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ORIGINAL RESEARCH

The influence of medium longitudinal arch on plant distribution and posterior pliability

Influência do arco longitudinal medial na distribuição plantar e na flexibilidade posterior

La influencia del arco longitudinal medial en la distribución plantar y la flexibilidad posterior

Jessica Caroliny de Jesus Neves[1], Fabíola Unbehaun Cibinello[2], Paola Janeiro Valenciano[3], Dirce Shizuko Fujisawa[4]

ABSTRACT | Objective: To evaluate whether the formation of the longitudinal arch of the foot interferes with the distribution of plantar pressure and the pliability of the posterior thigh muscles. Methodology: a cross-sectional study and the footprints were obtained using the footprinting mat and analyzed according to the Viladot method. Plantar distribution and pliability were assessed by baropodometry and Wells' bank, respectively. Results: It was observed that children with cavus feet present greater pliability when compared to those with normal feet (p=0.02). Also, the cavus feet exhibit higher pressure, that is, a greater heel overload compared to those with normal plantar arch (p=0.02 lower right limb and p=0.03 lower left limb). Conclusions: The evaluation of the medial longitudinal arch shows that children with cavus feet have greater pliability of the lower limb posterior muscles. The cavus feet are also associated with higher pressure in the calcaneal region.

Keywords | Child; Foot; Pliability.

RESUMO | O objetivo deste estudo foi verificar se a formação do arco longitudinal do pé interfere na distribuição da pressão plantar e na flexibilidade dos músculos posteriores da coxa. O método de estudo foi transversal e as impressões plantares foram obtidas usando o plantígrafo e analisadas segundo o método Viladot. A distribuição plantar e a flexibilidade foram avaliadas pela baropodometria e pelo banco de Wells, respectivamente. Foi observado que crianças com pés cavos apresentam maior flexibilidade quando comparadas às que têm o pé normal (p=0,02); e também que pés cavos apresentam maior pressão, ou seja, maior sobrecarga em calcâneo quando comparados àqueles com o arco plantar normal (p=0,02 membro inferior direito e p=0,03 membro inferior esquerdo). A avaliação do arco longitudinal medial mostra que crianças com pés cavos apresentam maior flexibilidade dos músculos posteriores de membro inferior. Os pés cavos também estão associados com maior descarga de peso em região de calcâneo.

Descritores | Criança; Pé; Flexibilidade.

RESUMEN | El objetivo de este estudio fue verificar si la formación del arco longitudinal del pie interfiere con la distribución de la presión plantar y la flexibilidad de los músculos posteriores del muslo. El método de estudio fue transversal y las huellas plantar se obtuvieron utilizando el plantigraph y se analizaron según el método de Viladot. La distribución plantar y la flexibilidad se evaluaron mediante baropodometría y el banco de Wells, respectivamente. Se observó que los niños con pies huecos tienen mayor flexibilidad en comparación con aquellos con pies normales (p=0,02); y también que los pies huecos tienen una mayor presión, es decir, una mayor sobrecarga del talón en comparación con aquellos con arco plantar normal (p=0,02 miembro inferior derecho y p=0,03 miembro inferior izquierdo). La evaluación del arco longitudinal medial muestra que los niños con pies huecos tienen una mayor flexibilidad en los músculos posteriores de la extremidad inferior. Los pies huecos también están asociados con una mayor descarga de peso en la región del talón.

Palabras clave | Niño; Pie; Docilidad.

[1]Universidade Estadual de Londrina (UEL) – Londrina (PR), Brasil. Orcid: 0000-0001-8269-5448
[2]Universidade Estadual de Londrina (UEL) – Londrina (PR), Brasil. Orcid: 0000-0002-8913-7331
[3]Universidade Estadual de Londrina (UEL) – Londrina (PR), Brasil. Orcid: 0000-0002-8363-0475
[4]Universidade Estadual de Londrina (UEL) – Londrina (PR), Brasil. Orcid: 0000-0001-8427-2860

Corresponding address: Jessica Caroliny de Jesus Neves – Avenida Paulo Marcondes, 1233, bloco 1, apartamento 13, Presidente Prudente (SP), Brasil – CEP: 19025-000 – E-mail: jessica_neves_3@hotmail.com – Funding source: Coordination for the Improvement of Higher Education Personnel (Capes), Financing Code 001 – Conflict of interests: nothing to declare – Presentation: June 29th, 2018 – Accepted for publication: Sept. 27th, 2019 – Approved by the Research Ethics Committee at Universidade Estadual de Londrina under Opinion No. 1,974,596.

INTRODUCTION

The foot is a structure that is in contact with the ground and controls the distribution of plantar pressure, support, impact absorption, balance, impulse; it supports the weight and adjusts the posture in an upright position[1,2]. Three arches constitute the foot: medial longitudinal arch (MLA), lateral longitudinal arch (LLA) and anterior transverse arch (ATA), which are suppported by the floor on three points, the first metatarsal, the fifth metatarsal and the calcaneus tuberosity[3].

Longitudinal arches are responsible for defining the type of foot (normal, cavus and flat)[4]. During the growth process of the first six years of life, there is the development of longitudinal arches and the loss of subcutaneous fatty tissue and reduced joint pliability[5]. The plantar pressure of the foot with normal arch is generally distributed evenly, without large regions of pressure peaks, resulting in a stable and smooth movement[6]. However, the cavus foot presents marked pressures on its lateral parts, which requires clinical attention because it causes lesions in the plantar tissue, calluses and pain[7]. On the flat foot, the pressures are greater inside, which causes loss of damping and triggers waste of energy[8]. Therefore, any change in the normal function of the foot can lead to unfavorable results, such as increased risk of imbalance and plantar injury.

The prevention of musculoskeletal injuries and the improvement of movement and muscle performance depend on body pliability[9]. It is closely linked to muscle extensibility, joint amplitude and plasticity of ligaments and tendons[10]. When there are limitations of pliability, the posture can be modified, as it generates compensations in order to adapt to these imbalances[11].

The sit and reach test is one of the most used to assess the pliability of children and adolescents[12,13]. As for the assessment of MLA, there is no consensus on which instrument to use, but plantigraphy is a low-cost and satisfactory resource for clinical analyses[14,15], which is widely used in the child and adolescent population[15-17].

The analysis of plantar distribution is relevant for the prevention of postural disorders and studies demonstrate the effectiveness of baropodometry in this evaluation[18]. It is used to assess typical and atypical children[19,20].

Thus, any imbalance or asymmetry caused by joint, ligament or muscle dysfunctions in the foot region will have an upward repercussion, as the feet influence other body structures[21]. By understanding the importance of the foot structure and its postural influences – especially in the child population, due to the adequate or inadequate stimuli that can interfere in the development of the plantar arch and, consequently, in the postural biomechanics –, this study aims to verify if the formation of the longitudinal arch of the foot interferes with the distribution of plantar pressure and pliability of the posterior thigh muscles.

METHODOLOGY

The cross-sectional study was carried out with a convenience sample of 40 children with typical development, aged between 8 and 12 years old, of both sexes, from the city of Londrina (PA). In addition, as an inclusion criterion, parents and/or guardians had to authorize the participation of minors in the study, and the child should sign the informed consent form. Children with orthopedic or neurological problems and who had recently undergone surgery were excluded. The evaluations were carried out at the Instituto de Educação Infantil e Juvenil (IEIJ).

Data collection consisted of: (1) assessment of anthropometric measurements; (2) measurement of pliability; and (3) analysis of the plantar impression and distribution of the plantar pressure. The anthropometric measurements evaluated were body mass (digital scale of the brand Omron Health Care, Inc. – model HN 289 (kg), height (cm) and length of feet (cm).

Pliability

Wells' bank was used to measure the pliability of the hip, back and posterior thigh muscles. In the test, participants were instructed to remain barefoot with their legs extended and joined, with one hand over the other, and were encouraged to make the reaching movement, without flexing their knees and without rocking movements (intermittent insistences). Three attempts were made, and the highest value reached was considered for analysis[22]; the maximum reach was measured in centimeters.

Plantar impression

The Podaly® plantigraph was used to evaluate the plantar arch. The protocol established that the child should stand up from the sitting position, flex the knee ipsilaterally (about 30°) with the help of the examiner and then return to the starting position. The examiner controlled the position of the foot on the platform to prevent slippage, which would invalidate the assessment. The plantigraphies accepted where the ones in which the foot was centered on the sheet of paper; the demarcation of the footprint was free of ink imperfections; and there was no damage to the morphology of the foot, such as imperfections in the demarcations of the toe and calcaneous region. This procedure was repeated in the contralateral limb[23].

Then, the longitudinal measurement of the foot was made, which comprises the union of its most extreme points, posteriorly to the calcaneus (A) and the most distal toe of the foot (B), determining the straight AB segment. Next, the foot isthmus (C) was measured by determining the midpoint of segment AB (AB/2) and measuring the width of that segment up to the external tip of the foot, corresponding to the midfoot measurement. To determine the width of the forefoot (D), lines were drawn adjacent to the middle and lateral borders of the forefoot, then joined by a straight line (Figure 1).

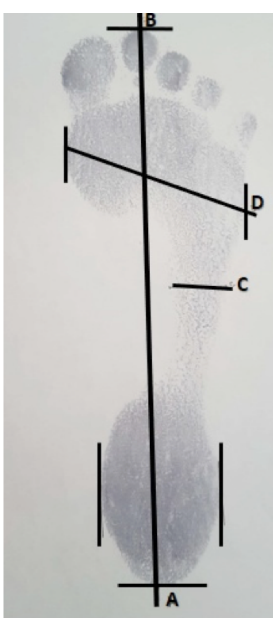

Figure 1. Traits used for plantar classification

The feet were classified according to the Viladot method: flat, whose footprints showed the region corresponding to the midfoot (C) with a width equal to or greater than half of the forefoot (C≥1/2D); cavus, those with decreased plantar footprint in the middle, less than the third of the forefoot or with complete disappearance (C≤/3D or C=0); and normal, those in which the measure of the midfoot was between half and one third of the width of the forefoot (1/2D≤C≤1/3D)[24]. The Viladot method was used to classify MLA, as the method is reliable to be applied to children, showing excellent reliability for the intra-rater condition and excellent and high for the inter-rater[17].

Plantar pressure distribution

The distribution of plantar pressure was obtained using computerized baropodometry (model FootworkPro, AM3 France). The data were filtered at a sampling rate of 100Hz and analyzed by the Footwork 2.1 software. The variables analyzed were the percentage of load on the forefoot and hindfoot of each hemibody. The children were instructed to remain motionless on the platform for 30 seconds, in bipedal support, barefoot, hip-width heels, with their mouth ajar, arms by their sides and their eyes open, looking at the mark from two meters away, arranged at eye level. The test was performed only once.

STATISTICAL ANALYSIS

Data distribution was verified using the Shapiro-Wilk test. Parametric data were represented as mean and standard deviation. The plantigraphy data, which did not present a normal distribution, were represented in median and interquartile range. The comparative analysis of the type of foot and plantar pressure between groups was performed by the Kruskal-Wallis test, followed by the post-test, a comparison in pairs to locate the differences between groups. Significance was established at $p<0.05$. The analyses were performed using the SPSS v.20 program.

RESULTS

The sample consisted of 40 children, 6 (15%) boys and 34 (85%) girls, with a mean age of 9.65 years (±1.42), corresponding to 80 feet analyzed. The participants' descriptive characteristics are shown in Table 1.

Table 1. Sample descriptive data

	Percentile		
	25%	Median	75%
Body mass (kg)	31.07	40.45	50.65
Height (m)	1.36	1.45	1.50
Right foot (cm)	20.12	22.25	23
Left foot (cm)	21	22	23

The average pliability obtained by the sit and reach test was 21.33 cm (± 8.82). According to the plantigraphy, 17 (42.5%) of the right feet were classified as normal, 16 (40%) as cavus and 7 (17.5%) as flat. Regarding the left feet, 23 (57.5%) were classified as normal, 12 (30%) as cavus and 5 (12.5%) as flat.

The pliability of the posterior thigh muscles differs according to the plantar arch (normal, cavus and flat), both in the right and left lower limbs (p=0.01). Children with cavus feet have greater pliability when compared to children with normal feet (p=0.02) (Table 2).

Table 2. Pliability according to type of foot

Type of foot		Pliability (cm)		
		Percentile		
		25%	Median	75%
Normal	Right foot (n=17)*	11.50	16	24.50
	Left foot (n=23)°	12	19	26
Cavus	Cavus right foot (n=16)*	21.12	29.25	32
	Left foot (n=12)°	22	29.50	32.37
Flat	Flat right foot (n=7)	11	16.50	23.50
	Flat left foot (n=5)	10.50	14	26.50

*: p=0.02 (right foot – normal and cavus); °: p=0.02 (left foot – normal and cavus).

The plantar pressure changes according to the type of foot. The statistically significant difference was observed in the distribution of anterior and posterior mass in the plantigraphy of the right lower limb (p=0.00 for both), as well as in the plantigraphy of the contralateral limb (p=0.03 for both). Children with cavus feet have greater pressure in the posterior region of the foot when compared to those with normal plantar arch (p=0.02 right lower limb and p=0.03 left lower limb) and, consequently, less pressure in the anterior region (p=0.02 right lower limb and p=0.03 left lower limb) (Tables 3 and 4).

Table 3. Right plantar pressure according to type of foot

Type of right foot		Plantar pressure (%)		
Mass division		Percentile		
		25%	Median	75%
Normal (n=17)	Anterior	31	42	51.50
	Posterior	48.50	58	69
Cavus (n=16)	Anterior	24.25	28	31
	Posterior	69	72	75.75
Flat (n=7)	Anterior	28	32	34
	Posterior	66	68.30	72

*: p=0.02 (normal and cavus – anterior mass division); °: p=0.02 (normal and cavus – posterior mass division).

Table 4. Right plantar pressure according to type of foot

Type of left foot		Plantar pressure (%)		
Mass division		Percentile		
		25%	Median	75%
Normal (n=23)	Anterior	28	34	49
	Posterior	51	68	72
Cavus (n=12)	Anterior	24.25	28	31
	Posterior	69	72	75.75
Flat (n=5)	Anterior	29.50	32	39.50
	Posterior	60.50	68	70.50

*: p=0.03 (normal and cavus – anterior mass division); °: p=0.03 (normal and cavus – posterior mass division).

DISCUSSION

The results show that the feet morphology significantly alters the posterior pliability and the distribution of plantar pressure in the hindfoot and forefoot. Children with cavus feet showed greater pliability in the hip, back and posterior thigh muscles. In the literature, it is clear that the hamstring muscles can interfere with posture when shortened or excessively stretched, changing the positioning of the pelvis and, in the ascending and descending segments, of the lumbar and knee, respectively[25,26]. Silva et al.[27] observed that knee hyperextension may be due to the excess pliability of the hamstrings, and that it usually occurs concomitantly with lumbar hyperlordosis and hip anteroversion.

In relation to cavus feet, there are factors that influence the formation of the plantar arch, among which age, sex, ethnicity, shoes and weight[28]. Cavus feet can have consequences such as high pressure peaks on the feet, which demands clinical attention for causing injuries to the plantar tissue, calluses and pain[7].

Therefore, it is important to perform the child's postural monitoring in the sagittal plane to detect possible changes in posture according to the types of feet.

The type of arch of the foot can influence the distribution of plantar pressure and have an impact on the biomechanics of posture[29]. In this study, children classified as having normal feet have better plantar distribution when compared to those with cavus feet. The literature points as ideal the weight unloading between 55% to 60% in hindfoot and 45% to 40% in forefoot[30]; thus, the normal plantar arch of the right lower limb presented the best distribution of plantar pressure. The plantar pressure of the foot with normal arch is generally distributed evenly, without large regions of pressure peaks, resulting in a stable and smooth movement[6]. In other studies, there is no relation between the type of foot and the posterior antero oscillation in bipedal support, justifying that changes in the plantar arch are insufficient to modify the weight distribution on the support base in the vertical position[31,32].

During the baropodometric evaluation, the pressures of the right and left feet are recorded, which allows determining the percentage of weight supported by each foot[20]. In all groups, weight distribution was symmetrical in most children.

In the results obtained, the most flexible children are those with cavus feet and who distribute their weight in a calcaneal region higher than recommended. It is assumed that when adopting the retropulsion posture, it leads to knee hyperextension and hip compensation in anteroversion. These results are in line with Wafai et al.[33], who reported that the alteration of the normal function of the foot can lead to a chain of unfavorable results, ranging from inflicting greater pressure to a new location in the foot to putting people at greater risk of imbalance, further increasing the chance of suffering a plantar injury[33].

The findings of this study reinforce that the foot has a fundamental role in the child's postural evolution and may be responsible for generating postural imbalances in childhood. The results have clinical implications, demonstrating that early assessment is important for the detection of MLA, since the pliability of the hamstrings and plantar pressures may be related. Early detection of the type of foot allows the promotion of guidelines and treatments appropriate to the child population.

Although the results found have scientifically supported value, it is necessary to take into account some limitations: convenience sample and the pains that may be present when there is a change in the plantar arch, but this variable was not investigated in our study. In addition, the child's posture in the sagittal plane was not verified in order to attest to the presence of upward changes arising from the feet. Further investigations are recommended, for example, with preschool children who assess the evolution of MLA, plantar pressure and pliability, so that preventive measures are implemented during the period of foot formation.

CONCLUSION

It was found in this study that most of the evaluated plantar arches are classified as normal. Children with cavus feet have greater pliability in the posterior muscles of the lower limb when compared to those with normal plantar arch. Cavus feet are also associated with greater weight discharge in the calcaneal region when compared to the normal plantar arch.

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