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Relationship of deformities of the medial Longitudinal arch with postural balance in woman of different age groups

Relação das deformidades do arco plantar com o equilíbrio postural em mulheres de diferentes grupos de idade

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ABSTRACT: The foot is a complex structure and essential for a function, having a fundamental role in gait and postural control. This structure is composed of three foot arches, which comprise an elastic system of absorption of mechanical shocks, aiding without postural control. Some authors have observed that the lowering of the medial longitudinal arch (ALM) of the foot causes a smaller oscillation of the center of force (COP) in conditions of manipulation of the postural balance, suggesting that non-planar deformities can influence the postural balance. The present study aimed to analyze the relationship between deformities of the medial longitudinal arch and postural balance in women of different age groups. It included 60 women, 20 in the young group (YG), 20 in the adult group (AG) and 20 in the elderly group (EG). Printing plant with plantar foot pressure method was used in order to obtain the plantar arch index (PAI). Variables obtained from the center of pressure were: range of anteroposterior displacement of COP (COPap), range of medial-lateral displacement of COP (COPml), average velocity of displacement of COP (COPvel), and ellipse area (ellipse). The results showed no correlations between the variables of COP (COPap, COPml, velocity and ellipse) and PAI with eyes opened and with eyes closed conditions. It was concluded that the plantar arch index did not alter postural control in women of this study, because there were no statistically significant correlations between variables of postural balance and the plantar arch index. We would suggest the development of new studies including assessment of dynamic balance and gait.

Key Words: Foot; Postural balance; Age groups.

RESUMO: O pé é uma estrutura complexa e essencial para uma funcionalidade, tendo papel fundamental na marcha e no controle postural. Essa estrutura é composta por três arcos podais, os quais compõem um sistema elástico de absorção de choques mecânicos, auxiliando sem controle postural. Alguns autores observaram que o rebaixamento do arco longitudinal medial (ALM) do pé causa uma menor excursão do centro de força (COP) em condições de manipulação do equilíbrio postural, sugerindo que deformidades não arco planar podem influenciar o equilíbrio postural. O presente estudo objetivou analisar a relação entre deformidades do arco plantar e o equilíbrio postural em mulheres de diferentes faixas etárias. Participaram do estudo 60 mulheres, 20 no grupo jovem (GJ), 20 no grupo adulto (GA) e 20 no grupo idoso (GI). Para o cálculo do índice do arco plantar (IAP) utilizou-se o método de impressão plantar, através de um pedígrafo. As variáveis analisadas, obtidas a partir do Centro de Pressão (COP), foram: amplitude de deslocamento ântero-posterior do COP (COPap), amplitude de deslocamento médio-lateral do COP (COPml), velocidade média de deslocamento do COP (COPvel) e área da elipse (elipse). Os resultados apontam que não houve correlações entre as variáveis do COP (COPap, COPml, velocidade e elipse) e o IAP na condição com os olhos abertos e com olhos fechados. Concluiu-se que o índice do arco plantar não alterou o controle postural em mulheres de diferentes faixas etárias deste estudo, pois não houve correlações estatisticamente significativas entre as variáveis do equilíbrio postural e o índice do arco plantar. Sugere-se a elaboração de novos estudos incluindo avaliação de equilíbrio dinâmico e marcha.

Palavras-chave: Pé; Equilíbrio postural; Grupos etários.

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Introduction

The human foot is a very complex structure formed by numerous muscles, bones, ligaments and joints. This structure is divided into three regions: forefoot, midfoot and hindfoot, and three foot arches, which have an elastic system absorbing mechanical shocks[1].

The lateral longitudinal arch gives support to the foot, once it makes contact with the ground and supports part of the body weight during locomotion. The medial longitudinal arch (MLA) is more dynamic, flexible and mobile than the lateral and it absorbs shocks when there is contact with the ground. The movement of this structure is important because it reduces the impact when transmitting the vertical load by deflection of the arch. The transverse arch, on the other hand, is responsible for sustaining an important part of the total body weight[2].

Some authors [3] observed that the lowering of the foot MLA causes a smaller oscillation of center of pressure (COP) in conditions of postural balance manipulation, suggesting that the contact area of the foot may influence on the functional balance.

The sensory, motor and nervous systems form the postural control system, which allows a body to remain in balance. Each system has a function for maintaining the standing posture. The sensory system provides information on the position of the body segments in relation to other segments and the environment itself, the motor system properly and correctly activates the muscles so that they perform the movements; and the central nervous system performs the integration of information that comes from the sensory system, and sends nerve impulses to the muscles, generating muscular responses[4].

The sole of the foot is considered one of the inputs of fine postural system, being rich in exteroceptive elements. The neuromuscular spindles are plentiful at the level of foot muscles and joint receptors in the ankles, thus making the foot an element of extreme importance for the postural system[5,6].

Through the MLA, we can classify the human foot into three types: normal, flat, and cavus foot[7]. These different types of feet may behave in different ways and their structure is as important as their function, as it can be observed in a study by Correa and Pereira[8] regarding the relation of the reduction of plantar arches and changes of gait, balance and posture in school children. It was observed that students with flat feet held uncoordinated and irregular movements of the upper limb, featuring a gait with inefficient balance and inadequate posture, however, students with normal feet did not show these disorders. Thus, the flat foot may alter the biomechanics of gait and balance, and body posture.

Due to the recurring exposures to various external factors our feet suffer deformities during the course of our life. These alterations can generate imbalances in the biomechanical podal system, bringing consequences in the functionality of our organism, as for example in the system of postural control, that is essential for the accomplishment of activities of daily life. Based on these assumptions, this study aims to analyze whether there is correlation between deformities of the medial longitudinal arch and the increase in postural oscillation in woman of different age groups and different conditions for the test.

Methods

Research subjects

In order to participate in the study (table 1), the subjects signed a Statement of Informed Consent. The inclusion criteria were established as follows: being a female, being at least 18 years of age and not having cognitive impairment. On the other hand, the criteria of exclusion were: having osteo-myo-articular problems (less related to the longitudinal foot arch), physical and/or mental disabilities, Body Mass Index (BMI) greater than 30 kg/m^2 [9], hypertension, diabetes, or labyrinthitis, having spine-related pain or other problems that could interfere with postural balance, and doing regular physical activity more than twice a week[10]. All these criteria were only reported by individuals through questions. The study was carried out in accordance with ethical aspects following the principles of Resolution 196/96 of the National Health Council (CNS), being approved by the Research Ethics Committee (CAAE - 08398612.8.0000.5346).

Table 1. Descriptive statistics of the characteristics of research groups.

	Age (years)		Body Mass (kg)		Stature (m)	
	Mean	**Standart Deviation**	**Mean**	**Standart Deviation**	**Mean**	**Standart Deviation**
YG	21,90	1,41	60,79	6,30	1,64	0,07
AG	43,90	8,17	58,79	6,63	1,59	0,06
EG	66,55	6,00	63,90	10,93	1,55	0,05

YG: Young group; AG: Adult group; EG: Elderly Group.

Instruments for data collection

In order to assess the BMI of the participants a stadiometer was used with resolution of 0.5 cm for height measurement, and for body mass measurement, a digital scale with resolution of 0.1kg. To assess whether there was cognitive impairment in the elderly group the Mini Mental State Examination[11] was performed. The elderly whose score was lower than 25 points were excluded from the study.

Plantar Arch Index

The assessment of plantar arch index was performed by the method of indirect measurement through the footprint, using a printing plant of the brand Capron. The procedure used to obtain the footprint was made as follows: a paint roller with black ink was spread on the textured surface of the printing plant, then a white sheet of paper was put in the appropriate place in order to be stamped, and the brim of the printing plant was laid with the painted surface in contact with the paper. Following, the individual in standing position stepped firmly onto the center of the printing plant, being the same procedure repeated with the other foot.

The footprints were scanned, the actual size of the image was maintained, and the images were subsequently processed using an image-processing software, in which the toes were removed.

The medial longitudinal arch was classified through the Plantar Arch Index (PAI)[12], which divides the footprint in three areas: hindfoot, midfoot and forefoot. Through the relationship between the midfoot area and the total area of the footprint we reached the index value shown in Figure 1.

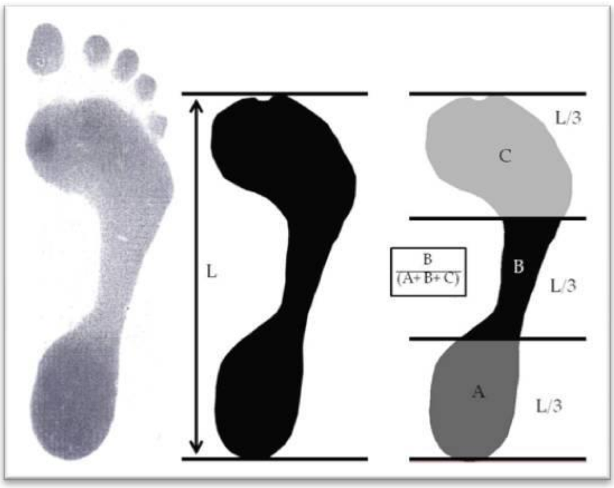

Figure 1. Method used for the classification of the plantar arch, according to Cavanagh e Rodgers (1987).

The calculation of PAI was carried out through a routine developed specifically for this purpose in IDL (Interactive Data Language) environment. From the images obtained, this routine initially identifies the most anterior point in the second metatarsal area and the more posterior region in the heel area. These points determine the axis of the foot, which is divided into three equal parts. This division defines the three regions of the foot, whose areas are then calculated. Finally, the division of the midfoot area by the total area of the foot is made.

The classification of the arch was made according to Cavanagh and Rodgers[12], who classify MLA through the following values:

- high MLA or cavus foot (PAI $\leq$ 0,21)
- normal MLA or normal foot (0,21 < PAI < 0,26)
- low MLA or flat foot (PAI $\geq$ 0,26)

Postural Balance

For the data acquisition regarding postural balance a force plate AMTI model OR6-6 (Advanced Mechanical Technologies, Inc.) was used.

The sampling rate of the force plate was 100 Hz. The raw data of force and moment obtained by the platform were filtered with a low pass Butterworth filter of 4^{th} order and cutoff frequency of 10 Hz. After filtering, the data were used to calculate two coordinates of the center of pressure (COP) at each instant, one in the anteroposterior direction and another in the medial-lateral direction. From these data, the variables of interest related to the individual's balance[13] were obtained.

The variables evaluated were range of anteroposterior displacement of COP (COPap), range of medial-lateral displacement of COP (COPml), average velocity of displacement of COP (COPvel) and ellipse area (ellipse), whose values, whenever high, indicate a greater postural sway.

Procedures for data collection

The collection was performed at the Biomechanics Laboratory of an educational institution. The individuals received a brief explanation about the collection procedure, and the elderly performed the Mini Mental State Examination. The participants were then taken to a room where they performed the height, body mass, PAI and postural balance assessments, all barefoot and in standing position. In order to characterize the PAI, the participants, barefoot and in standing position, placed their right foot followed by the left foot on the printing plant, to obtain their footprints. For the assessment on the force plate, individuals were instructed to position themselves on the platform in standing position with the feet hip-width apart directed forwards. The feet position was bounded on graph paper so that all attempts were made in the same position. During the test, the individual should keep their head directed forwards in two conditions: open eyes (OE) focused on a target at a distance of about 2 meters, and closed eyes (CE), both with arms resting along the body. Attempts of 30 seconds each were performed: three with open eyes and three with closed eyes, and individuals who wore glasses remained with them throughout the samplings. There was a short interval between each attempt, which consisted of the individual's exit and return to the platform.

The data were submitted to descriptive statistics. Normality was verified by the Shapiro-Wilk test. Pearson correlation test was used to assess associations between the plantar arch index and the variables of balance within each group. The level of significance adopted for all tests was 5% (α= 0,05).

Results

Table 2 presents the descriptive values of mean and standard deviation of all variables used in the study, thus showing the behavior of each age group regarding postural control and classification of the plantar arch.

Table 2. Means and standard deviations of the variables of postural balance and of right and left plantar arch indexes in the three groups.

	YG		AG		EG	
Postural Balance	OE Mean ± SD	CE Mean ± SD	OE Mean ± SD	CE Mean ± SD	OE Mean ± SD	CE Mean ± SD
COPap (cm)	1.86 ± 0.52	2.03 ± 0.78	1.91 ± 0.61	2.00 ± 0.54	1.98 ± 0.52	1.96 ± 0.49
COPml (cm)	1.09 ± 0.69	1.04 ± 0.46	1.16 ± 0.65	1.05 ± 0.46	1.37 ± 0.46	1.32 ± 0.65
Ellipse (cm^2)	1.43 ± 1.17	1.56 ± 1.23	1.63 ± 1.24	1.52 ± 0.85	1.66 ± 0.73	1.73 ± 1.04
CopVEL (cm/s^2)	0.77 ± 0.20	0.90 ± 0.22	0.80 ± 0.19	0.94 ± 0.21	0.94 ± 0.24	1.10 ± 0.52
	YG		**AG**		**EG**	
Plantar arch indexes	PAI_rig	PAI_lef	PAI_rig	PAI_lef	PAI_rig	PAI_lef
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
	0.18 ± 0.06	0.21 ± 0.04	10.18 ± 0.06	0.21 ± 0.04	0.24 ± 0.02	0.24 ± 0.02

YG: Young group; AG: Adult group; EG: Elderly Group; COPap: anteroposterior range of displacement of COP; COPml: medial-lateral range of displacement of COP; COPvel: average velocity of displacement of COP; Ellipse: ellipse area; PAI_rig: plantar arch index of the right foot; PAI_lef: plantar arch index of the left foot.

Table 3 shows the values of p in the correlations between the variables of the postural control (COPap: anteroposterior range of displacement of COP, COPl: average velocity of displacement of COP, Ellipse: ellipse area) and the index of the plantar arch (PAI_rig: plantar arch index of the right foot; PAI_lef: plantar arch index of the left foot). With the study group available there were no statistically significant correlations between variables of postural balance and plantar arch indexes. In the studied groups, the deformities found in the plantar arch do not influence the postural control.

Table 3. Values of correlations between right/left plantar arch indexes and variables of balance in the young group, adult group and elderly group.

		Open Eyes				Closed Eyes			
		COPap	COPml	Ellipse	COPVel	COPap	COPml	Ellipse	COPVel
YG	PAI_right	-0.04	-0.08	0.00	0.00	0.03	0.38	0.34	0.10
	PAI_left	-0.25	-0.14	-0.15	0.03	-0.26	0.30	0.21	0.11
AG	PAI_right	0.10	-0.14	-0.10	-0.09	0.09	-0.24	-0.00	-0.25
	PAI_left	0.15	-0.08	0.18	-0.16	0.02	-0.24	-0.00	-0.37
EG	PAI_right	-0.33	0.04	-0.20	-0.07	0.04	-0.24	-0.21	-0.25
	PAI_left	-0.40	0.06	-0.21	-0.06	0.06	-0.32	-0.15	-0.09

YG: Young group; AG: Adult group; EG:Elderly group; PAI_rig: plantar arch index of the right foot; PAI_lef: plantar arch index of the left foot; COPap: anteroposterior range of displacement of COP; COPml: medial-lateral range of displacement of COP; COPvel: average velocity of displacement of COP; Ellipse: ellipse area.

In the chart below (figure 2) we present the classification of foot types in each age group. The percentage of each type of foot in each group was obtained by the plantar arch index.

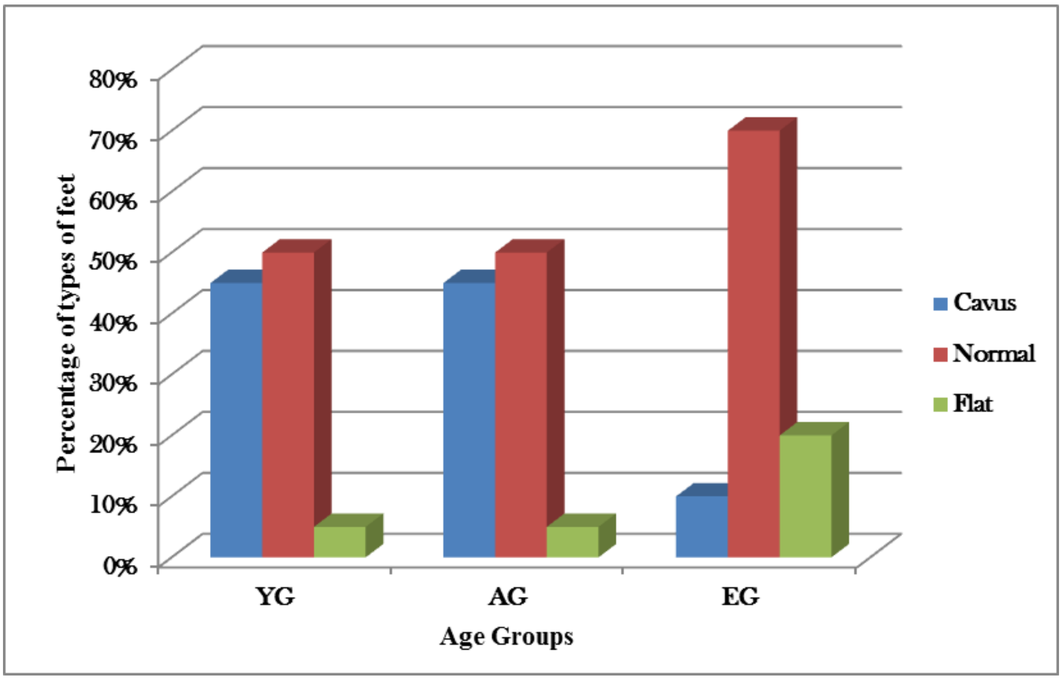

Figure 2. Percentage of types of feet in each group; YG: Young group; AG: Adult group; EG: Elderly Group.

Discussion

There are several studies that provide information about anthropometry and podal deformities that address postural balance analysis, however, there is a lack of correlation between these variables. The present study sought to do exactly that, to make correlations between anthropometric variables of the feet and variables of the pressure center, which give us precise information about the postural control system, something important to be studied, especially in elderly populations, in which the index of falls and injuries increase dramatically.

The present study aimed to assess the possible relationship between the deformities of plantar arch and the postural balance in women of different age groups. The results indicate no correlations between COP variables (COPap, COPml, COPvel and ellipse) and the PAI in conditions of open and closed eyes, showing the deformities found in the plantar arch do not influence the postural control in the studied groups.

In order to perform the maintenance of the body posture, the foot acts as an important base, and small changes in its structure and/or alignment with the ankle joint and other joints may influence on strategies of postural control[3]. In this study, however, no correlations were found between changes in the plantar arch index and COP variables, suggesting that the conformation of the plantar arch has no effect on the postural sway, as there is no relationship with the age group.

One of the justifications for not having found a correlation between prosthetic deformities and postural control may have been the method used in the evaluation, which was static only. The static balance in bipedal support may impose insufficient demands on the postural control system to detect deficits resulting from altered feedback or poor structural alignments, what can justify the absence of a negative effect of changes in the MLA in postural balance[14].

Another study which compared the dynamic situation was conducted by Corrêa and Pereira[8], who assessed the correlation between the reduction of the plantar arches and the changes in gait, balance and posture in school children. The authors found out that the students with flat foot had irregular and uncoordinated movements of upper limb without synchrony with the lower limb, very long steps before the step from one supporting foot to another, evidencing inefficient balance, inadequate posture, being characterized as pathological gait. On the other hand, students with normal foot showed normal gait.

Saibene and Minetti[15] emphasize that the biomechanics of every lower limb shows changes with the loweringof the MLA, which interferes in the standing position, in tasks of weight discharge, as well as locomotor abilities, and Miyashio and Tanaka[16] report that individuals with a normal plantar arch have a better postural balance than those who have cavus or flat feet, but these changes in the MLA did not influence on the static balance of the women in our study. According to Ledoux and Hillstrom[17], the mechanics of gait is not so efficient in individuals who have flat feet due to the increase of the contact area and the load below the midpart of the foot, which may result in an abnormal load on the adjacent ligaments and tendons, what may thus alter the normal mechanics of the joint.

Ferreira and colleagues[18] carried out a study regarding the influence of the morphology of feet and knees in postural balance. Our results corroborate with the findings of these authors, who observed that the morphology of the feet does not significantly change the sway velocity, the sway area or the anteroposterior displacement of the COP of individuals in bipedal support with open and closed eyes. The authors justified the results found due to the fact that the contact changes among the different types of feet were insufficient to cause changes in the distribution of load in the supporting base in vertical position.

Although no relationship was found between changes in the MLA and postural control, Wilder and Connor[19] emphasize that individuals who have high or low arches can apparently have no problems or symptoms, or do not need treatment. However, these conditions increase the risk of injuries such as plantar fasciitis and pain in ankles, because it is believed that both conditions reduce the dissipation of impact loads of the foot. Regarding the increase in the probability of injury due to the types of foot, Queen[19] and colleagues claim that individuals with normal foot can have lower risk of injuries in the midfoot (medial and lateral regions), such as fractures of the metatarsals due to stress.

Results of other studies[14,21,22] demonstrate an increase in the oscillation area of the COP in individuals with high MLA, probably due to a smaller plantar contact area compared with normal or flat feet. This decrease in the plantar contact area creates a greater anatomical blockage between the medial aspect of the foot and the force plate, thus decreasing the plantar sensory information.

According to Cote and colleagues[14], the changes in the pressure of contact surface that may exist between the three different types of foot are not sufficient to alter the weight distribution, what may explain our findings. The fact of not having found significant correlations in the present study suggests that somatosensory feedback of the skin and joint mechanoreceptors have not changed sufficiently in the individuals with cavus or flat feet, thus keeping the postural balance in both the assessed conditions[14].

Conclusions

It was concluded that the deformities of the plantar arch did not alter the postural control in women of different age groups of this study, since there were no correlations between the variables of the postural balance and the index of the plantar arch.

We would suggest the development of new studies including assessment of dynamic balance and gait and a greater number of subjects in each group.

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