these systems could affect balance [34].

The findings of this study showed significance difference in thestability indexes that coincided with the results of Tsaiet al.[35]who stated that subjects with pronated foot structure would have poorer standing postural control than subjects with normal feet because of reduced stability within the foot joints.They found that subjects with pronated feet had significantly greater and maximum displacement in the anterior-posterior direction, used more trials to complete force plate testing, and had shorter single-limb stance duration normalized center-of-pressure than those in the neutral group.However, they had some advantage from the increased medio/lateral dimension of the base of support. The possible deleterious influence on postural control caused by passive instability in the joints of the foot, therefore, might be attenuated somewhat in the mediolateral direction by the positive influence of an enlarged base of support.

Our findings werealso supported by Cote et al.[7]who examined the effects of pronated and supinated foot postures on static and dynamic postural stability. The findingsrevealed that structural foot type affected sway index in static postural stance and dynamic reach measures.Theyfound that pronators reached farther in the anterior direction than both neutrals and supinators that may be attributed to increased foot mobility. Pronators tend also to collapse toward the medial aspect of the foot and have a reduced ability to maintain a rigid support in full weight bearing. This medial deviation plus greater foot mobility may account for pronators' reduced dynamic reach in the lateral direction.

Similarly, Cobb et al.[36]reported that subjects in the pronated group had poorer standing postural control than subjects in the neutral group in terms of a greater normalized center-of pressure and maximum displacement in the anteroposterior direction.

As opposed to our findings,Hertel et al.[6]noted no postural deficits in subjects with a pronated foot posture. However, their findings were limited to testing in a static stance with eyes open. In this study we used dynamic balance with two different levels, level (8) and level (4) so we found a significant difference in postural stability between pronated feet and normal feet.

Finally, being interested in investigating the relationships between body weight and navicular drop, findings revealed that there was a non-significant correlation between body weight and navicular drop and this disagrees withresearchers who recorded thatobese subjects showed increased forefoot width and higher plantar pressure during standing and walking. Compared with normal weight children, obese subjects displayed subtalar pronation that contributed to a degree of out-toeing[37].

LIMITATION

The limitation of this study was that there were few subjects. A larger sample size would have been desirable.

CONCLUSION

In this study, it was concluded that there was balance affection in children with pronated feet that appear at difficult stability situation at stability level (4).

Conflict of interest statement

There is no conflict of interest.

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