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Original Article

# Classification of foot type from podography: correlation of results between six quantitative assessment methods

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## Abstract

**Objective:** Apply the different methods available in the literature to classify a sample of podography and evaluate the level of agreement between the results.

**Methods:** Six quantitative and one qualitative method to classify foot type from podography were recorded on 30 feet. The podography indexes were calculated, and the level of agreement between methods was explored.

**Results:** Correlation values were above r = 0.84 except for the test arch footprint angle. The highest correlation values were found between the truncated arch index and footprint index (0.99), arch index and footprint index (-0.94), and arch index and truncated arch index (-0.94), and the lowest was the arch footprint angle with the other parameters. However, there was a difference in the classification between the foot types, indicating a lack of agreement of thresholds between foot types. Qualitative visual inspection was the faster method to classify foot type.

**Conclusion:** The visual inspection was the fastest test to apply, followed by the quantitative arch footprint angle test. High correlation values were found between tests, especially the arch index and the footprint index, arch-length index, truncated arch index, and Chippaux-Smirak index tests.

**Level of Evidence IV; Therapeutic Studies; Case Series.**

**Keywords:** Evaluation; Foot; Podography.

## Introduction

Feet are the base of support to the human body, allowing functional tasks such as standing, gait, and running[1]. Foot alignment can be classified as normal, flat, or high-arch[2]. Misalignments of the foot in stance position or during movement can overload interrelated muscles and joints, increasing the risk of injuries[3]. Evidence has shown high correlations between flat and high-arch foot with stress fractures[4]. Flat foot is associated with a greater number of injuries reported in midfoot and knee in a cadet population[5]. Another study found that runners with high-arched foot present a greater incidence of ankle and bone injuries and injuries on the lateral anatomical structures of lower limbs[6]; runners with low-arched foot are more likely to develop soft tissue injuries on the medial side of the lower extremity, and knee pain[7].

Foot alignment classification can be performed by qualitative techniques, such as visual inspection (VI), or quantitative

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methods using baropodometry[8] or podography[9]. Visual inspection is a method to assess the arch and foot alignment and is widely used by physicians; however, their classification is subjective and has high inter-rater variability[10]. Regarding quantitative methods, podographs are low-cost and easier to apply compared to baropodometry[11]; podography has lower variability than VI[12]. The interpretation of podography can be based on different methods, such as VI, arch index (AI), arch footprint angle (AFA), footprint index (FI), arch-length index (ALI), truncated arch index (TAI), and Chippaux-Smirak index (CSI)[12-17]. However, each technique uses different parameters to classify foot posture, and some do not present cut-off thresholds between classifications. Furthermore, the parameters used to classify the foot for each podography method are different[12-17]; it is important to clarify whether the agreement between techniques is satisfactory to allow physicians to use their preferred choice. Thus, the objective of this study is to compare the efficiency of different parameters used in the literature to classify foot types from podographic images and determine the levels of agreement between them.

## Methods

A sample of 15 volunteers (11 women and four men) was recruited by convenience through posters fixed at the university physiotherapy clinic. Both feet were assessed, giving a sample of 30 feet. The inclusion criteria of the volunteers were: A) age between 18-25 years, B) capability of staying in a uni-pedal stance, and C) ability to walk without assistance. Exclusion criteria were: A) existing foot deformities or amputations, B) pain in the lower limb during stance, and C) balance deficit or postural instability when in a uni-pedal stance.

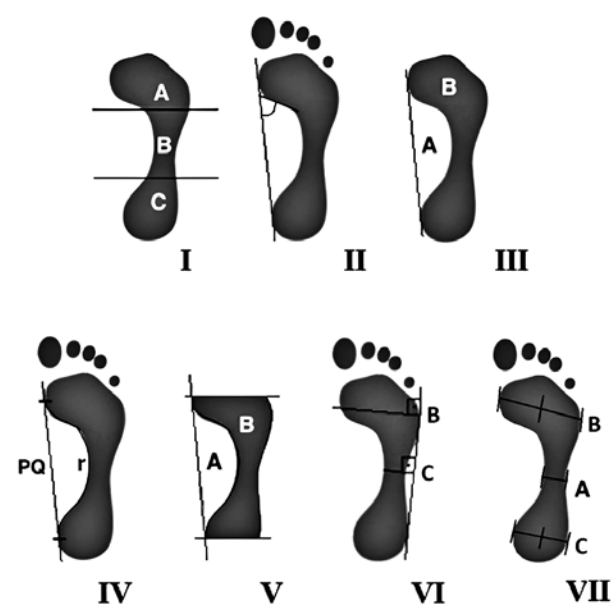
Podography was obtained using an APEX Harris Mat Set (Apex Foot Products Corporation, Englewood, NJ, USA). This instrument consists of two rectangular plastic plates mediated by textured rubber. To obtain a podography with homogeneous color, an equivalent smooth rubber replaced the textured rubber. A Deskjet 2050 scanner (Hewlett-Packard Development Company, LP, Hanover Street, California, CA, USA) was used to digitalize the podography. In addition, a universal goniometer (Carci, São Paulo, SP, Brazil) was used to measure angles for the AFA test.

The study was approved by the Human Research Ethics Committee at UFVJM, and informed consent was obtained from all participants. Demographic data collected were age, gender, body mass index (BMI), height, shoe size, history of foot and ankle injuries, level of physical activity, and limb dominance. After preparing the foot printer with a layer of black ink, a white paper was positioned inside the mat, and the volunteer was asked to keep one foot centralized on the APEX Harris Mat Set. Then, the volunteer was asked to elevate the opposite foot and sustain a uni-pedal position for 30 seconds. Subsequently, the podography was re-inked, and the same procedure was undertaken with the contralateral leg. During the test, the examiner ensured the knee alignment remained in a neutral position. Volunteers were allowed to rest their hands on a table to maintain stability during a uni-pedal stance.

The same researcher, previously trained, obtained and analyzed all podography. Podography order was randomized before applying qualitative and quantitative tests, described below, to classify the foot as flat, neutral, or high-arched. In addition, podographies were scanned with a resolution of 200 dots per inch and transferred to software developed in MatLab (MathWorks, Massachusetts, MA, USA). This software calculates the number of black and white pixels inside the scanned image and the foot area (Figure 1).

The podography was divided into three equal sections, proportional to the length of the foot, by two parallel lines excluding the toes to calculate the AI. Then, the printed area of each section was calculated, and the index was calculated as the ratio between the midfoot area B and the area of the whole foot (A + B + C), as shown in Figure 1(I).

The AFA was calculated from the intersection of two lines; the first was a line connecting the prominent points of the calcaneus and the first metatarsal. The second line was drawn towards the concavity of the foot arch following the medial foot border. The angle between the two lines was obtained by a goniometer, as shown in Figure 1(II). The FI was calculated by the formula A/B, where A was the arch area, delimited by the medial line connecting the most prominent point in the




Arch index = B/(A+B+C); (II) Arch footprint angle; (III) Footprint index = A/B; (IV) Arch-length index = PQ/r; (V) Truncated arch index = A/B; (VI) Chippaux-Smirak index = C/B; (VII) Visual inspection = A≥½ of B or A≤½ of C.

**Figure 1.** Methods to access podography.

medial aspect of the forefoot and the rearfoot, and B was the area of the toeless podography as shown in Figure 1(III).

To calculate the ALI, the length of a medial line (PQ), which starts at the most prominent point on the medial aspect of the forefoot and ends at the most prominent point on the medial aspect of the rearfoot, was measured. The length of the "r" line was obtained starting from the same point defined on the forefoot, following the contour of the arch, and ending at the same medial point on the rearfoot. The ALI was obtained by calculating the ratio of the length of the medial line and the arc length (PQ/r), as shown in Figure 1(IV).

The TAI was calculated as the FI; however, the foot area (B) was limited to the truncated area. The truncated area is restricted between two horizontal lines through the most medial points of the metatarsal and the heel region, as shown in Figure 1(V) and defined as detailed in the ALI test.

The CSI was drawn as a lateral line connecting the prominent points of the calcaneus and the fifth metatarsal. In addition, two perpendicular lines with a 90º angle to the lateral line were drawn in the podography. One line in the wider zone of the forefoot (B) and another line in the narrower zone of the midfoot (C). The result was obtained by calculating C/B as shown in Figure 1(VI).

Visual inspection of podographs was performed according to the criteria presented by Viladot (1987). According to the Viladot method (Figure 1(VII)), the flat foot is present when the midfoot width is equal to or greater than half the width of the forefoot. High-arched foot is present when the width of the midfoot impression is equal to or less than half of the rearfoot or not visible. Podography not classified as flat or high-arched foot was considered neutral[18].

## Data analysis

Data analysis was performed using SPSS version 11.0 (SPSS Inc. Chicago, IL, USA). Initially, the normality of the variables was tested using the Shapiro-Wilk test. The quantitative scores tests were analyzed using Spearman's correlation coefficient, considering a significance level of 5%.

## Results

Eleven women and four men were recruited, and the mean age was 23 years (SD = 2.7). According to their BMI, ten participants were classified as normal, two as pre-obese, one as mild thinness, one as moderate thinness, and one as severe thinness. Regarding regular physical activity, ten were physically inactive, while five stated to practice exercise.

Table 1 describes the frequency of different foot categories when using VI, AI, AFA, and CSI. Categorization among the four tests was not similar. The AFA test categorized the sample into the high-arch classification. Conversely, the CSI categorized most of the sample as neutral and flat arched foot.

Table 2 shows the results of Spearman's correlation coefficient among the six different categorization methods. Correlation values were above r = 0.84 except for the AFA test. The highest correlation values were found between TAI and FI (0.99), AI and FI (-0.94), and AI and TAI (-0.94), and the lowest was the AFA with the other parameters.

Table 3 shows the mean time taken to classify individuals' feet using different methods. The VI was the quickest method compared to all other approaches.

**Table 1.** Feet categorization according to the different indexes

| | High-arch (n) | High-arch (%) | Neutral (n) | Neutral (%) | Flat arch (n) | Flat arch (%) |
|---|---|---|---|---|---|---|
| Visual inspection | 9 | 30% | 12 | 40% | 9 | 30% |
| Arch index | 15 | 50% | 11 | 37% | 4 | 13% |
| Arch footprint angle | 27 | 90% | 2 | 7% | 1 | 3% |
| Chippaux-Smirak index | 1 | 3% | 16 | 53% | 13 | 44% |

**Table 2.** Spearman's correlation coefficient among six different scores

| | AI | FI | ALI | TAI | AFA | CSI |
|---|---|---|---|---|---|---|
| AI | 1.0000 | | | | | |
| FI | - 0.9431 | 1.0000 | | | | |
| ALI | 0.8413 | - 0.8853 | 1.0000 | | | |
| TAI | - 0.9400 | 0.9933 | - 0.8780 | 1.0000 | | |
| AFA | - 0.4883 | 0.5469 | - 0.6276 | 0.5218 | 1.0000 | |
| CSI | 0.8836 | - 0.7751 | 0.6703 | - 0.7794 | - 0.3844 | 1.0000 |

AI: Arch index; FI: Footprint index; ALI: Arch-length index; TAI: Truncated arch index; AFA: Arch footprint angle; CSI: Chippaux-Smirak Index.

**Table 3.** Mean time taken in seconds for feet classification using different methods

| VI | AI | AFA | FI | ALI | TAI | CSI |
|---|---|---|---|---|---|---|
| 1.03 | 646 | 19 | 814 | 52 | 832 | 33 |

VI: Visual inspection; AI: Arch index; AFA: Arch footprint angle; FI: Footprint index; ALI: Arch-length index; TAI: Truncated arch index; CSI: Chippaux-Smirak index.

## Discussion

The aim of our study was to assess the agreement between different methods to classify a sample of podography. The hypothesis was that the quantitative tests would show high correlation scores; therefore, regardless of the method used by physicians, patients would be categorized under the same group. Moreover, because the time taken to perform each test was recorded, it would be possible to show which test is faster to use, although producing similar results.

Many different methods for podography assessment are available in the literature; however, many have been published before 1987, making access to the full text challenging[12,13,19-24]. In addition, many methods have been adapted and do not follow the original procedure, which can be misleading and result in systematic errors[25-27].

The findings of this study demonstrated that the quantitative and qualitative methods might not classify the podography under the same category. According to Forriol and Pascual[17], the classification is sensitive to the method used. Moreover, the cut-off points differed, which may be the main reason for the low correlation scores[21]. Another important point is that because of soft tissue malleability, feet with similar structural shapes can have different podography[25]. According to Razeghi and Batt[28], quantitative methods are discouraged when assessing high-arch feet because of the medial area discontinuity.

The different quantitative indexes can be categorized as those that use total area, angle values, or length measurements in their formula. These methods require additional time to perform the calculations needed for final results. As shown in Table 3, the VI, which does not need extra time, was the quickest way to assess the foot. However, the results from VI may vary according to the assessor's experience, making their results less reliable than more systematic methods[24]. However, Dahle et al.[21] demonstrated that experienced physiotherapists have high agreement rates while using VI.

One way of improving VI reliability could be by using more systematic methods, which in this study was the criteria proposed by Viladot[18]. Xiong et al.[22] demonstrated a high correlation between AI and VI. Therefore, in the clinical setting, the VI is of great value as it is quick and does not require any equipment, which may not always be available in the clinical setting.

After VI, the methods that used the angle or length of the podography were those that required less time to classify the podography. Among them, the AFA was the quickest. These tests require only drawing lines dividing the podography into areas. They are measured in millimeters with a simple ruler, or in the case of angles, lines are traced and then measured with a goniometer. However, the ALI does not have cut-off points, which are only available for the AFA and the CSI in this category of tests.

Regarding AFA and the CSI, a recent study demonstrated the advantage of a 5-level stratification system (high, normal, intermediary, lowered, and flat medial longitudinal arch). However, Sacco et al.[27] study, comparing the AI, CSI, and AFA, demonstrated that only the AI and the CSI are reliable for anthropometric assessment as the AFA showed strong disagreement with the other indexes.

The tests using the area for podography classification were more time-consuming. The AI is the most commonly described in the literature and was the fastest among the indexes in this group[29,30]. The extra time needed for this index is due to the additional steps, such as digital processing of the image or other equipment, such as planimeters, to obtain the figure area.

Only the AI has cut-off points established among the three methods in the group of indexes using area for classification. Therefore, although the FI and the TAI have similar scores to the AI, it is not possible to determine if the same cut-point from the AI can be used for the other two[31-33].

Regarding the correlation scores, the high correlation scores among tests found were opposite to Hawes et al.[17], where the authors performed a regression analysis in relation to the plantar arch height with five different podography indexes: AFA, FI, AI, ALI, and TAI. In our findings, most of the correlation scores were over 0.84 with the AI, which may suggest that the cut-off points from this index can potentially be adopted for the others, but more studies are needed. The test with the lowest correlation values was the ALI; however, because it was the one with the shortest time needed, it might also be useful in a clinical setting as it has cut-off points that enable the classification of flat, normal, or high-arched foot.

## Conclusion

The visual inspection was the fastest test to apply, followed by the quantitative arch footprint angle test. High correlation values were found between tests, especially the arch index and the footprint index, arch-length index, truncated arch index, and Chippaux-Smirak index tests.

**Authors' contributions:** Each author contributed individually and significantly to the development of this article: RGTF *(https://orcid.org/0000-0001-6118-1181) Data collection and clinical examination; TCP *(https://orcid.org/0000-0002-5245-1298) Survey of the medical records and data collection; ACB *(https://orcid.org/0000-0003-3670-3616) Participated in the review process, formatting of the article and approved the final version; NLMR *(https://orcid.org/0000-0003-1981-8606) Bibliographic review and formatting of the article; BFM *(https://orcid.org/0000-0003-1566-9551) Interpreted the results of the study and statistical analysis; JR *(https://orcid.org/0000-0002-4004-3115) Conceived and planned the activities that led to the study and approved the final version. All authors read and approved the final manuscript.*ORCID (Open Researcher and Contributor ID) iD.

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