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ARTIGO ORIGINAL

Avaliação computacional da impressão plantar. Valores de referência do índice do arco em amostra da população brasileira

Computational evaluation of the footprint: reference values of the plantar arch index in a sample of the Brazilian population

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RESUMO

A presença do arco longitudinal medial (ALM) é característica dos pés humanos e através dele o pé tem sido classificado como normal, cavo e plano. A literatura permite escolher entre variados métodos e técnicas de mensuração do ALM, cada qual com vantagens e desvantagens. Optou-se pelo método da impressão plantar com medida do índice do arco (IA) para avaliar indiretamente a altura do ALM. A escolha foi motivada por ser a impressão plantar exeqüível com baixo custo e não invasiva. Seguiu-se o princípio básico do método de mensuração do IA proposto por Cavanagh & Rodgers, modificado pela introdução do escaneamento da impressão plantar e pelo cálculo do IA através de programa computacional elaborado por um dos autores. Foram avaliadas 100 impressões plantares de 25 homens e 25 mulheres sadios, não obesos, com média de idade de 34,7 anos, extremos de 10 a 59 anos. Obtiveram-se os valores de referência do IA de amostra da população brasileira: $0,21 < IA < 0,25$. A comparação estatística dos valores nacionais com os da amostra americana não mostrou diferença estatística significativa.

PALAVRAS-CHAVE

pé/anatomia & histologia, dermatoglifia, população, Brasil

ABSTRACT

The presence of the medial longitudinal arch (MLA) is characteristic of the human feet and has been used for the classification of the normal, cavus and flat foot. The literature provides information on several methods and different techniques for the measurement of the MLA, each of them presenting advantages and disadvantages. We chose the footprint method and the measurement of arch index (AI) as an indirect evaluation of the MLA height. This method was chosen due to its simple, cost-effective and noninvasive characteristics. We followed the basic principles of the IA measurement proposed by Cavanagh & Rodgers, but modified it, by introducing the footprint scanning and AI calculation using a software program created by one of the authors. A total of 100 footprints were analyzed from 25 male and 25 female healthy, nonobese subjects, with a mean age of 34.7 years, ranging from 10 to 59 years. The AI reference values obtained from a sample of the Brazilian population were $0.21 < IA < 0.25$. There was no significant statistical difference between the values obtained from the Brazilian and American samples.

KEYWORDS

foot/anatomy & histology, dermatoglyphics, population, Brazil

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INTRODUCTION

The development of the medial longitudinal arch (MLA) was a fundamental step in the evolution of bipedal gait in humans and its alterations can increase the risk of musculoskeletal injuries[1].

The visual inspection of the foot is the easiest method of MLA evaluation; however, even experienced clinicians can disagree on the classification of types of foot, when based exclusively on this method[2].

Several techniques are mentioned in the literature to objectively evaluate the MLA height and there are controversies regarding its validation, revalidation and variations in many of them[3].

The MLA valuation methods can be direct or indirect[4]. The direct ones include anthropometric measurements and x-rays[1,5]. The indirect methods include the footprint method[3,6,7,8,9,10,11,12] and the photographic analysis of the feet[2].

Obtaining the footprint is simple and easy. Several measurements and parameters regarding the footprint have been proposed aiming at classifying the MLA as normal, high or low[9].

Schwartz *et al.*, in 1928, proposed to measure the footprint angle to assess the foot type. The angle was defined between a line connecting the most internal points of the metatarsal and heel region in the medial border; and another line connecting the metatarsal region and the most point in the medial border, in the MLA region.
The higher the arch, the higher the angle of the footprint is[7].

Irwin developed the footprint index, which consisted in the ratio between the non-contact area of the foot with the ground and the area of contact observed in the footprint drawing[7]. Jung[6] used the Brucken Index (BI) as part of a study of marathoner women. For the calculation of the BI, the footprint was divided in the forefoot and heel regions. Tangent lines were drawn along the most internal points from the medial border (AC) and the most external points from the lateral border (BD) of the footprint; to the most anterior point from the metatarsals (AB) and to the most distal point from the heel (CD). The AC tangent was later divided in 10 equal parts. Between the second and the sixth parts, lines (EG) were drawn parallel to AB. The intersection point of these lines with the medial border of the foot was called the F point. The BI was calculated by the ratio between EF and FG (BI=EF:FG).

Cavanagh & Rogers[7] measured the footprints with emphasis on the arch index (AI), which consisted in the ratio between the intermediary area of the footprint in relation to the total area of the footprint, excluding the toes. The AI allowed the classification of MLA as high, normal and plane.

Forriol & Pascual[13] used the Chippaux-Smirak index, which described the ratio between the measurement of the largest diameter in the metatarsal region and the measurement of the smallest diameter in the MLA region, obtained with the footprint.

Considering the several prior proposals, the AI described by Cavanagh& Rodgers[7] has received the largest number of positive references from other authors[3,8,11,12]. However, there are still controversies regarding the validity of the AI as a reliable indirect measurement of MLA height. Studies have shown a correlation between the AI and radiographic or clinical measurements of AI[3,11,12], whereas others have found no correlation between the clinical measurements of MLA height and those based on the footprint[9]. For the authors[9], the thickness of the soft tissue in the lower foot region invalidates the use of the AI as a measurement of MLA height.

Among the several uses of the MLA height measurement through the footprint, it is worth mentioning the growth follow-up and the development of the foot structure[10,13], the study of the feet of obese individuals[3,11], the role of MLA height in the lower extremity function and the occurrence of lesions due to excess use[8,11].

Gilmour & Burns [3] reported AI alterations in obese children, whereas the direct clinical measurements of the arch did not present alterations. It was proposed that the increase in the soft tissue of the foot due to the obesity could contribute to the increase of the footprint area. Wearing et al[11] also reported an influence of body composition on the AI in obese adults. Thus, the AI measurements based on the footprint must be interpreted with caution in obese individuals.

Despite the several studies using the AI, the only available normative study has been carried in the North-American population[7]. No studies identifying normal parameters of MLA in the Brazilian adult population were found in the Literature.

OBJECTIVE

The aim of the present study was to attain the normalization of the footprint measurements in a sample of the Brazilian population considered to be healthy, using the AI value through computational analysis for the area calculation.

SUBJECTS AND METHODS

Fifty healthy individuals volunteered for the study, of which 25 were males and 25 females aged 10 to 57 years. Written informed consent was obtained from all volunteers prior to the start of the study, which was approved by the Ethics Committee of our Institution (FCM-UNICAMP). Obese subjects or individuals with neurological or orthopedic diseases were excluded from the study.

Both feet of each subject were analyzed. In order to obtain a footprint, the individual sat on a chair whereas hydrosoluble paint was applied to the plantar region of one foot. After that the subject was asked to stand up and distribute the body weight equally on both feet, as the paint-coated plantar region was pressed against a white sheet of paper. The sheet was removed with the individual sitting down. The same procedure was followed for the contralateral foot.

After the 50 pairs of footprints were obtained, its borders were enhanced with a soft-point pen, excluding the toes, in order to obtain a higher contrast of the border. A known-radius (0.65 cm) circular marker was attached to the footprint, in a safe and distant position from the footprint. The set consisting of the footprint and control marker were digitized simultaneously. The digital images segmented, filled in with a uniform texture and converted into binary images, defining the areas of the footprint and the control marker with unitary values for each pixel. Using the Matlab software (MathWorks, Inc. version 6.5), all pixels were added for each image. The value attributed to the control marker indicated the adjustment to be made when obtaining the footprint area according to the equation (1):

TA = Pi x R^2 x MP/MC
TA ~ Total area of the footprint
Pi ~ 3.1415
R ~ 0.65
MP ~ Sum of unitary pixels of the footprint.
MC ~ Sum of unitary pixels of the control marker.

The digitized images of the footprints were divided in A (forefoot), B (midfoot) and C (rearfoot) areas (Figure), corresponding to the delimitation of 1/3 of the longitudinal length for each fraction of the total area. Later, the coefficient in the B sub-area was established according to the equation (2): AI = B / AT.

The mean, median, standard deviation (SD) minimum and maximum AI, 1st and 3rd quartiles (Q_1 and Q_3) of the sample were established. The comparison between the AI of the right feet *versus* the left feet was performed through the paired *t*-test. The comparison between the AI of male and female individuals and between our sample and the North-American sample was carried out through Student's *t* test. The statistical software Minitab v. 13 was used for the statistical analysis.

RESULTS

The study evaluated the footprints and AI of both feet of 50 individuals, 25 males and 25 females, with a mean age of 34.7 and median of 33.5 years, ranging from 10 to 59 years.

The AI of the right feet resulted in a mean of 0.234, median of 0.236, with a SD of ±0,026; minimum AI of 0.162 and a maximum AI of 0.283. The AI of the left feet resulted in a mean of 0.229, median of 0.233, SD of ±0.026; minimum AI of 0.170 and maximum AI of 0.277.

The AI of the total sample resulted in a mean of 0.232; median of 0.234 and SD of ±0.026. The minimum AI was 0.162 and the maximum AI was 0.283. No statistically significant difference was observed at the paired *t*-test (p=9.5%) between the AI means from right and left feet. When the AI means from males (mean = 0.237) and females (mean=0.226) were compared, a statistically significant difference was demonstrated by the student's *t* test (p=3.0%), with the MLA in the female sex being slightly higher than in the male sex.

The distribution of the AI was represented at the histogram and divided in quartiles. Q_1 and Q_3 occurred in 0.215 and 0.251, respectively. Q_1 indicated the distance of 25% from the minimum value of the sample and Q_3 the distance of 75% of the minimum value of the sample. Based on this division, the MLA of the normal sample was defined as 0.21< AI< 0.25.

Assuming that the AI data set of Cavanagh & Rodgers[7] study (n = 107, mean AI = 0.230 and SD = 0.026) had a normal distribution and equal variance, the weighted variance was calculated (0.0014), which was used in the Student's *t* test. There was no statistically significant difference (p=87.99%) between the AI means of both samples.

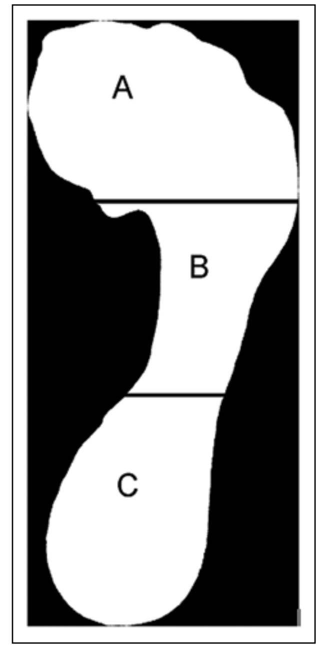
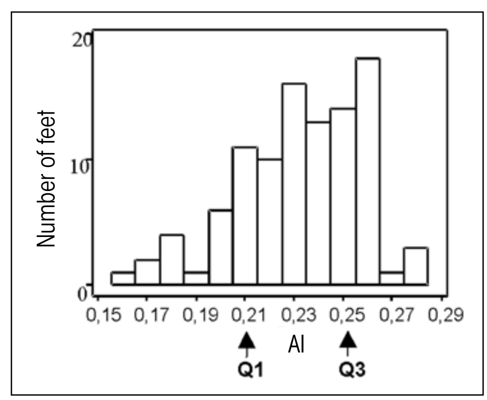


Figure 1
A (forefoot), B (midfoot) and C (rearfoot) areas used in the AI calculation.



The arrows indicate the first and third quartiles in the distribution.

Figure 2
AI distribution in a sample of 100 feet.

DISCUSSION

The analysis of the footprint has been considered an objective method for MLA height evaluation[3,4,10]. Mainly, the AI calculation as described by Cavanagh & Rodgers[7] has received considerable attention[3,8,11,12] and it has allowed the classification of MLA as high (≤ 0.21), normal (0.21<AI<0.26) or low (IA ≥ 0.26), corresponding to cavus, normal or flat foot, respectively. However, as the authors' sample referred to the North-American population, some questions remained unanswered. Could we compare our population to that of the authors? Would the AI reference values be identical or different?

The present study provides the AI reference values in a sample of the Brazilian population. One hundred footprints (50% males, 50% females) were assessed, whereas Cavanagh & Rodgers [7] assessed 107 footprints.

The footprint technique was chosen because it is a non-invasive, easily applied and low-cost procedure. The chosen footprint assessment method was the AI[7], which had the calculation of the plantar areas as the biggest pitfall, as they are irregular. To overcome this difficulty, the computational analysis of the forefoot, midfoot and rearfoot footprint was performed. Except for this calculation, the fundamentals of the Cavanagh & Rodgers[7] method were followed. The computational analysis simplified the AI calculation and the program can be obtained upon request by contacting one of the authors (FRSP).

The present study showed no statistically significant difference (p=9.5%) between the AI means of right and left feet, suggesting a homogeneity between the feet. A statistically significant difference was found when the AI means of the males were compared to those of the female individuals.

Gilmour & Burns[3], assessing the AI of 272 children, found a statistically significant difference between the right and left feet. However, the authors considered the fact devoid of clinical significance.

When comparing the AI means of the present study and the values of the Cavanagh & Rodgers[7] sample, there was no statistically significant difference (p=87.99%) between them. Therefore, the values obtained in the Brazilian sample did not differ from those in the North-American population.

Wearing et al.[11] suggested that the assessment techniques of footprints such as AI should be interpreted carefully, particularly in people with large amounts of body fat, the so-called fat mass. Gilmour & Burns[3] postulated that obesity can increase the foot soft tissue and thus, increase the contact area of the footprint as a whole. In the present study, obese individuals were excluded through a qualitative phenotypical evaluation.

It was not possible to verify the development of MLA as the age of the patients was above that of arch development. Volpon[10] and Forriol & Pascual[13] verified that the development of MLA occurred during infancy, with the higher modifications taking place between the second and sixth years, with a tendency towards stabilization by 7 years of age. The youngest subject in our sample was 10 years.

CONCLUSION

The reference values of the AI in a sample of the Brazilian population was 0.21< AI< 0.25. The normal values of the AI in a sample of the Brazilian population were comparable to those observed in the North-American population, as seen in the study by Cavanagh & Rodgers[7].

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