CALCULATION OF STAHELI'S PLANTAR ARCH INDEX AND PREVALENCE OF FLAT FEET: A STUDY WITH 100 CHILDREN AGED 5-9 YEARS

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SUMMARY

The authors studied 100 normal children from the general population of both genders with ages ranging from 5 to 9 years old in order to evaluate the plantar arch index and the flat-feet prevalence. The flat-feet evaluation was obtained by means of the footprint and the plantar arch index (IP), which establishes the ratio between central and posterior regions of this footprint, determining a mean IP and a limit to the flat-foot. They conclude that the plantar arch index is easy to obtain from footprints and that there are no differences in terms of gender or age. The mean values of the plantar arch index within this age group are stable and range from 0.61 to 0.67, with plantar arch indexes greater than 1.15 being regarded as flat feet.

Keywords: *Flat foot; Children; Evaluation.*

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INTRODUCTION

One of the most commonly discussed topics in orthopaedics, particularly in the pediatric realm, are the static-postural changes of the feet. Reviewing the concepts about human foot evolution, we notice that the lower limb, and particularly the foot, is amongst the most distinctive characteristics of human anatomy. The overwhelming development of human brain cortex, vocal apparatus, and lower limb and foot structure make a triad distinguishing men from other mammalians. Footprints of hominoids already demonstrated the existence of a plantar arch 3.7 million years ago, and, during human evolution, feet - and not hands - experienced extraordinary changes [1,2].

Ilfeld[3], worried about the fact that, regardless of the symptoms, individuals with flat feet are not able to join U.S. Army, makes footprints of the feet with load by painting their plantar regions. The assessment of plantar arch development, by the relationship between arch region width and heel region width obtained on a footprint, is proposed by Engel and Staheli[4]. This relationship is greatly reduced up to 4 years old, and the standard deviation through this age group is very high, showing a large variation at the initial foot arch development. The longitudinal arch during childhood shows a wide variation, and, from 4 years old on, this relationship remains at about 0.75 in average [5]. Among the many clinical test steps, the study of footprints should be included [6]. The incidence of flat feet, as shown by footprints, reduces with age, reaching 4% at 10 years old [7]. In Brazil, Volpon[8] presents the results of footprints of 637 individuals between zero and 15 years old. The study reports that plantar arch shows a great deal of development up to the 6th year of life, increasing little after that age. It also reports the stabilization of flat foot incidence at around 2%. The prevalence of flat feet declines with age, being higher in children with ligament laxity and the early shoes wearing impairs longitudinal arch development [9].

Human foot is the region most affected by anatomical variations in the entire human body, and one of the most important characteristics presenting the highest level of variability is the medial longitudinal arch, and an arch index provides a quantitative measurement of the plantar arch, which can be compared to other measurements [10].

The objective of the present study is to evaluate whether Staheli's plantar arch index shows a stable behavior or not, and the occurrence of flat feet in children aged 5 - 9 years old, in our environment. This fact is relevant both for clinical practice and, perhaps, for shoemaking industry for this age group.

CASE SERIES AND METHOD

The case series in this study is constituted of 100 children registered at a middle-class Elementary/ Junior School in São Paulo city. The children were divided into 5 subgroups. Each subgroup corresponds to children aged 5, 6, 7, 8, and 9 complete years, respectively. Each subgroup comprises 20 children. For each age, frequency distribution regarding gender was 10 male children and 10 female children, totaling 50 children from each gender in the whole group. All children, after parents' or caregivers' previous consent, were submitted to investigation of personal history as reported on school me-

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dical tests files and by an overall orthopaedic examination, seeking to study children regarded as clinically normal. Any relevant clinical condition, such as palsy sequels, myelomeningocele, meningitis sequels, orthopaedic surgeries or serious traumas on limbs, among others, would determine an exclusion criterion to the study.

Footprint Study

For obtaining footprints, we selected a pedigraphy instrument, which is usually employed for that end in our environment (Figure 1). The rubber layer remains about 2 mm above the plastic platform, parallel to it, when the metal structure is supported on the platform. A sheet of paper is placed on the platform and the metal structure is closed upon the first. The surface impregnated with stamp ink faces paper's upper surface. The child remains seated in front of the platform. With the aid of an investigator, the child places the foot to be studied on the rubber layer, with contralateral foot out of the platform. We requested the child to stand up and perform a small flexion of the ipsilateral knee (about 30º), with the aid of the investigator (Figure 2) and, then, to go back to the initial position, removing the foot from the platform. The investigator should control foot position on the platform so as to prevent foot slip, a fact that would invalidate the test, which should show a clear footprint.

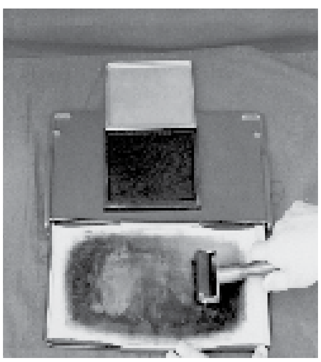

Figure 1- *Rubber layer and plastic base impregnated with regular stamp ink for capturing footprints.*

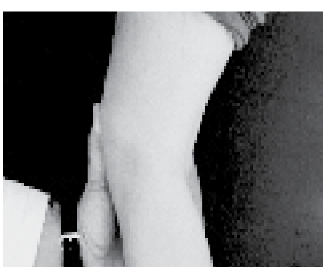

Figure 2- *Captured with body weight load.*

Calculation of the Plantar Arch Index

The plantar arch index establishes a relationship between central and posterior regions of the footprint, and it is calculated as follows: a line is drawn tangent to the medial forefoot edge and at heel region [3,5]. The mean point of this line is calculated. From this point, a perpendicular line is drawn crossing the footprint. The same procedure is repeated for heel tangency point. We thereby obtain the measurement of the support width of the central region to the foot (A) and of the heel region (B) in millimeters (Figure 3). The plantar arch index (PI) is obtained by dividing the A value by B value (PI = A/B)[5].

Evaluation Criteria

A normal plantar arch index (PI), according to the Pediatric Orthopaedic Society is the one comprised within 2 standard deviations (SD) of the population average [11]. Thus, PI values equal or above the sum of 2 SD with the average were considered as indicative of flat foot, and named as threshold indexes for this condition.

Statistical Analysis

A cross-sectional study, with previous descriptive analysis and average calculation of the standard deviation and standard error of the mean plantar arch indexes in the population sample. For purposes of comparing these averages, the following parametric tests were used: Student's t test and paired t Test for two samples and Variance Analysis for more than two grouped samples. In all tests, the adopted significance level was 5% ($\alpha = 0.05$).

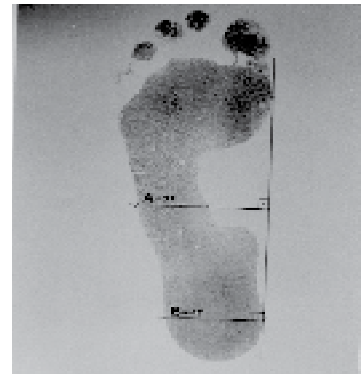

Figure 3- *Measurement of the width of the central region (A) and heel region (B) of the foot, in millimeters, on a footprint. The plantar arch index is obtained by dividing A value by B value.*

RESULTS

On Table 1, average, minimum, maximum, and standard deviation values for central arch region (A) and heel (B) on footprint, and for the plantar arch index (PI) corresponding to right and left feet, respectively.

Following the PI analysis, significant differences were noted between sides (Table 2), with average plantar indexes being 0.67 for right side and 0.61 for left side.

No significant differences were reported between genders (Tables 3 and 4) or between different age groups (Tables 5 and 6) for both sides.

	RIGHT FOOT			*LEFT FOOT*		
	A	*B*	*PI*	*A*	*B*	*PI*
Average	*26,20*	*38,97*	*0,67*	*23,84*	*38,53*	*0,61*
SD	*9,79*	*4,80*	*0,24*	*10,70*	*4,64*	*0,26*
Minimum	*0*	*29*	*0,00*	*0*	*30*	*0,00*
Maximum	*53*	*56*	*1,27*	*56*	*50*	*1,30*
Number	*100*	*100*	*100*	*100*	*100*	*100*

Table1- *Values for average, minimum, maximum and standard deviation (SD) of the measurements of the central region of the arch (A) and heel (B) on footprints and of the plantar arch index (PI) for right and left foot.*

	SIDE	
	RIGTH	*LEFT*
Average	*0,67*	*0,61*
SD	*0,24*	*0,26*
ASE	*0,02*	*0,03*
N	*100*	*100*

Paired *T* test (single-tail)

*t = 3,87 p = 0,0002**

Table 2- *Plantar indexes average, standard deviation (SD), average standard error (ASE) and number of studied feet (N), according to side in the population sample.*

	GENDER	
	MALE RIGHT	*FEMALE RIGHT*
Average	*0,67*	*0,66*
SD	*0,24*	*0,25*
ASE	*0,03*	*0,03*
N	*50*	*50*

Student's *T* test (single-tail)

t = 0,22 p = 0,91

Table 3- *Plantar indexes average for right feet, standard deviation (SD), average standard error (ASE) and number of studied feet (N), according to gender in the population sample.*

	GENDER	
	MALE LEFT.	FEMALE LEFT
Average	0,62	0,61
SD	0,25	0,27
ASE	0,04	0,04
N	50	50

Student's *T* test (single-tail) $t = 0{,}19$ p = 0,92

Table 4- *Plantar indexes average for left feet, standard deviation (SD), average standard error (ASE) and number of studied feet (N), according to gender in the population sample.*

	AGE (RIGHT)				
	5	6	7	8	9
Average	0,71	0,66	0,64	0,63	0,72
SD	0,26	0,26	0,29	0,17	0,21
ASE	0,06	0,06	0,06	0,04	0,05
N	20	20	20	20	20

*Variance Analysis S * = 0,24 F = 0,59 P = 0,91*

Table 5- *Plantar indexes average for right feet, standard deviation (SD), average standard error (ASE) and number of studied feet (N), according to age (years) in the population sample.*

	AGE (LEFT)				
	5	6	7	8	9
Average	0,70	0,59	0,55	0,60	0,63
SD	0,28	0,27	0,37	0,14	0,19
ASE	0,06	0,06	0,08	0,03	0,04
N	20	20	20	20	20

Variance Analysis S * = 0,26 F = 0,94 P = 0,55

Table 6- Plantar indexes average for left feet, standard deviation (SD), average standard error (ASE) and number of studied feet (N), according to age (years) in the population sample.

After applying the criterion recommended by the Pediatric Orthopaedic Society of two standard deviations of the average 11 the limits for flaccid flat foot were 1.15 for right side and 1.14 for left side, regardless of gender, for the ages studied.

DISCUSSION

The foot has two functions: to be a strong and stable support for the body, and the lever to ambulation [12]. This double function makes feet to present a unique behavior during ambulation, when it is submitted to a successive load and unload cycle. The deformation experienced by the medial longitudinal arch during support makes feet to be the region suffering the highest variations in a human body [10]. These functional features make clinical examination of this region complex.

The wide variability found in all concepts concerning feet may be exemplified by the various names for flat feet. This condition has received many different names, not necessarily reflecting characterization of different problems [6].

The incidence of flaccid flat feet is reduced with age [7,8,13,14]. Engel and Staheli[4] found a strong reduction up to the age of 4, because medial longitudinal arch development happens primarily through that age, thus, higher plantar arch indexes are expected in younger children, while these indexes are lower in older children. Other authors admit that major variations on plantar arch happen until the age of 7 [10,15,16]. The suggestion of this index having a decreasing incidence up to approximately 5 years old, remaining stable after that, was responsible for our decision to study a group of children above that age, working with lower age groups we could reduce the usefulness of our indexes to the intended end.

Some pathological conditions are known to influence on flat feet genesis [17,18]. Identifying personal history and problems that may directly or indirectly affect feet posture is paramount in studies like this. Thus, we decided to study only children regarded as clinically normal.

Similarly, the orthopaedic examination served to recognize disorders that are known to change feet consistency. The identification of congenital problems, particularly involving the feet [19,20]; postural abnormalities of the spine, pelvis, hips and knees [18]; Achilles Tendon shortening[21,22], and restraint to subtalar joint movements are essential for ruling out the possibility of secondary flat feet.

Although there are people considering footprint a poor evaluation approach [23], there is almost an uncountable number of authors who advocate its use: Gervis[24], Engel and Staheli[4], Viladot[25], Cavanagh and Rodgers[10] and Staheli et al.[5], Viladot[26], Volpon[27], Chen[28] among others. The correlation between X-ray studies and footprint shows that the footprint is effective for individual studies and population-based investigations [29]. Some cannot find a correlation between footprint and clinical measurement of the plantar arch, regarding it as invalid to determine plantar arch height [30], others also consider that footprints present several approach failures [31]. The plantar arch index and the navicular vertical height are correlated, but the second is better, because it directly measures navicular, which is the key to medial arch, in addition to be easy to achieve [32].

Using a sophisticated methodology, such as strength platforms, graded scales [10] or "moirè" photopodometry [33], increases measurements accuracy, but these are more difficult to apply in clinical routine. The classification proposed by these authors may be used by obtaining a carton-based template of the area of plantar region of the feet [15]), which allows for calculating the plantar index from the areas of different regions of the feet. However, for large-scale studies (population-based), its practical application is more cumbersome. Any method showing a clear and homogenous footprint is, at first, worthy for assessing it. Roehm[34] and Cavanagh and Rodgers[10], mention several cases. The technique employed for obtaining footprints in this study is simple, not expensive, easy to apply and satisfactory for routine clinical analyses. Footprint is simple, available, low-cost, and non-invasive, and does not use radiation as well [29]. The plantar arch index (PI) correlates foot central region, also called arch region, to the heel region, and has also been used by some other authors [35,36]. The relationship between the areas of these regions was used by Cavanagh and Rodgers[10], nevertheless making calculation difficult. Similarly to footprint, the PI calculation was performed in a simple and practical way, and both can be done in an outpatient basis - in clinical cases - as well as in large groups, for population-based studies.

Although literature shows no significant difference between right-side and left-side plantar arch indexes [5,37], our indexes presented a significant difference regarding side, with p value significantly below 5%. Sá et al.[16], in a study on plantar arch in 302 children aged 3-10 years, called attention to the differences between sides in the various feet measurements, although they emphasize that these are almost unnoticeable on plantar index dimensions. The crucial issue at that point turns to be 'why such a difference between sides'. We could not find an answer to that question, but we can build some theories. We believe that the reason is somewhere in footprint capture. The fact that these had been obtained through a static manner didn't seem to be the responsible factor, since the objective of the knee flexion performed by the child during the procedure was to cause an inner rotation of the leg and increase foot pronation, similar to what happens during gait support phase, although with a lighter load [23,38]. In addition, Cavanagh and Rodgers[10] state that the static indexes are preferred for standardization purposes. We suppose that performing measurements with bilateral support could lead to differences if one side supported a heavier body load than the other, being subjected to a higher level of foot deformation. It was impossible to use monopodal support due to balance problems in this age group.

No significant differences were found in PI for different ages. This finding is consistent to literature, which shows a higher level of medial longitudinal arch development and a strong decrease on flat feet incidence up to approximately 5 years old, tending to little variations after that age [4,7,8,13,27]. Following the study of plantar arch indexes, no significant differences were found between genders. Accordingly, Staheli et al. [5], did not find such difference for PI.

The criterion proposed by the Pediatric Orthopaedic Society11 regards as normal all values within two standard deviations from the average. Using this criterion, we found threshold indexes for flaccid flat feet of 1.15 for the right side, and 1.14 for the left one. Any values above the latter are indicative of flaccid flat foot in our sample. One can easily notice that although there is a significant index difference between right and left sides, the difference between threshold indexes is small, and we believe that a single index can be used in clinical practice. According to our calculations, five cases of flaccid flat feet were identified in our sample population studied, with two bilateral cases. It is well established that a rigorous clinical application of an index not always leads to a correct diagnosis. The plantar arch index, as any other, must be applied in the light of clinical history and physical examination of the patient, and never in an isolate and absolute manner. By analyzing age and gender of the 5 children diagnosed as having a flaccid flat foot in this population sample, we have not been able to establish a statistical relationship for any of the parameters. These analyses were not presented in our results because the number of children with this kind of foot was small, which determined poor validity to this kind of study.

CONCLUSIONS

1) The average values for plantar arch index between five and nine years old are stable and range from 0.61 to 0.67 in our sample.

2) Based on this sample, plantar arch indexes above 1.15 should be regarded as indicative of flat foot.

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