



An Analysis of Arches of Foot: A Comparison between Ink Foot Print Method and Custom Made Podoscope Device Method

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present study aimed to assess the validity of the podoscopic images compared with ink footprint methods (comparing the two different methods using the same parameters). Objective: The evaluation of the reliability and accuracy of arch angle (AA) is the purpose of this paper's study. It includes Chippaux-Smirak Index (CSI), Staheli Index (SI), and Arch Index (AI) by comparing footprints obtained from ink footprint and custom-made podoscopic footprints. Methods: Measurements of AA, CSI, SI, and AI are obtained from ink footprints and custom-made podoscope among 416 healthy participants (aged 21 to 65). Accuracy and reliability were calculated for all the footprint indices obtained using the two methods. Minimal detectable change and the Standard error (SE) of measurement were also calculated. Results: SPSS Statistical software (version 20) at 95% confidence interval was used to execute and observe the statistical analysis. Descriptive analysis was used to calculate the Mean and standard deviations (SD). The intrarater reliability of ink footprints and podoscopic footprints were analyzed using Intraclass

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correlation (IC) executed at 95% confidence intervals (CIs). Reliability of the podoscopic method was interpreted when the values (≥ 0.75) as excellent, (0.4-0.74) as moderate, and (0-0.39) as poor. Our study reported that AA, CSI, SI, and AI obtained from the ink footprints and podoscope had high intrarater reliability and reproducible. The podoscope was designed in a lightweight manner for transportation purposes and utilized in under-served and rural areas. This custom-made device may be utilized in orthopedics, and it can also be used to collect data and for diagnostic purposes.

Keywords: Custom-made podoscope; pesplanus; pescavus; intrarater; intraclass; arches of the foot

1. INTRODUCTION

The paper aims to assess the validity of the podoscopic images compared with ink footprint methods (comparing the two different methods using the same parameters). The foot is mechanically strong and complex among the body parts, strengthened by tarsal & metatarsal bones that are supported by ligaments & tendons in the foot [1]. Ink footprint parameters are quick and cost-effective, but repeated measurement makes significant errors and makes the footprints messy, and the ink also remains in the foot for 3-4 days [2]. The podoscopic images are obtained for the diagnosis of different types of arches of the foot.

The study of the foot dimensions and Medial Longitudinal Arch (MLA) structure among 30 participants by using the mirror foot photo box using Intraclass Correlation (IC) between the dimensions and digital measurements.

The greater values in ink footprints are compared with podoscopic images; this is due to the spread of excessive ink over the footprints that showed a greater value. The difference between the foot anthropometric measurement and footprint by using the 3D model of ankle and foot reported that the scanner showed accurate values and reduced the measurement duration.

2. LITERATURE SURVEY

Among the body parts, the foot is mechanically strong and complex, strengthened by the tarsal and metatarsal bones, supported by ligaments and tendons in the foot [1]. The Ink footprint parameters are quick and cost-effective, but repeated measurement makes significant errors and makes the footprints messy, and the ink also remains in the foot for 3-4 days [2]. This paper study compares the ink footprints, anthropometric measurements, and digitalized methods among 1002 participants using footprint indices such as Chippaux-smirak index, Clarke's

angle, and Staheli index reported that ink footprint method is not much clear when compared with digitalized method [3].

The study of the foot arches with the obesity among 50 Bharatanatyam dancers using a self-designed scanner device reported that the images obtained from the scanner device are taken. It took a short period for the measurements [4]. The above studies show that the footprint index is the standard tool for measuring the foot's arches' integrity, but with some of the major drawbacks such as exposure to radiation, expensive, and expertise to operate the device.

The foot is the terminal part of the lower extremities that promotes locomotion. Arches are the specialized structure present in the foot, which acts as a shock absorber and a lever to propel the body forwards. MLA, Transverse Arch (TA), and Lateral Longitudinal Arch (LLA) are the three types of arches present in the foot. The LLA is lower than the MLA, and during the weight-bearing, the MLA acts like a spring [5].

A flat-arched foot or Pes Planus is in a condition that MLA will be completely or partially collapsed, and the foot's plantar surface comes in contact with the ground [6]. High arch foot or Pes cavus is the condition in which the height of MLA increases [7]. In Pes cavus, an excessive amount of stress is placed on the foot's heel and ball during standing, walking, or running [8]. Foot morphology and foot morphometry were used to identify certain factors such as age, gender, Body Mass Index (BMI), environmental conditions, and the race to which the individual belongs [9]. These existing assessment methods also have major drawbacks. For example, the subject has to be exposed to x-rays in the radiograph method, 3-D foot scanning is quite expensive, but the ink footprint method is considered an effective and cheaper method [10].

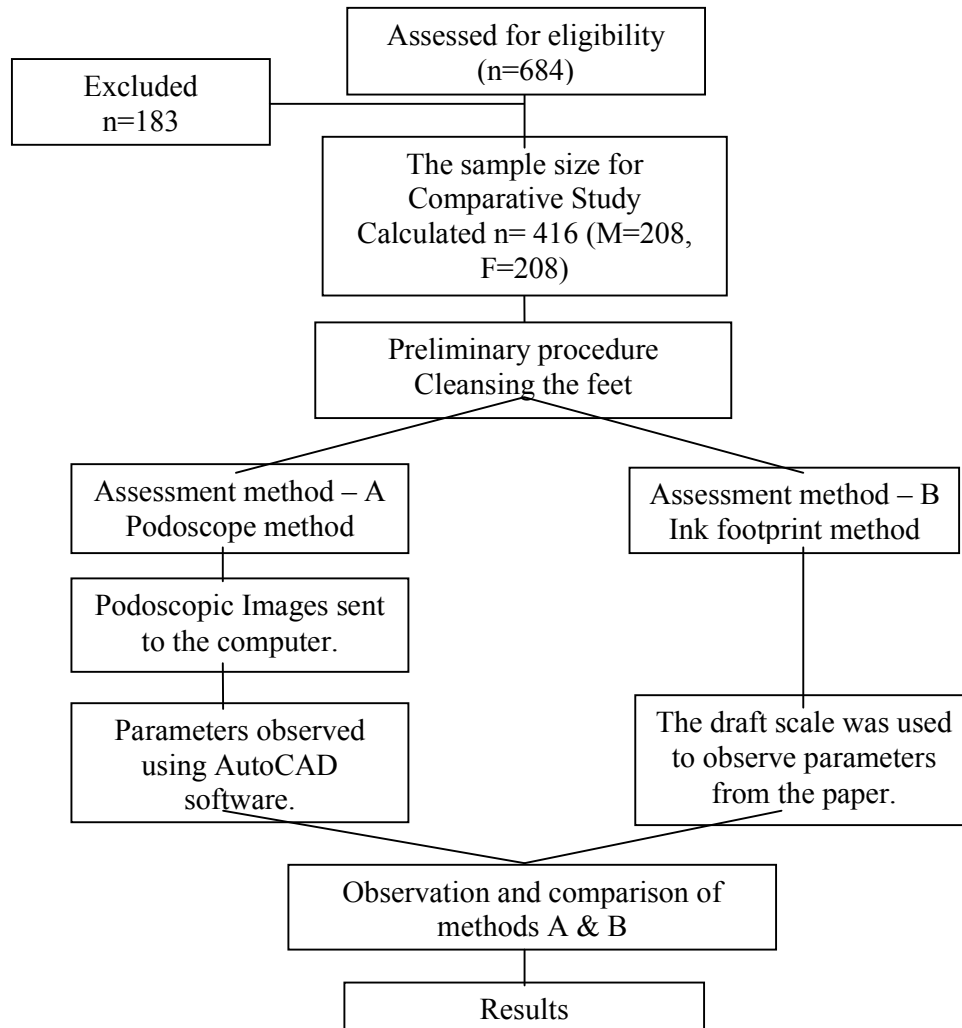


Fig. 1. Work plan flow chart

Knowledge of foot anthropometrics is very important in the field of the footwear industry [11]. The Foot shape and the measurements of the arch structure may vary between is one person to another. Therefore, different foot types have to be considered while designing and manufacturing the shoes [12]. The custom-made and high - quality health observation shall use the new technologies such as mobile system with the cloud computing system [13].

Clinical assessment, radiography, magnetic resonance imaging, 3-D foot scanning device, and ink footprint methods are some of the classical methods to quantify the foot's arches [14]. To address these issues and fill the cavities, the study aimed to develop a low-cost custom-

made portable podoscopic device [15]. The reliability was standardized by comparing the podoscopic method with the standard ink footprint method [16].

3. METHODOLOGY

For this comparative study, a total number of 416 healthy volunteers (208 men and 208 women) aged between 21 to 65 were included. Subjects with neurological conditions, orthopedic conditions like surgery, fracture (within six months), any ulcers or open wounds in the lower extremity were excluded.

All the subjects' foot was first cleansed with water and mild soap and then wiped thoroughly

using the towel, for podoscopic method and ink footprint method assessment as shown as work plan flow chart in Fig. 1.

3.1 Assessment Method A –Podoscope

The podoscope for this study was custom-made with unbreakable toughened glass, wood, and a document scanner. Each participant was instructed to stand over the podoscopic device in erect posture facing forwards; for familiarization, few trials were performed. Then, the images obtained from the podoscope were transferred to the computer. The image calibration technique was performed to measure the parameters using AutoCAD software.

3.2 Assessment Method B – Ink footprint

After the podoscopic method, the subjects are advised to stand over the custom-made ink pad made with a sponge and non-irritant ink. Then the subjects were instructed to stamp their footprint on the 700 cm length x 70 cm breadth of paper. For better impregnation, two to three sets of footprints were taken from each participant. Glossy transparent sheets and draft scale and was used for measuring parameters from the ink footprints.

3.3 Measurements

The footprints obtained from Method A and Method B were measured using these parameters.

Arch angle (AA): The angle formed by joining the Anatomical points of (a, b) as shown in Fig. 2.

Chippaux-Smirak Index (CSI): CSI was calculated by dividing the minimal midfoot width (d) from the maximal forefoot width (c).

$CSI = (c/d)$ as shown in Fig. 2. Taheli Index (SI): was calculated by dividing the minimal midfoot width (d) with the widest rear foot width (e) region.

$SI = (e/f)$ as shown in Fig. 2.

Arch index (AI): was calculated by dividing the toes into three equal parts (a, b, c), excluding the toes. The AI is then obtained as the entire footprint area is divided into the third middle footprint.

$AI = b/a + b + c.$

The measurement of footprint is indicted AA, CSI, SI in ink footprint method and podoscopic method in a normal arched foot.

Fig. 3 shows the footprint index AI's measurement in ink footprint method and podoscopic method normal arched foot.

4. RESULTS

SPSS (version20) software executed at 95% (CI) Confidence interval was used to observe the statistics. Descriptive statistic was used to observe the Mean and standard deviations (SD), as shown in Table 1. The distribution of Normal, Pesplanus, and Pescavus by both ink footprint and podoscopic method was shown in Table 2. The intrarater reliability of ink footprints and podoscopic images was observed by intraclass correlation (IC), executed at 95% confidence intervals (CI), as shown in Table 3. The interpretation of reliability was considered (≥ 0.75) as excellent, (0.4-0.74) as moderate, and (0-0.39) as poor. The measurement errors of both ink and podoscopic methods were expressed as standard errors (SE) in Table 3. The PPV and NPV are observed using standard logit confidence intervals. Accuracy, sensitivity, and specificity were observed using Clopper-Pearson confidence intervals as shown in Table 4.

5. DISCUSSION

In this research analysis, among 416 participants (208 men and 208 women), normal arch foot, pescavus (PC) and pesplanus (PP) have been identified as shown in Fig. 3, Fig. 4, and Fig. 5, respectively. The present study's goal was to observe the self-designed podoscope's ability to evaluate the foot's arches by comparing them with the ink footprint method. The major findings were that the podoscopic images are very clear and took a short period. Hence, it was easy to observe the normal and abnormal arches compared to the ink footprint method.

The validity of obtained podoscopic images is compared with ink footprint methods (comparing the two different methods using the same parameters). Our study results show that the podoscopic images obtained are suitable for diagnosing different foot arches.

The study of the foot dimensions and MLA structure among 30 participants by using the mirror foot photo box and observed good

intrarater reliability (> 0.800) using intraclass correlation (IC) between the dimensions and digital measurements. Similarly, in the

present study, both the ink and podoscopic methods showed excellent interpreter reliability (>0.9).

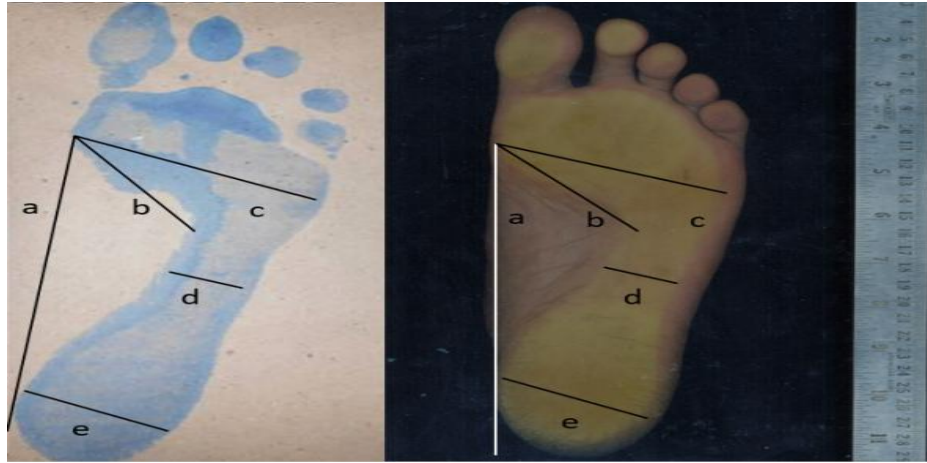


Fig. 2. Footprint index AI's

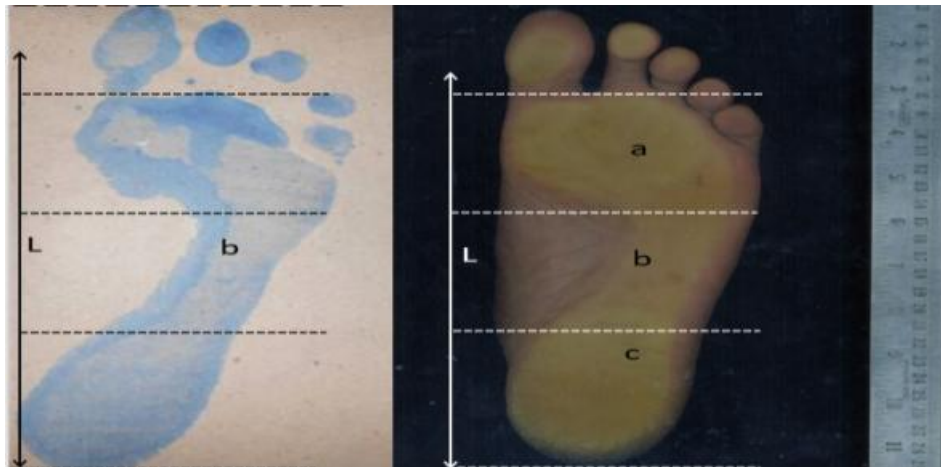


Fig. 3. Ink footprint

Table 1. The characteristics of subjects mean (SD) n=416

Gender	Age mean (SD)	Height mean (SD)	Weight mean (SD)
Males	36.8(8.9)	177(3.8)	81.4(7.4)
Females	38.4(6.8)	162(3.9)	65.4(8.1)

Table 2. Distribution of different types of arches of foot determined using both ink footprint method and scanner device method (n=416)

Variables	Ink footprint method		Scanner method	
	M	F	M	F
Normal Arch	63.30%	54.60%	58.00%	53.50%
High Arch	16.55%	17.80%	19.50%	18.50%
Flat Arch	20.15%	27.60%	22.50%	28.00%

Table 3. Standard deviation (SD), intraclass correlation(IC), standard error (SE), IC - p >0.01

Parameters	Ink footprint			Scanner footprint			95% C.I
	Mean (SD)	IC	SE	Mean± SD	IC	SE	
AA	43.3(3.2)	0.98	0.89	42.1(3.6)	0.98	1.74	0.71-0.69
CI	35.7(1.9)	0.97	0.18	34.3(3.8)	0.96	1.29	0.66-0.79
SI	0.95(0.04)	0.99	0.13	0.78(0.04)	0.95	1.38	0.66-0.68
AI	0.24(0.12)	0.98	0.16	0.23(0.17)	0.99	1.07	0.68-0.87

Table 4. The positive predicted value (PPV), negative predicted value (NPV)

Statistics	Values	Confidence interval 95% CI
PPV	91.73%	86.48% - 95.32%
NPV	100%	100%
Accuracy	96.50%	95.80% - 98.87%
Sensitivity	100%	98.14% - 100%
Specificity	94.68%	93.43% - 98.66%

The evaluation of the sensitive platform's footprint accuracy is compared with ink footprints and reported that the AI showed greater values in the ink footprints. Similarly, the present study also observed greater values in ink footprints when compared with podoscopic images; this is due to the spread of excessive ink over the footprints that showed greater values. The difference between foot anthropometric measurement and footprint by using a 3D model of ankle and foot reported that the scanner showed accurate values and reduced the measurement duration. Compared with the present study with the previous one, our study showed excellent reliability of ≥ 0.75 in the podoscopic method compared with the ink footprint method, as shown in Table 3. Hoffman stated that a clinical test with 90% specificity and sensitivity could have a good diagnostic value. The present study reported 100% sensitivity 94.68% specificity with 96.50% of accuracy. The podoscopic method doesn't show any (-ve as +ve) abnormal as normal too, but to a certain extent, it has shown some (+ve as -ve) normal as abnormal; therefore, our PPV was 91.73%, and NPV was 100% as shown in Table 4.

- Ink Footprint method versus custom-made Podoscope method.
- Fig. 4 shows the difference between the ink footprint and podoscopic footprint in the Pescavus foot.
- The mid-foot width marked with a red-colored line shows an exaggerated ink footprint.
- Visibility of the toes was observed in podoscopic images.
- The clarity of the image is very clear in podoscopic images when compared with ink footprint.
- In Fig. 5, the difference between the ink footprint and podoscopic footprint are in Pesplanus foot.
- The width of the midfoot is underestimated in the ink footprint shown in the red-colored line.
- Some uncovered area is seen in the midfoot area of the ink footprint.
- Only in podoscopic images, excessive pressure is visible below the great toe, medial aspect of the whole foot region, and the heel region.



Fig. 4. Ink footprint



Fig. 5. Podoscopic footprint

The accuracy of the podoscope was greater than the ink footprint, and maybe due to some errors present in the ink footprint method like, it may not stick properly over the plantar surface, poor absorption or excessive absorption of ink in the paper, and manual errors when measuring the parameters from the ink footprints. The podoscopic method identifies the foot's outer border very sharp and clear, and it scans the overall plantar surface, thus providing a high quality of the plantar surface image. Thus, the podoscopic images are obtained in high-resolution images and measured using standard and valid AutoCAD software. Moreover, the ink footprints' accuracy was lost when there are more than 3 or 4 trial measurements. It makes the footprint darker, impregnating or impregnating additional areas with the footprint's blunt edges becomes difficult for measurement.

6. CONCLUSION

This study reported that the observed parameters AA, CSI, SI, and AI using the ink footprints method and custom-made podoscopic method showed high intrarater reliability. The images obtained are reproducible and can be stored as a soft copy. The podoscope method exhibited higher precision and accuracy for analyzing the arches of the foot. The advantages of using the podoscope device to observe the foot's arches took a shorter period and had a higher efficiency for assessing the larger number of samples. The podoscopic images can be stored as data and can be used for assessment. The foot dimensions of 130 subjects using 3D foot scanner and described that 3D foot scanner method is an accurate method to analyze the foot dimensions (30). That study also reported that the installation of the scanner is more expensive, the dimensions of the 3D foot scanner are 68.5cmL x 40cmW x 31cmH, and it is not portable. When compared our study with Lee Y, the present study had developed a self-designed podoscope in a very cost-effective manner, the size of our podoscope was 52cmL x 38cmW x 8cmH, and a single person can carry the device in a portable manner.

Classification of the normal arch foot, pes planus, and pes cavus is done using both methods. The images obtained from the podoscope are very clear and took very little time for the assessment when compared ink footprints method. The podoscope was designed like a portable device; hence it can be carried easily or transported by a single person for assessment purposes. The

information obtained from the podoscope will be useful in orthopedics and can be used to diagnose in under-served rural areas without any cost.

CONSENT AND ETHICAL APPROVAL

Formally obtained from the consent patients and the study were approved by the Institutional Research Ethics Committee (IREC) of Sri Ramachandra Institute for Higher Education and Research and Symbiosis Medical College for Women, Symbiosis International (Deemed) University, Pune.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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