International Journal of Science and Research Archive

eISSN: 2582-8185 CODEN (USA): IJSRO2

Cross Ref DOI: 10.30574/ijsra

Journal homepage: https://ijsra.net/

Reliability of photographic method and its comparison with foot arch parametric method for assessment of arch width, arch height and arch index

Saloni Mor *, Rajashree Naik

Department of Physiotherapy Teaching and Treatment Centre, Lokmanya Tilak Municipal Medical College, Sion, Mumbai.

International Journal of Science and Research Archive, 2025, 14(03), 1191-1199

Publication history: Received on 07 February 2025; revised on 20 March 2025; accepted on 22 March 2025

Article DOI: https://doi.org/10.30574/ijsra.2025.14.3.0822

Abstract

Assessing foot arches is essential for comprehending foot biomechanics, detecting irregularities, and creating suitable footwear. Conventional techniques for assessing foot arch parameters, including arch height, arch width, and arch index, depend on manual footprint analysis, which is susceptible to measurement inaccuracies and variability. This study sought to analyze the reliability of a photographic technique for evaluating foot arch and to compare it with the traditional parametric method for foot arch assessment. A total of 108 people aged 18 to 30 years, with a BMI range of 18.5 to 22.9, were evaluated using both methodologies. The photography technique entailed collecting photos of feet on a transparent footplate including a grid structure, whereas the traditional method employed hand footprint impressions. Bland-Altman analysis was conducted to evaluate the concordance between the two methodologies. The results indicated that the photographic method yielded measures closely aligned with those derived from the conventional method, with no statistically significant variations in arch height, arch width, and arch index ($p > 0.05$). Moreover, the photographic technique demonstrated efficacy in identifying foot arch anomalies, including pes planus and pes cavus, at early stages with subtle measurement variations. The photographic method shown benefits including less human error, enhanced accuracy, and user-friendliness. Moreover, its digital format facilitates efficient data storage and analysis. The study affirms the reliability of the photographic method; nonetheless, additional research on varied populations is advised to establish its wider application. The results indicate that this technique is a viable, non-invasive option for evaluating foot arches in clinical and research environments.

Keywords: Foot arch assessment; Arch height; Arch width; Arch index; Photographic method; Conventional method; Bland-Altman analysis; Biomechanics; Footprint analysis; Measurement reliability

1. Introduction

In order to bear weight, the foot's arches are crucial. A person's entire body weight is distributed among the bones of their foot via the arches. Arch Index, Arch Width, and Arch Height are the three foot measurements that distinguish healthy individuals from those with abnormalities. The foot-arch prevents damage to the foot and allows for a highly natural and attractive gait since it supports the body's weight and provides propulsive force during push-off. It's common knowledge that reducing area pressure, relieving impact force, and improving shoe comfort can be achieved by filling the space between the foot-arch and the shoe. [1,2] The geometric shape of the foot and arch can be better understood for therapeutic and clinical purposes.[3]

A shoe's Arch Index can be calculated by dividing the footprint's midfoot area by the footprint's total area (toes included) [4]. Both the arch width and arch height are measured in relation to the medial border line, which connects the most medial border of the metatarsal and heel regions of the foot. This line is located at the midline of the foot [5][6]. Traditional methods rely on these definitions to manually measure these values with the use of footprints on grid paper."

* Corresponding author: Saloni Mor

The accuracy of the foot parameters depends on clarity of the foot impressions and the skill of individual who is assessing. Thus, to overcome this problem we aimed to develop a more advanced technique for calculation of arches of foot with the help of web / phone camera. In a static standing position, the proposed system takes color and 3D geometry data of the foot's plantar surface using a camera placed beneath a transparent footplate that is affixed with transparent grid paper. The parameters of the foot arch were calculated by referring to the footprint image, which shows the contact area of the foot, and utilizing the foot axis and the MBL. Using 3D geometric and color data obtained from the camera, this study outlines the process for recognizing the foot's contact zone and estimating the foot arch characteristics. It also compares the results to those from more traditional approaches and determines how reliable the estimated foot arch characteristics are.

1.1. Review of literature

1.1.1. "Lee H, Lee K, Choi T. Development of a low cost foot-scanner for a custom shoe tailoring system. In Symposium on Footwear Biomechanics 2005 Jul."

In this study several PC cameras are used instead of expensive CCD cameras. And this system consist new concept called the foot database is introduced. In above both studies 12 cameras were used and 12 images of foot were taken from different view, the system calculates major foot parameter such as foot length, width to scale the foot model. Notably, our scanner eliminates the need for pricey moving mechanisms, emitters (like laser or pattern generators), and specific controllers. They introduce a novel concept of a foot database during the shape acquisition process. This study tested strangely shaped foot models (according to their criteria). The error was +1.5mm of this study and max error allowed was + 3mm. Each parameter difference between two data is less than ±2mm which signifies the correlation of the study.(7)

1.1.2. "Wang J, Saito H, Kimura M, Mochimaru M, Kanade T. Human foot reconstruction from multiple camera images with foot shape database. IEICE TRANSACTIONS on Information and Systems. 2006 May 1; 89(5):1732-42."

The foot models in this study's database have been generated by computations involving morphing and deformation. The study encompassed 397 samples. The proposed method is demonstrated by reconstructing a human foot in a virtual reality environment utilizing computer-generated multi-camera images, as well as replicating the same in the physical world with eight CCD cameras. Compared to the conventional volume intersection method, which produces an error of approximately 4 mm, the research indicated that the reconstructed shape error utilizing the virtual reality environment with CG multi-camera images averages around 2 mm.(8)

1.1.3. "Amstutz E, Teshima T, Kimura M, Mochimaru M, Saito H. PCA based 3D shape reconstruction of human foot using multiple viewpoint cameras. In Computer Vision Systems: 6th International Conference, ICVS 2008 Santorini, Greece, May 12-15, 2008 Proceedings 6 2008 (pp. 161-170). Springer Berlin Heidelberg."

The authors of this piece describe a technique for reconstructing the three-dimensional form of a foot using a network of cameras. An initial three-dimensional model of the foot is constructed using a database of feet and a point cloud. The usage of Principal Component Analysis allowed for the characterization of over 92% of the foot. After that, using "active shape models," the 3D model is adjusted to fit the target foot in a series of pictures. They performed the study on 17 plastic foot model as well as human. In this purposed study 10 cameras were used, and all the cameras were connected to one PC with the help of laser projected system the images were then analyzed for the required data.(9)

1.1.4. "Novak B, Babnik A, Možina J, Jezeršek M. Three-dimensional foot scanning system with a rotational laser-based measuring head. Strojniški vestnik-Journal of Mechanical Engineering. 2014 Nov 15; 60(11):685-93."

In this study the rotational laser-based measuring head was used with 3D foot scanning system. The main aim of the system was to find correct design and the proper fitted shoes. The system work on laser-multiple-line-triangulation principle. System contains two cameras which rotates around the platform and the main part of a system is the measuring head comprising a three laser lines projection unit. On the center of platform individual was made to stand and both the feet were measured simultaneously. 20 samples were taken 10 male and 10 female. Results of the test object repeatability measurement. Plastic feet were measured 10 times with confidence kept on 95%. And it was concluded this system is accurate for the accurate footwear measurement.(10)

1.1.5. "Van den Herrewegen I, Cuppens K, Broeckx M, Barisch-Fritz B, Vander Sloten J, Leardini A, Peeraer L. Dynamic 3D scanning as a markerless method to calculate multi-segment foot kinematics during stance phase: Methodology and first application. Journal of biomechanics. 2014 Aug 22; 47(11):2531-9."

This system uses multi-scanner-system DynaScan4D which has 5 scanner unit which is placed under the glass unit on which foot will be placed. "This study used 4 structured light scanning modules which was used to calculate the foot parameters during walking using the iterative closest point. Purpose of the system was to analyses the static and the dynamic foot situation in various phases of gait." 5 individuals were scanned 6 dynamic scan of each individual were recorded and was analyzed. In validation, this method shows consistent rotation patterns when compared qualitatively with a marker-based model. This user-friendly and effective technique holds potential for enhancing foot analysis in clinical settings.(11)

1.1.6. "Liu S, Cui Y, Sanchez S, Stricker D. Foot scanning and deformation estimation using time of-flight cameras. Footwear Science. 2011 Jun 1; 3(sup1):S98-9."

Two methodologies are proposed for creating a distinctive three-dimensional foot model from two-dimensional data. The method commenced with the creation and amplification of a standard foot shape from pre-existing 2D data. For the primary technique, we employed foot measurements and height; for the alternative, we utilized foot scaling and profile. Forty individuals participated in the model creation and validation processes. "The findings indicate that the initial system can precisely forecast the shape of each foot with a mean absolute error of 1.36 mm for the left foot and 1.37 mm for the right foot, whereas the alternative system achieves a mean absolute error of 1.02 mm for both the left and right feet."(12)

1.2. Need for the study

Calculation of arches of foot is important because it allow us to distinguish the type of foot that is flat foot, pes planus ,pes cavus or normal depending on the main three parameters arch height , arch width and arch index. Any disturbances in arches of foot may lead to biomechanical instability in corresponding joints of the kinematic chain. Arches of foot play a significant role in our day-to-day activities. They distribute the body weight throughout the foot. They also have a role in shock absorption and propulsion of foot while walking. Until now the traditional methods were used to calculate the arches of foot by taking an impression of foot on the graph paper and measurements were largely dependent upon the individual doing it. In this method we are taking the image of foot using a system which includes camera and a glass which is having transparent grid system on it and image of foot was taken with the help of camera. By this method we are aiming at reducing the errors which commonly happen while taking impression of foot on graph paper (conventional method). The technique uses image and analyses the arches of foot with help of transparent grid system which is printed as well as with the image measurement. Online (now image meter) tool which helps us to calculate the required parameters. This online tool is available free of cost.

1.3. Research question

Is Photographic Method for assessment of Foot Arch Parameters reliable and comparable to the foot arch parametric method?

1.4. Hypothesis

- NULL HYPOTHESIS: The new Photographic method will not be reliable as compared to conventional method.
- ALTERNATE HYPOTHESIS: The new Photographic method will be reliable as compared to conventional method

1.5. Aim

To check reliability of Photographic method and to compare it with the conventional Foot Arch Parametric method.

1.6. Objectives

- To compare the Photographic method with the conventional Foot Arch Parametric method.
- To measure Arch height, Arch width, and Arch Index using conventional method.
- To assess same parameters using Photographic method.
- To check the reliability of the Photographic method.

2. Methodology

2.1. Study Design

This study employed a cross-sectional design to assess the reliability of the photographic method compared to the conventional foot arch parametric method. The Bland-Altman method was used for statistical analysis.

2.2. Location of Study

The study was conducted at a tertiary healthcare center.

2.3. Study Population

The participants were normal individuals aged 18-30 years with a BMI range of 18.5-22.9.

2.4. Duration of Study

The study was carried out over eight months.

2.5. Sampling Method

Convenience sampling was employed to select participants.

2.6. Sample Size

The sample size was determined to be 108 using the Bland-Altman method, achieving 90% power with a confidence level of 95%.

2.7. Inclusion Criteria

- Participants aged 18-30 years.
- BMI within the range of 18.5-22.9.

2.8. Exclusion Criteria

Any musculoskeletal or neurological disorders affecting weight-bearing ability.

2.9. Ethical Considerations

Institutional Ethics Committee approval was obtained before commencing the study. Participants provided informed consent before enrollment.

2.10. Data Collection Procedure

2.10.1. Photographic Method

- Participants stood on a transparent toughened glass surface embedded within a specially constructed wooden box.
- A mobile camera positioned inside the box captured images of both feet.
- The medial border line (MBL) was drawn from the first metatarsal head to the calcaneal tuberosity.
- Arch width and height were measured using the Image Meter app, which analyzed the images through color depth mapping.
- Arch index was calculated by segmenting the footprint into three equal parts and computing the ratio of the middle segment to the total footprint area (excluding toes).

2.10.2. Conventional Method

- Participants made an inked impression of their right foot on graph paper.
- Arch width and index were manually measured using a scale and counting the number of painted boxes on the graph paper.
- Arch height was determined using a scale placed at the medial aspect from the floor to the highest point of the arch.

2.10.3. Data Analysis

- The reliability of the photographic method was assessed using Bland-Altman analysis.
- Statistical comparisons were made between the two methods for arch height, width, and index.
- Descriptive statistics were computed, including mean, standard deviation, and confidence intervals.

2.10.4. Results Interpretation

- "The Bland-Altman plots showed that the majority of data points fell within the upper and lower limits of agreement, indicating no significant difference between the photographic and conventional methods.
- The photographic method demonstrated comparable reliability to the conventional method for assessing foot arch parameters.

3. Results

108 subjects were taken for assessment of foot arch parameters by two methods a) conventional method b) the photographic method.

All the data analysis was done with help of Bland-Altman test.

Results were analyzed by keeping 95% confidence interval and significant at p value 0.95.

Table 1 Descriptive statistics for Foot Arch Parameter

Variable	Arch Height		Arch width		Arch Index	
	G	**P**	**G**	**P**	**G**	**P**
Count	108	108	108	108	108	108
Min	0.9	0.9	1.7	1.7	0.11	0.11
Max	3.5	3.5	5.5	5.55	0.33	0.96
Q1	1.7	1.7	3.4	3.3	0.23	0.23
Median	1.8	1.8	3.5	3.5	0.26	0.25
Q3	2.6	2.5	3.95	3.92	0.28	0.28
Mean	2.05	2.03	3.59	3.58	0.25	0.25
SD	0.61	0.62	0.67	0.67	0.05	0.08
SEM	0.06	0.06	0.06	0.06	0	0.01

G- Measurements by conventional method; P- Measurements by photographic method

Mean Arch Height in conventional group was 2.05 with SD of 0.61 and in photographic method was 2.03 with SD 0.62 with the measurements varies in between 0.9-3.5 which was same for both methods .The mean Arch Width in Conventional group was 3.59 with SD of 0.67 measurements varies in between 1.7-5.5 and in photographic method was 0.67in this measurements varies in between 1.7-5.55. The mean Arch Index in Conventional method and photographic method is 0.25 with SD of 0 and 0.01 measurement varies in between0.11-0.33 for conventional method 0.11- 0.96 For the photographic method.

Table 2 Descriptive statistics for the limits in sample and in population

Variable	Arch Height		Arch width		Arch Index	
	G	**P**	**G**	**P**	**G**	**P**
LLS	0.8544	0.8148	2.2768	2.2668	0.152	0.0932
ULS	3.2456	3.2452	4.9032	4.8932	0.348	0.4068
LLP	1.9324	1.9124	3.4724	3.4624	0.25	0.2304

ULP	2.1676	2.1476	3.7076	3.6976	0.25	0.2696

G- Measurements by conventional method; P- Measurements by photographic method

The table above shows upper limit and lower limit of the sample and the population in conducted study for all 3 variables of Foot Arch Parameters that has been calculated for the photographic method (P) as well as conventional method (G).

Table 3 One Sample Statistics

One-Sample Statistics				
	N	**Mean**	**Std. Deviation**	**Std. Error Mean**
Diff Arch Height	108	0.0235	0.14762	0.0142
Diff Arch Width	108	0.0109	0.08432	0.00811
Diff Arch Index	108	-0.0041	0.06529	0.00628

The above table presents the results of three variables, one – sample analyses comparing different arch measurements. Each analysis is based on sample size of 108.The mean difference in Arch height between the two groups is 0.0235 with SD of 0.14762. Mean difference in Arch Width between the two groups is 0.0109 with SD of 0.08432, mean difference in Arch Index between the two groups is -0.0041 with SD of 0.006529. Indicating that the individual differences vary considerably from the mean differences.

Table 4 One -Sample Test for Foot Arch Parameters

One-Sample Test						
	Test Value = 0					
	T	**Df**	**Sig. (2tailed)**	**Mean Differece**	**95% Confidence Interval of the Difference**	
					Lower	**Upper**
Diff Arch eight	1.651	107	0.102	0.02346	-0.0047	0.0516
Diff Arch Width	1.343	107	0.182	0.0109	-0.0052	0.027
Diff Arch Index	-0.653	107	0.515	-0.0041	-0.0166	0.0083

The T –statistic for test comparing Arch height difference to 0 is 1.651.with p-value (two –tailed) 0.102, The T –statistic for test comparing Arch width difference to 0 is 1.343 with p value of 0.182, The T –statistic for test comparing Arch Index difference to 0 is -0.653 with p-value 0.515.The degree of freedom associated with the test are 107 for all the three foot arch parameters with confidence interval 95% which indicates that there is no statistically significance difference between Arch Height, Arch Width, Arch Index.

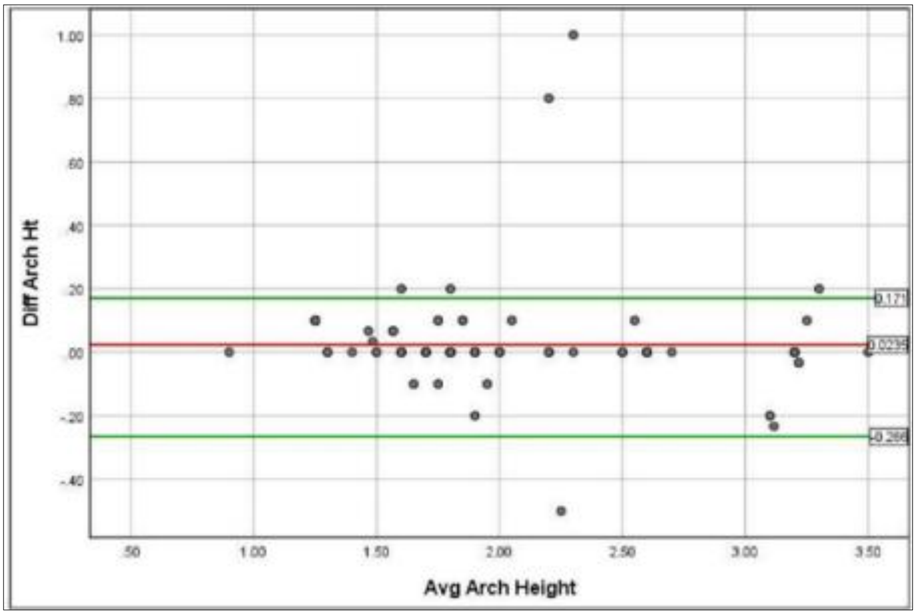

Figure 1 Bland-Altman graph for Arch Height

Bland-Altman graph for the mean difference between arch height for both conventional and photographic method:-red line showing mean difference of 0.235.the upper limit represent in green is 0.11 and lower limit represented in green is -0.266.According to statistical analysis the most of the data collected which is represented by dots as shown in above graph is in between the upper and the lower limits which signify that that there is no significant difference between conventional method and the photographic method for the calculation of arch height.

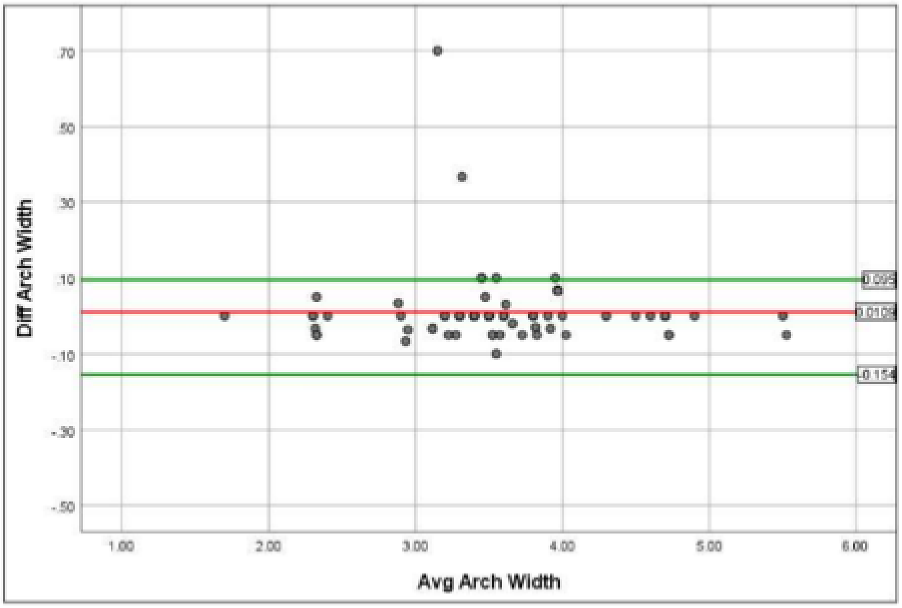

Figure 2 Bland-Altman graph for Arch Width

Bland-Altman graph for the mean difference between arch width for both conventional and photographic method:-red line showing mean difference of 0.0109.the upper limit represent in green is 0.095and lower limit represented in green is -0.154. According to statistical analysis the most of the data collected which is represented by dots as shown in above graph is in between the upper and the lower limits which signify that that there is no significant difference between conventional method and the photographic method for the calculation of arch width.

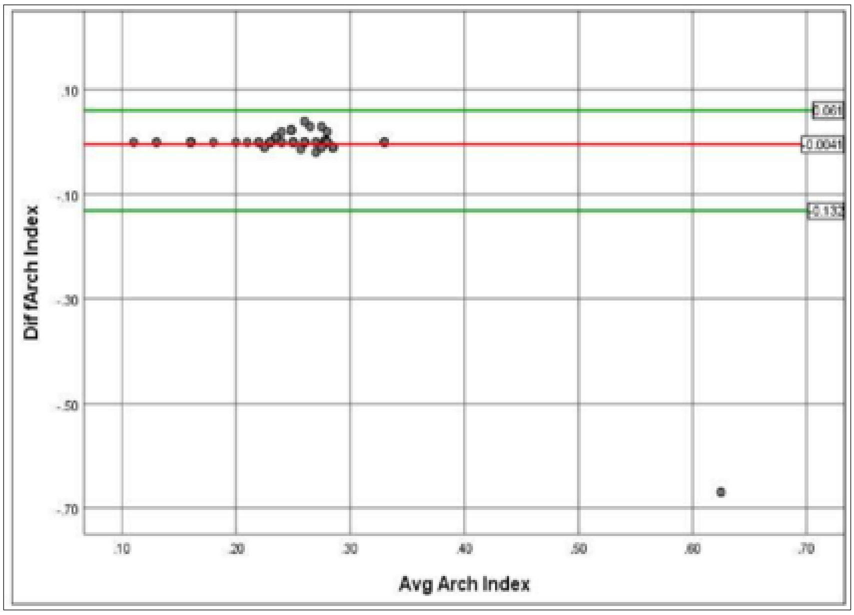

Figure 3 Bland-Altman graph for Arch Index

Bland-Altman graph for the mean difference between arch width for both conventional and photographic method:-red line showing mean difference of 0.0041the upper limit represent in green is 0.061and lower limit represented in green is -0.132. According to statistical analysis the most of the data collected which is represented by dots as shown in above graph is in between the upper and the lower limits which signify that that there is no significant difference between conventional method and the photographic method for the calculation of Arch Index.

4. Discussion

The study aimed to evaluate the reliability of the photographic method for assessing foot arch parameters and compare it with the conventional foot arch parametric method. The results demonstrated that the photographic method produced measurements for arch height, arch width, and arch index that were highly comparable to those obtained through the conventional method. The Bland-Altman analysis confirmed that the differences between the two methods were within acceptable limits, indicating no significant statistical variation.

The photographic method offers several advantages over the conventional method, including reduced human error, improved measurement accuracy, and ease of use. The conventional method relies on manually taken impressions, which may be subject to inconsistencies based on the skill level of the examiner. In contrast, the photographic method provides an objective and repeatable approach by using digital image processing techniques. The use of a transparent footplate with a grid system and an image measurement tool facilitated precise assessment, reducing the variability associated with manual tracing and calculations.

Another significant advantage of the photographic method is its potential for widespread application in clinical and research settings. With the integration of modern imaging techniques and mobile applications, foot arch assessments can be performed more conveniently and efficiently. This method eliminates the need for physical footprint impressions, making it a non-invasive and time-efficient alternative. Additionally, the photographic method's ability to store and analyze images digitally allows for long-term monitoring of foot arch variations, which can be beneficial for patient follow-up and longitudinal studies.

Nevertheless, specific limits must be recognized. The research was performed on a constrained sample size within a certain age and BMI range, perhaps limiting the applicability of the results to wider groups. Additional research involving bigger and more heterogeneous populations is necessary to corroborate these findings. Moreover, although the photographic method mitigates human-related mistakes, slight variations in image acquisition and measurement interpretation may persist. Subsequent research need to concentrate on optimizing the methodology via automated software advancements to raise measurement accuracy and dependability.

5. Conclusion

This study successfully established the reliability of the photographic method for foot arch assessment by demonstrating its comparability with the conventional foot arch parametric method. The results indicate that the photographic method is an effective, accurate, and non-invasive alternative to traditional footprint-based assessments. Given its ease of use, digital accessibility, and potential for clinical and research applications, the photographic method represents a promising advancement in foot arch measurement. Further research is recommended to expand the scope of its applicability across different demographic groups and refine the technique through technological advancements.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

References

[1] "Hong W, YH L, YH L, SF T, HC C. Effect of shoe heel height and totalcontact insert on muscle loading and foot stability while walking. Foot ankle Int. 2013;34(2):81–273.

[2] Hong W, YH L, HC C, YC P, CY W. Influence of heel height and shoe inserton comfort perception and biomechanical performance of young female adults during walking. Foot ankle Int. 2005;26(12):1042–8.

[3] Kouchi M, M K, M. M. Deformation of foot cross-section shapes during walking. Gait Posture. 2009;30(4):482–6.

[4] Menz H, MR F, E W, MJ. S. Visual categorisation of the arch index: a simplified measure of foot posture in older people. J foot ankle Res. 2012;5(1):1–7.

[5] Razeghi M, ME B. Foot type classification: a critical review of current methods. Gait Posture. 2002;15(3):282–91.

[6] Ramos A, S F, PJ P, P K. Assessment of flat foot using plantar arch index in young adults. Biomedicine. 2021;41(3):535–8.

[7] Lee H, K L, T. C. Development of a low cost foot-scanner for a custom shoe tailoring system. In7th Symp Footwear Biomech. 2005;

[8] Wang J, H S, M K, M M, T. K. Human foot reconstruction from multiple camera images with foot shape database. IEICE Trans Inf Syst. 2006;89(5):1732–42.

[9] Amstutz E, T T, M K, M M, H. S. PCA based 3D shape reconstruction of human foot using multiple viewpoint cameras. Comput Vis Syst 6th Int Conf ICVS 2008 Santorini, Greece. 2008;161–70.

[10] Novak B, A B, J M, M. J. Three-dimensional foot scanning system witha rotational laser-based measuring head. Strojniški vestnik-Journal Mech Eng. 2014;60(11):685-93.

[11] Herrewegen I Van den, K C, M B, B B-F, J VS, A L, et al. Dynamic 3D scanning as a markerless method to calculate multi-segment foot kinematics during stance phase: Methodology and first application. J Biomech. 2014;47(11):2531–9.

[12] Liu S, Cui Y, Sanchez S, D S. Foot scanning and deformation estimation using time-offlight cameras. Footwear Sci. 2011;98–9.