FOOTPRINT STUDY IN CHILDREN DURING THE JACK TEST

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ABSTRACT

Objective: To assess the plantar impressions obtained in children during the Jack test, with the aim of quantifying and analyzing their variability in the critical period for plantar foot arch formation. Method: A hundred and twenty feet from 60 healthy White children, recruited in an outpatient pediatric clinic, were examined. Our sample included 35 boys and 25 girls, ranging from 2 to 5 years. The Jack test was simulated using a 45o wedge-shaped orthosis applied to the hallux. Bilateral plantar impressions were acquired in the alternate single-foot standing position using a pedigraph. Two plantar impressions were obtained for each foot, with and without the orthosis. The exams were analyzed using the Valenti and Volpon methods. Statistical tests were applied. Results: In all cases, both the Valenti and Volpon indexes decreased as the orthosis was applied. Furthermore, the difference between both indexes with and without the orthosis decreased with age. Conclusions: It is possible to quantify the Jack test using plantar impressions with the Volpon and Valenti methods. The variability observed in plantar shape tended to decrease after 4 years of age. Finally, the Jack test gradually lost its capability to change plantar impression with age, which reduces its accuracy as a parameter for a good prognosis in longitudinal medial arch formation. Level of Evidence: Level IV, observational descriptive study.

Keywords: *Flatfoot. Anthropometry. Child. Physical examination.*

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INTRODUCTION

The plantar impression can be a polemical means of evaluating the foot in body weight-bearing, but we cannot deny that this image directly represents how the foot touches the ground.[1]

Observing its shape we can notice areas of contact and absence of contact, forming a design that identifies the actual human being. This design determined the plantar impression as our first signature, defining whether we are carriers of any anomaly.

We use this exam on a routine basis in the surgery, as the first concern of parents when their children start to walk is to discover how their feet are placed on the ground. The narrowing of the middle region of the plantar impression provides a notion of how the longitudinal arch of the foot is forming and, when measured periodically, becomes a temporal record of the development of the plantar arch.[2,3] If we fail to observe isthmus formation, we conduct a very common propaedeutic test: the Jack test. The purpose of this maneuver consists of evaluating longitudinal arch formation when we perform passive hyperextension of the hallux.[4-6]

When unclear about the true interpretation of these data, we seek studies in literature that address these methods of analyzing plantar support in a scientific manner.[2-4,6-15]

Some authors affirm that the plantar impression does not demonstrate the true condition of the medial longitudinal arch. However, the vast majority uses it as a method of direct evaluation of this parameter in epidemiological studies, in the assessment of normal feet, determination of normality criteria and even in flat foot classifications.[1-4,6-8,11,12,14-16]

We also find in literature studies that employ other conjugate propedeutic methods to interpret the true meaning of plantar contours, ranging from radiographic measures[2,17-19] to computerized scanning.[20]

Therefore its use as a method for studying plantar support becomes undeniable.

As regards the Jack test, although widely used as a plantar arch formation prognosis test, it has limitations due to its simplistic scaling in positive or negative, and because its expressivity is directly dependent on the examiner's technique.[3-6,15] Searches

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Study conducted in the Pediatric Orthopedics Discipline of the Department of Orthopedics and Traumatology – Escola Paulista de Medicina da Universidade Federal de São Paulo.
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performed in literature reiterated this concept as we did not come across any studies related to its quantification.
The aim of this study was to evaluate whether the footprint obtained during the Jack test could quantify it, and to observe the variability of the test in the critical plantar arch formation period, between 2 and 5 years of age.

METHODS

All the procedures described and carried out in this study were approved by the committee of ethics in research of UNIFESP-EPM, in compliance with the standards of CONEP (National Committee for Research Ethics). The detailed information on the study was provided to the parents of the children included in the study, who agreed to take part by signing an informed consent term.
One hundred twenty feet were evaluated in 60 White children, with age ranging from 2 to 5 years (averaging 3 years and 5 months). These children were screened in the Pediatric Outpatient Clinic, and only individuals asymptomatic in relation to the anatomical region to be examined were included in the study.
As regards gender, the sample group was made up of 35 boys and 25 girls; their weight varied between 12 to 23 kilograms (kg), averaging 15.8 kg.
All the children underwent a sequence of procedures with the purpose of obtaining an adequate plantar impression. Two impressions were obtained of each foot using a pedigraph. (Figure 1) The first, in single-foot plantigrade posture. (Figure 2) The second, using a triangular orthosis (Figure 1), made from nontoxic vinyl foam (EVA), to keep the hallux at 45 degrees of passive extension, simulating application of the Jack test[4-6,15].
Jack test – this test is conducted with the patient in bipedal orthostatic position, when the examiner promotes, with one of their thumbs, passive extension of the metatarsophalangeal joint of the hallux. This enables them to observe varus formation in the hindfoot, the appearance or the accentuation of the foot arch and external leg rotation. The test is considered positive when these three phenomena are observed.[4-6,15]
Modified Jack test –consists of the application of a triangular orthosis with 45 degrees of angulation, which keeps the hallux extended and simulates the application of the original test.
Although the Jack test is described in double-foot standing position, we observed that in extending the hallux of the examined foot there is a natural tendency for the children to lose their balance and shift their weight onto the contralateral foot, impairing the correct obtainment of the plantar impression. Therefore, we opted to conduct the test in single-foot standing position with the help of an assistant who guided the body axis during this stance, while the mother kept the contralateral knee flexed.
All poorly defined impressions were disregarded.
The plantar impressions selected, with and without orthosis use, were evaluated according to the methodology described by Volpon[7] and also to that used for obtainment of the Valenti index.[3,6,15]

Volpon Methodology

Two lines were drawn tangential to the lateral and medial edges of the plantar impression, followed by a third line called the foot axis, drawn from the center of the calcaneal impression to the center of the third toe impression. The most lateral point of the medial rim was called point D, and a line was drawn at this level, perpendicular to the foot axis. The points relating to the intersections of this line with the lines tangential to the lateral and medial edges were named, respectively, point E and point C, with the measurement of distances CE and DE.[7]
The Volpon index was calculated using the DE/CE ratio, called index S, without orthosis, and index C, with orthosis.

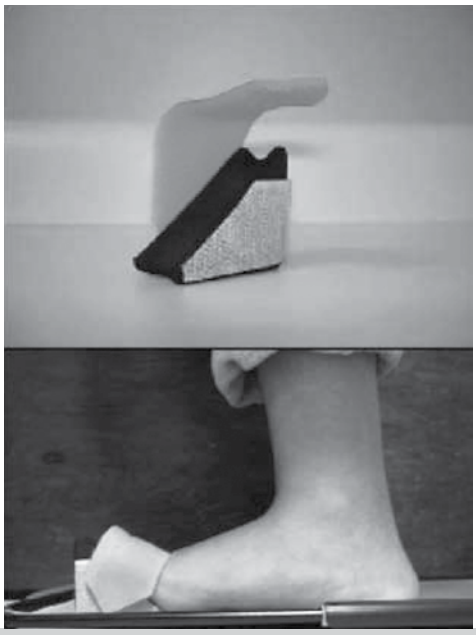

Figure 1. *Orthosis and means of Obtainment of footprint with the help of the pedigraph*.

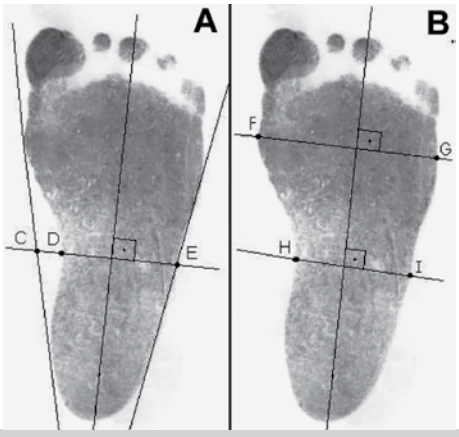

Figure 2. *Measurement of footprint by the Volpon (A) and Valenti (B) methods.*

Valenti index methodology

A longitudinal line called foot axis was drawn that passed through the center of the calcaneal impression and through that of the third toe impression. We determined the narrowest region of the plantar impression, the foot isthmus, and drew a line perpendicular to the foot axis naming it measurement HI. A new line was drawn, perpendicular to the foot axis and passing through the most medial point of the forefoot impression, point

F, to reach the lateral edge, point G, for determination of its width, called measurement FG.

The Valenti index[3,6,15] was calculated through the HI/FG ratio, called index RS, without orthosis, and index RC, with orthosis. Note: To distinguish between the measurements obtained without orthosis use and with orthosis use, we used the apostrophe on standard denominations DE, CE, HI and FG.

Footprint size

The footprint size was obtained by measuring the distance between the posterior margin of the hindfoot and the most distal part of the largest toe (first or second).[7]

Statistical Method

The sample was submitted to the statistical analysis by non-parametric tests due to the characteristics of the variables studied. The values were grouped by the t-student tests, intraclass correlation coefficient.

RESULTS

Applying the methodology already described in the data gathered from the plantar impressions, we obtained the following results:

The values of the indices, without orthosis, of Volpon[7] (index S) and of Valenti[3,6,15] (index RS) are grouped in Table 1. Evaluating the concordance between indices, we calculated the intraclass correlation coefficient. A value of 0.609 [0.419; 0.748] was obtained for the right side, while for the left side, the values obtained were 0.637 [0.460; 0.766]. Such results indicate concordance between the methods. With the Student's t-test for related samples, it was verified (p = 0.001) that the Volpon index tends to present higher results than the Valenti index, in both feet.

Analyzing plantar impressions with and without orthosis use, and submitting them to the calculation of the Volpon index,[7] it can be noticed that this index presents lower results whenever the orthosis is used. Likewise, in analyzing the measurements with and without orthosis use and submitting them to the calculation of the Valenti index, it can be noticed that the values also decrease when the orthosis is used. The tables below contain summary measures of the values encountered with and without orthosis use, respectively, index S and index C for the Volpon methodology[7], and index RS and index RC for the Valenti methodology.[3,6,15]

To evaluate the concordance between right and left feet, we calculated the intraclass correlation coefficient and obtained values that indicated concordance between right and left feet, both in the Volpon index with and without orthosis, and in the Valenti index. Thus, we considered the right and left feet a single class and the results below are in line with this consideration. The absence of association was noticed between the variables weight and gender, in relating them with the results of the Volpon[7] and Valenti[3,6,15] indexes.

As regards the variable age, in relating it with the results of the Volpon and Valenti indexes with and without orthosis, respectively indices S, C, RS and RC, (Figure 3), it was noticed that these vary in a decreasing manner as the age increases.

Table 1. *Descriptive measures of the Volpon and Valenti indices with and without orthosis on each side.*

VOLPON INDEX				
	Index S LEFT	**Index C LEFT**	**Index S RIGHT**	**Index C RIGHT**
Mean	0.71	0.62	0.71	0.59
Standard deviation	0.18	0.16	0.18	0.15
Minimum	0.38	0.32	0.38	0.29
Maximum	0.96	0.93	1.00	1.00
Asymmetry	-0.36	0.37	-0.37	0.46
Kurtosis	-1.40	-0.93	-1.22	-0.16
VALENTI INDEX				
	Index RS LEFT	**Index RC LEFT**	**Index RS RIGHT**	**Index RC RIGHT**
Mean	0.54	0.49	0.55	0.47
Standard deviation	0.17	0.16	0.17	0.14
Minimum	0.14	0.18	0.16	0.18
Maximum	0.87	0.87	0.83	0.84
Asymmetry	-0.29	0.38	-0.43	0.33
Kurtosis	-0.73	-0.39	-0.52	0.01

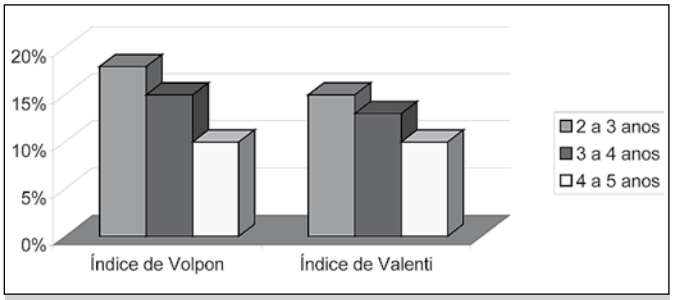

Figure 3. *Distribution by age bracket of the percent differences between the indices with and without orthosis use.*

DISCUSSION

In the original study by Jack,[5] it is described that in normal feet the axis formed between talus, navicular bone, medial wedge and first metatarsal bone is a straight line. The angulation of this line, with vertex downwards, leads to the appearance of flat feet. This phenomenon can occur at three levels: in the talonavicular joint, naviculocuneiform joint, or in both. The angulation of this line does not occur at the level of the metatarso cuneiform level, as it is a joint with low mobility. The Jack test stimulates the formation of the medial longitudinal arch when the line break occurs at the level of the naviculo cuneiform joint, which is not the case when the break is located in the talonavicular joint.[5]

In the office, the Jack test is widely used to evaluate pes planus. However, its conventional application does not quantify MLA formation. To achieve a quantitative analysis of formation of the MLA and of the isthmus, we associated the plantar impression to assess the behavior of the foot support area when applying the test. The use of the plantar impression enabled us to analyze not only how much narrower the isthmus becomes, but also at which analyzed age this happens with greater intensity.

The Jack test is not a standardized test, since its description does not mention how much the hallux should be passively extended.[5,6] This variation in the degrees of passive hallux extension can alter the midfoot contact area, which would make the data found highly variable according to the examiner. For passive hallux extension to be standardized for all the patients, we used a triangular orthosis with fixed angulation of 45 degrees.

In literature there is controversy surrounding the actual definition of flat foot and its possible functional implications, particularly in relation to the methods used to quantify it. Several techniques were developed in an attempt to evaluate plantar impressions. One of the first attempts was described by Schwartz[16], as the footprint angle. Two lines were drawn to obtain this angle, one tangential to the most medial points of the forefoot and hindfoot, and the other connecting the most medial point of the forefoot to the most lateral point of the medial edge of the foot. Another technique developed to evaluate the footprint index considers the division of the plantar arch area without contact by the area with contact[8]. Other techniques were described later, such as that of Jung[21], which determined several tangents along the plantar image. All these techniques, however, had important limitations, as they were imprecise, subject to interpretation errors, and often hard to reproduce.[8] Although these comments made by Cavanagh and Rogers[8] are true, the actual technique described thereby, the Arch Index, is also hard to reproduce, since it uses computer graphics methods for analysis of the footprint area, making its execution considerably more expensive and impracticable in daily practice. Accordingly, we opted for the use of two well-known techniques to analyze the data obtained. The methodologies described by Volpon[7] and Valenti[3] for footprint analysis were used on account of their easy reproducibility.

With the purpose of comparing the data found in our sample with those obtained in literature, we initially measured the mean length of the feet to make sure that we were analyzing feet of similar sizes.

In relation to the variable gender, there was no statistically significant variation between the indices.

When we compared all the indices obtained for the right and left foot, the statistical analysis showed that there was no significant difference, which enabled us to interpret the 120 footprints as a single sample.

We can see that the values for the Volpon and Valenti indices without orthosis use, respectively indices S and RS, decrease as the children's age increases. (Figure 3) This observation is consistent with countless published studies, explained by the natural tendency for formation of the medial longitudinal arch, reflected by the narrowing of the isthmus region.

When we evaluate the Volpon and Valenti indices with orthosis use, respectively indices C and RC, and compare them with the same indices without orthosis use, respectively indices S and RS, we can see that the percentage difference between them decreases gradually as the age increases.

Specifically in the Volpon index, we noticed that in the younger children aged from 2 to 3 years, it decreases on average 18% when the orthosis that simulates the Jack test is used. In slightly older children, aged 3 to 4 years, this variation drops to 15% and, finally, in the children from 4 to 5 years old, this variation is just 10%. This is because the older the child, the more alike their footprints with and without orthosis, which in turn, leads to closer values of the Volpon index with and without orthosis, thus decreasing the percentage difference between them.

The percentage decrease of the Valenti index has a similar behavior, yet in a more discreet fashion. An important observation was the discovery that the standard deviation of both indices reaches its maximum value in the older children from the sample. This indicates that, in this age bracket (4 to 5 years), the feet tend to define their prognosis in terms of formation of their permanent plantar arches.

CONCLUSION

The footprint format presents a strong tendency towards definition from the age of 4 years.

The Jack test gradually loses the ability to modify the plantar impression, reducing its acuity as a parameter of good prognosis in MLA formation.

In this study the Volpon and Valenti methodologies appeared easily applicable.

The plantar impressions associated with the Jack test represent permanent documentation of the MLA formation process, and can be used for future comparative analyses.

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