Original Article

An Analysis of Arches of the Foot: Grading the Severity of Pesplanus and Pescavus using a Newly Designed Podoscope and Parameters

K. Vijayakumar, S. Senthilkumar[1], Soham G. Chandratre[2], Vaishaly Bharambe

Departments of Anatomy and [2]Medical Records, Symbiosis Medical College for Women, Symbiosis International (Deemed University) Lavale, Pune, Maharashtra, [1]Department of Anatomy, SRIHER, Sri Ramachandra University, Porur, Chennai, Tamil Nadu, India

Abstract

Introduction: The aim of this study was to establish a new grading system of pesplanus (PP) and pescavus (PC) based on the severity by a newly proposed parameter plantar surface area (PSA) using a newly designed podoscope device. **Material and Methods:** A total number of 416 healthy participants; 208 men and 208 women aged 21–50 years were included in this study. Plantar surface images were obtained from the podoscope and measurements were made by using the newly proposed parameter and existing parameter. Statistical analysis was conducted using the SPSS Statistical software (version 16.0) and executed at 95% confidence interval. Mean and standard deviations were observed by using the descriptive analysis. The Chi-square test has been performed to find the association, dependency, and validity. **Results:** The analysis of the present study encompasses the grading system of "PP and PC" and also developed a classification system with three grades in PP and PC. This grading system will be a substantiate assessment tool for the diagnosis and also to record the prognosis during the treatment of PP and PC. **Discussion and Conclusion:** The present study has developed a newly designed podoscope and established a newly proposed parameters PSA index and analyzed the prevalence of normal, PP and PC. In this study, gender wise normative value for new parameters PSA index was proposed under the influence of height and foot length. According to our knowledge, this is the first study to grade the PP and PC in a proper scientific morphometric analysis using a newly designed podoscope with a PSA index.

Keywords: *Flat foot grades, high arch foot grades, pescavus, pesplanus, podoscope*

Introduction

The foot structure is a stable pliable platform in static condition, acting as a shock absorber helping in propelling of the body forward during locomotion.[1] The arches of the foot are formed by the tarsal and metatarsal bones and supported by tendons and ligaments in the foot.[2] Structurally, the arches of the foot are classified into transverse arch, medial longitudinal arch (MLA), and lateral longitudinal arch (LLA).[3] The MLA is higher than the LLA and acts like a spring during weight bearing.[4] Pesplanus (PP) or flat arched foot is a medical condition in which the height of MLA will be partially or completely flat and almost whole plantar surface of the foot comes in contact with the ground.[5] When the height of MLA exaggerates, it is termed as high arch foot.[6] In high arch foot, an excessive amount of weight is placed on the ball and heel of the foot when walking or standing.[7] Morphometric analysis and clinical assessment of the arches of foot were developed to compute the geometry as well as the purpose of diagnosis of certain ailments.[8-10] Foot print indices, anthropometric measurements, and radiographic methods are the classical methods for analyzing the arches of foot.[11] Chippaux index, Staheli index (SI), Arch index (AI), and truncated AI are the common parameters used to assess the integrity of the arches of the foot.[12] Studies reported that arches of the foot were analyzed using foot print indices to rule out the flat and high arched foot.[13] Johnson and Strom classification method of grading the flat foot composed of radiological, pathological, and clinical examinations to correlate with the progression of deformity.[14] Abousayed *et al*. in 2015 described that the Johnson and Strom method of flat foot classification is not a successful method because it does not contain the anatomical

How to cite this article: Vijayakumar K, Senthilkumar S, Chandratre SG, Bharambe V. An analysis of arches of the foot: Grading the severity of pesplanus and pescavus using a newly designed podoscope and parameters. J Anat Soc India 2021;70:85-92.

Article Info

Received: 11 April 2020
Accepted: 20 April 2021
Available online: 30 June 2021

Address for correspondence:
Dr. K. Vijayakumar, Symbiosis Medical College for Women, Symbiosis International (Deemed University) Lavale, Pune, Maharashtra, India. E-mail: asstprof.anatomy1@smcw.siu.edu.in

Access this article online

Website: www.jasi.org.in
DOI: 10.4103/JASI.JASI_61_20
Quick Response Code:

aspects of assessment.[15] Chang *et al*. in 2014 stated that the classification of flat foot should be established universally for assessment, treatment, and also to clear controversial issue regarding the diagnosis.[16] The above literature shows that foot print indices is a standard tool for measuring the integrity of arches of the foot but it is not a tool for classifying the grades of flat or high arched foot. Enormous scientific research papers have been published in relation to flatfoot but a few studies have been shown to controversial by other authors. Researchers and clinicians assess the arches of the foot by foot print parameters are unable to record the prognosis in the absence of a reliable grading system. There is no substantial research to show the grading of flat and high arch foot. Therefore, to address this issue and to fill the lacunae, the present study aims to develop the grading system of PP and pescavus (PC) by newly proposed parameter plantar surface area (PSA) index using a newly designed podoscope.

Material and Methods

Participants and study area

This is a comparative study conducted among 416 (208 males and 208 females) healthy participants aged between 21 and 50 years. Participants with open wounds, recent fractures, surgery (within 6 months), or any neurological conditions affecting the lower extremities were excluded. Ethical approval was obtained from the institutional ethics committee of Sri Ramachandra Medical College and Research Institute, Tamil Nadu, Chennai. Written consent was obtained from the patients after detailed explanation of the study, their role, risks and benefits involved, and their rights.

Instrumentation and podoscope specifications

A newly designed podoscope was used in the present study; it was made with wood, toughened glass and a document scanning machine. The device measures 60 cm length, 53 cm breadth, and 16 cm width can withstand up to 200 kg, when the subject stands over the equipment, as shown in Figures 1 and 2. The market price of standard readymade podoscope device was minimum Rs. 1.2 lakhs and an expert may be needed to operate certain devices, but the cost for designing our new device was just around Rs. 7000 and without an expert we can operate the device.

Methodology

As preliminary procedure, the entire participant's foot was cleansed with mild soap water and wiped thoroughly with a towel. Each subject was requested to stand erect, facing forwards, on the podoscopic device; after a few trials of familiarization with the device, the digitalized plantar scan images were obtained.

Image calibration method

The images of the plantar surface were transferred to the computer. Calibration of images was carried out in AutoCAD software by placing the calibration marks on two points that are a known distance apart, and entering the actual distance spanned by the points in centimeters.

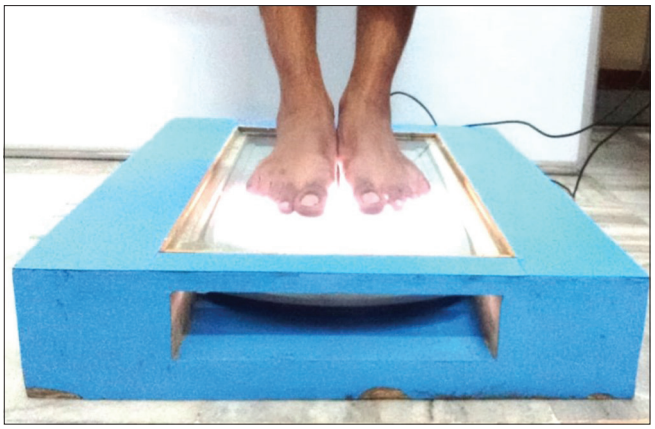

Figure 1: Newly designed podoscope

Observation

The images obtained from the podoscope device were observed and measured using existing parameter as well as new (PSA) index.

Existing parameters

Arch angle (AA), Chippaux-Smirak Index (CSI), Staheli index (SI), and Arch index(AI) are the existing parameters from the literature used to assess the arches of the foot, as shown in Figures 3 and 4.

i. AA is the angle between the medial line of the footprint (a) and the line connecting the most medial aspect of the metatarsus and the most lateral point of the medial foot (b)[17-20]
ii. CSI was measured by dividing the minimal distance of the (d) midfoot by the maximal distance of the (c) forefoot[21-23]
iii. SI obtained by dividing the minimal width of the midfoot (d) by the widest width of the (e) rear foot region[24-26]
iv. AI The length of the footprint excluding the toes (L) is divided into equal thirds. The AI is then calculated as the area of the middle third of the footprint divided by the entire footprint area (AI = B/A + B + C).[27-29]

Newly Proposed Parameter – Plantar surface area (PSA) index

PSA index was calculated based on the plantar surface area of the foot; the total plantar surface area (TPSA) [Figure 5] consists of plantar surface contact area (PSCA) and a plantar surface non-contact area (PSNCA). The PSCA [Figure 6] is formed by the width of forefoot, midfoot and hindfoot which will be in contact to the ground. PSNCA [Figure 7] is situated at the concavity of medial longitudinal arch which is not in contact to the ground.

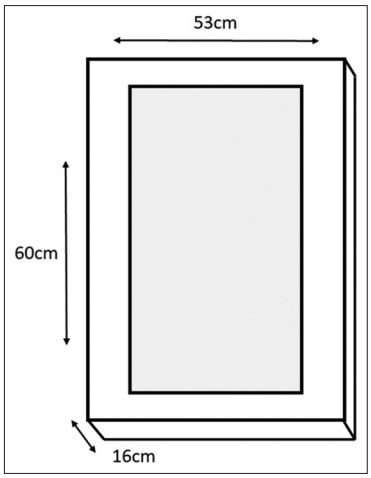

Figure 2: Specifications of newly designed podoscope

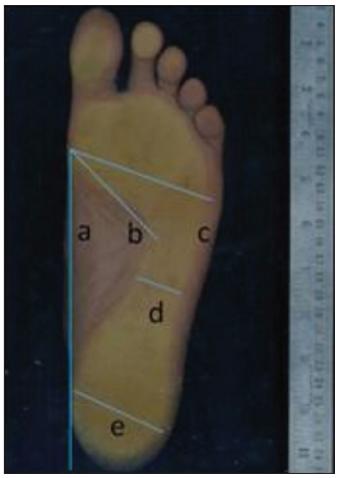

Figure 3: Podoscopic image shows the measurement of Arch angle, Chippaux-smirak index, Staheli index

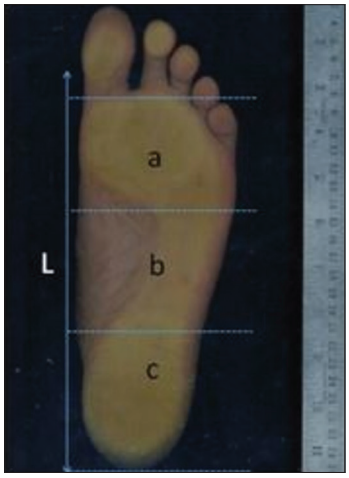

Figure 4: Podoscopic image shows the measurement of arch index

Figure 5: Podoscopic image shows the measurement of total plantar surface area (TPSA) in normal arched foot.

Grading pesplanus

Based on the PSA index, the flat arch foot was classified into three different grades. In Grade 1, the width of midfoot was increased, and the normal structure of MLA was altered, midfoot supports equal to or more than 1/3 of the total foot region, the plantar surface contact area PSCA is around 80%–90%. In Grade 2, the width of the midfoot reached to the level of the forefoot width, the MLA disappears, the PSCA was around 91%–100% and the PSNCA was 0%–10%. In Grade 3, the MLA was completely collapsed and dominant medial protuberance was seen rear foot width decreases, the contact region of the plantar surface was 100% and the PSNCA was 0%, as shown in Figure 8.

Grading pescavus

Based on the newly proposed parameters, the high arch foot was classified into three different grades. In Grade 1, the midfoot width was reduced, and the concavity of the MLA increases, the PSCA was around 51%–60%. In Grade 2, the structure of MLA was interrupted and complete absence of midfoot contact to the ground, the major contact region to the floor is the heel and the metatarsal region, and the PSCA was around 41%–50%. Grade: 3 – The overall contact area of the plantar surface to the floor was decreased; the PSCA is only around 21%–40%, as shown in Figure 9.

Results

The statistical analyses were undertaken using the SPSS Statistical software (version 16.0) and executed at 95% confidence interval. Mean and standard deviations for age, height, and weight were observed by the descriptive analysis, as shown in Table 1. The normative values for newly proposed parameters (PSA) are tabulated in Table 2. The Chi-square test has been performed to find the association, dependency, and validity of the newly proposed parameter PSA index with the existing parameters with statically significant $P < (0.001)$ for both males and females, as shown in Tables 3 and 4. Cramer's V is 0.985 for male and 1.00 for female group shows that newly proposed parameters

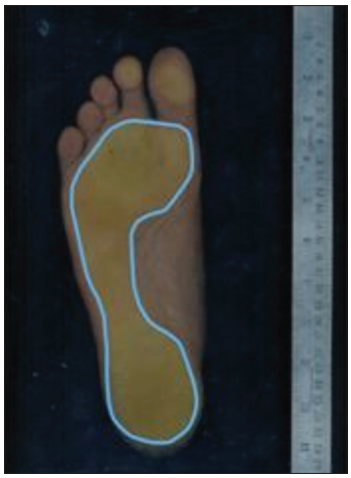

Figure 6:Podoscopic image shows the measurement of Plantar surface contact area (PSCA) in normal arched foot

Figure 7: Podoscopic image shows the measurement of plantar surface non-contact area (PSNCA) in normal arched foot

PSA index and the exciting parameters are highly correlated. The distribution of different types of arches among the participants is shown in Table 5. Grading of PP and PC using by PSA parameter is shown in Tables 6 and 7.

Discussion

In this study, among 416 participants, normal arch, (PP) and (PC) have been identified. The PP and PC are categorized as abnormal arches, and the normal arched foot remains the same, as shown in Table 4. The goal of the present study was to examine the ability of the newly proposed parameter (PSA index) compared with existing parameter using newly designed podoscope device. The analysis of the present study encompasses the grading system of "PP and PC" and also developed a classification system with three grades in PP and three grades in (PC) among 208 men and 208 women. This grading system will be a substantiate assessment tool for diagnosis and also to record the prognosis during the treatment of PP and PC.

Dunn *et al*.[30] conducted an epidemiological study among 784 participants and reported that the prevalence of flat foot was 19.0% (17.2% in men and 20.1% in women). Xiong *et al*.[31] analyzed the ankle and foot morphometry of 48 participants using footprint and also with static measurements and reported that 24% of them had abnormal arches. Nguyen *et al*.[32] assessed the arches of foot using MatScanPedo barographic device among 386 women and 214 men and found 17% flat foot in men and 20% in women. The present study reports that the prevalence of PP and PC according to the newly designed podoscope was 34.13% (39.0% in women and 28.8% in men), as shown in Table 4. The difference between the above-mentioned studies and the present study is that none of the studies have reported about the grading or classification of PP and PC, but the present study a grading system of both PP and PC was established, as shown in Tables 3 and 4 and Figures 6 and 7.

Table 1: Characteristics of subjects (Mean±SD)

Gender	Mean±SD		
	Age	Height (cm)	Weight (kg)
Men	31.6±9.3	178±3.6	78.6±10.3
Women	28.4±7.6	162±4.4	65.2±8.2

SD: Standard deviation

Table 2: Normative values of newly proposed parameters - Plantar surface area

Different Types of arches	% of contact area
NA	61%-79%
PP	80%-100%
Grade I	80%-90%
Grade II	91%-100%
Grade III	100% with protrusion
PC	<61%
Grade I	51%-60%
Grade II	41%-50%
Grade III	21%-40%

NA: Normal arch, PP: Pes planus, PC: Pes cavus

Pourghasem *et al*.[33] evaluated the relation between the severity of flatfoot and obesity among 653 males and 505 females between the age group of 6 and 18 years using the Dennis method of classification and reported that the prevalence of flatfoot was 17.5% in boys and 14.5% in girls. Chougala *et al*.[34] examined and graded the flatfoot among 228 subjects, based on body mass index using the Dennis method of classification of flat foot and revealed that 44.2% had flat arch foot. The contrast between the present study and studies of Pourghasem *et al.* and Chougala *et al.* shows that they have used a Dennis method for classifying the flat arched foot, Chang *et al*., Abousayed *et al*. and that the exact prevalence of flat foot is unknown due to deficit of exact criteria for defining flat foot, and a new method should be established based on the anatomical perspective to classify

Table 3: Association between height, foot length and TPSA in women (*n*=208)

Height (cm)	Foot length (cm)												Total
	15-20				21-25				26-30				
	TPSA												
	140-180				140-180				140-180				
	140-150	151-160	161-170	171-180	140-150	151-160	161-170	171-180	140-150	151-160	161-170	171-180	
145-154	1	1	1	0	0	16	1	0	0	0	0	0	20
155-164	16	13	1	0	6	51	31	0	0	1	0	0	119
165-174	0	0	0	0	1	16	36	2	0	1	11	2	69
Total	33				160				15				208

TPSA: Total plantar surface area

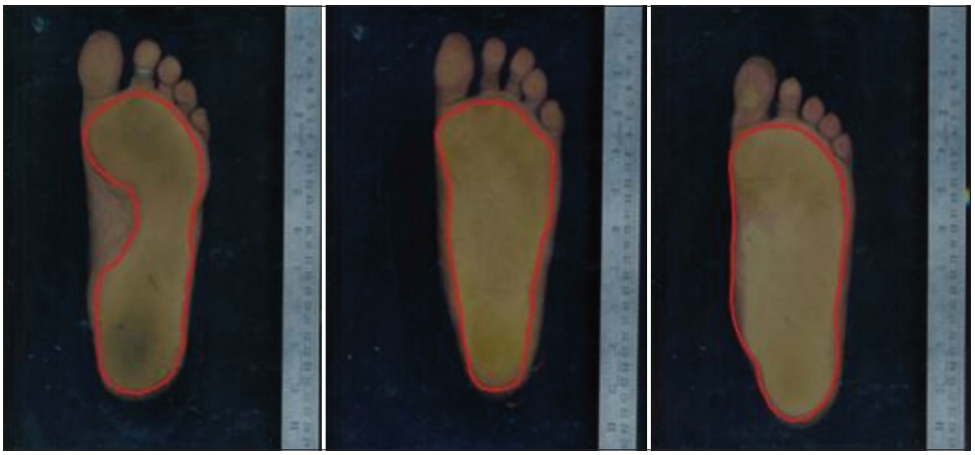

Figure 8: Grades of pesplanus classified based on newly proposed parameters

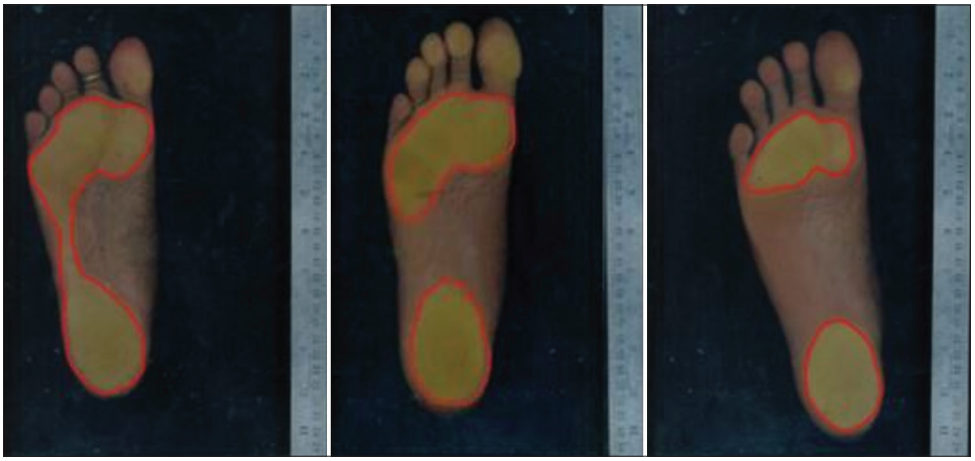

Figure 9: Grades of pescavus classified based on newly proposed parameters

the arches of the foot. Dennis method involves image representation and plotting lines in the footprint. The authors propose the above parameters based on the anatomical and biomechanical configuration of arches of the foot be used for detailed grading of abnormality of arches of foot.

Existing parameters versus newly proposed parameter plantar surface area (PSA)

The morphometry of the foot was studied by using indices, lines, and angles called as foot print parameters. CI, SI,and AA are some of the parameters used by the researchers to assess the integrity of arches of the foot.[35,36] Foot print parameters are basically calculated by lines and angles in some particular areas such as forefoot, midfoot, and hindfoot and not with the entire surface, so there are many areas which are left unmeasured, as shown in Figures 1 and 2. Therefore, these parameters are only capable of diagnosing whether it is a normal, flat, or high arched foot; hence, these parameters are unable to grade the severity of PP and PC.

Table 4: Association between height, foot length and TPSA in men (*n*=208)

Height (cm)	Foot length																		Total
	15-20				21-25				26-30				31-35						
	TPSA																		
	150-160	161-170	150-190	171-180	181-190	150-160	161-170	150-190	171-180	181-190	150-160	161-170	150-190	171-180	181-190	150-160	161-170	150-190	171-180	181-190	
155-164	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
165-174	0	1	0	0	0	48	16	0	0	0	15	19	11	1	0	0	0	0	0	0	111
175-184	0	0	0	0	0	1	1	1	0	0	0	17	20	5	0	0	0	9	40		94
185-195	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2		2
Total			1					68					88					51			208

TPSA: Total plantar surface area

Table 5: Distribution of NA,PP,PC based on gender

Gender	NA	PP	PC	Total
Female	126	47	35	208
Male	148	41	19	208
Total	274	88	54	416

NA: Normal arch, PP: Pes planus, PC: Pes cavus

The newly proposed PSA index was derived based on the individual's height, foot length, and the PSA, as shown in Tables 3 and 4. The parameters are based on the calculation of the entire plantar surface of the foot; PSA index covers the measurement of whole plantar surface of the foot, and no areas remains unmeasured, as shown in Figures 3-5. Therefore, the PSA index is capable for finding whether it's normal arch foot, PP or PC, as well as it also reveals the grading of PP and PC based on the severity Figures 6 and 7. Variability was present practically in each and every stage of this research process, the existing diagnostic tests were modified and updated in the current study by new parameters PSA index to confirm the presence or absence and to grade the PP and PC.

The existing parameters can be used only to assess or differentiate the normal and abnormal arches of foot. Witana *et al*.[37] used 3D scanner to assess the morphometry of 16 participants for the purpose of the preparing the foot orthotics. Similarly, with the available measurements of the newly proposed PSA index, it can be utilized for assessing the arches of the foot, to record the prognosis of PP and PC during the treatment and also it will be useful for manufacturing footwear and orthotics.

Conclusion

The present study has developed a newly-designed podoscope and established a newly proposed parameter (PSA) index and analyzed the prevalence of normal, flat, and high arch foot between the age group of 21–50 years. In this study, gender-wise normative value for new parameters PSA index was proposed under influence of height and foot length. The device was designed in a portable manner so it can be carried easily by a single person to any places, which allows to diagnose or to collect data in the rural and under-served areas without any cost. The podoscope and the newly proposed PSA index were designed in a simplified manner so it does not require a technical person to handle it. The outcome acquired by this study will be helpful for accurate diagnosis and to record the prognosis during the treatment of PP and PC, it will be also helpful in the field of orthopedics.

Acknowledgment

I thank R.Mohanasankari for helping in preparing this manuscript.

Table 6: Existing parameters shows only the different types of arches of foot, but newly proposed parameter (PSA) shows the grades of PP and PC in women

Different types of arches	Existing parameters	Newly proposed parameters (PSA)					
		F 1	F 2	F 3	H 1	H 2	H 3
NA	126	0	0	0	0	0	0
PC	35	0	0	0	15	7	13
PP	47	18	10	19	0	0	0
Total	208	18	10	19	15	7	13

NA: Normal arch, PC: Pes cavus, PP: Pes planus

Table: 7 Existing parameters shows only the different types of arches of foot, but newly proposed parameter (PSA) shows the grades of PP and PC in men

Different types of arches	Existing parameters	Newly proposed parameters (PSA)					
		F 1	F 2	F 3	H 1	H 2	H 3
NA	148	0	0	0	0	0	0
PC	19	0	0	0	14	4	1
PP	41	10	19	12	0	0	0
Total	208	10	19	12	14	4	1

NA: Normal arch, PC: Pes cavus, PP: Pes planus

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Ker RF, Bennett MB, Bibby SR, Kester RC, Alexander RM. The spring in the arch of the human foot. Nature 1987;325:147-9.
2. Ogon M, Aleksiev AR, Pope MH, Wimmer C, Saltzman CL. Does arch height affect impact loading at the lower back level in running? Foot Ankle Int 1999;20:263-6.
3. Allen J. Subfossil mammalian tracks (Flandrian) in the Severn Estuary, S. W. Britain: Mechanics of formation, preservation and distribution. Philosophical Transactions of the Royal Society of London Series B: Biological Sciences. 1997;352:481-518.
4. Bennett MR, Harris JW, Richmond BG, Braun DR, Mbua E, Kiura P, *et al.* Early hominin foot morphology based on 1.5-million-year-old footprints from Ileret, Kenya. Science 2009;323:1197-201.
5. Lovett HW, Dane J. The affections of the arch of the foot commonly classified as flat-foot. J Bone Joint Surg 1896;8:78-92.
6. Jahss MH. Spontaneous rupture of the tibialis posterior tendon: Clinical findings, tenographic studies, and a new technique of repair. Foot Ankle 1982;3:158-66.
7. Mann RA. Acquired flatfoot in adults. Clin Orthop Relat Res. 1983:46-51.
8. Garrow AP, Silman AJ, Macfarlane GJ. The cheshire foot pain and disability survey: A population survey assessing prevalence and associations. Pain 2004;110:378-84.
9. Gorter KJ, Kuyvenhoven MM, de Melker RA. Nontraumatic foot complaints in older people. A population-based survey of risk factors, mobility, and well-being. J Am Podiatr Med Assoc 2000;90:397-402.
10. Hawes MR, Nachbauer W, Sovak D, Nigg BM. Footprint parameters as a measure of arch height. Foot Ankle 1992;13:22-6.
11. Forriol F, Pascual J. Footprint analysis between three and seventeen years of age. Foot Ankle 1990;11:101-4.
12. Queen RM, Mall NA, Hardaker WM, Nunley JA 2nd. Describing the medial longitudinal arch using footprint indices and a clinical grading system. Foot Ankle Int 2007;28:456-62.
13. Kaufman KR, Brodine SK, Shaffer RA, Johnson CW, Cullison TR. The effect of foot structure and range of motion on musculoskeletal overuse injuries. Am J Sports Med 1999;27:585-93.
14. Johnson KA, Strom DE. Tibialis posterior tendon dysfunction. Clin Orthop Relat Res 1989;239:196-206.
15. Abousayed MM, Tartaglione JP, Rosenbaum AJ, Dipreta JA. Classifications in brief: Johnson and Strom classification of adult-acquired flatfoot deformity. Clin Orthop Relat Res 2016;474:588-93.
16. Chang CH, Chen YC, Yang WT, Ho PC, Hwang AW, Chen CH, *et al.* Flatfoot diagnosis by a unique bimodal distribution of footprint index in children. PLoS One 2014;9:e115808.
17. Lo HC, Chu WC, Wu WK, Hsieh H, Chou CP, Sun SE, *et al.* Comparison of radiological measures for diagnosing flatfoot. Acta Radiol 2012;53:192-6.
18. Butterworth PA, Landorf KB, Smith SE, Menz HB. The association between body mass index and musculoskeletal foot disorders: A systematic review. Obes Rev 2012;13:630-42.
19. Vijayakumar K, Senthilkumar S, Subramanian R. A study on relationship between BMI and prevalence of flat foot among the adults using foot print parameters. Int J Adv Res 2016;4:1428-31.
20. Younger AS, Sawatzky B, Dryden P. Radiographic assessment of adult flatfoot. Foot Ankle Int 2005;26:820-5.
21. Irving DB, Cook JL, Young MA, Menz HB. Obesity and pronated foot type may increase the risk of chronic plantar heel pain: A matched case-control study. BMC Musculoskelet Disord 2007;8:41.
22. Lopez N, Alburquerque F, Santos M, Sanchez M, Dominguez R. Evaluation and analysis of the footprint of young individuals. A comparative study between football players and non-players. Eur J Anat 2005;9:135-42.
23. Vijayakumar K, Senthilkumar S. Morphometric analysis of ankle and foot in classical bharathanatyam dancers using foot posture index (FPI) and plantar scan images (PSI). IOSR J Dent Med Sci 2019;15:20-5.
24. Mauch M, Grau S, Krauss I, Maiwald C, Horstmann T. A new approach to children's footwear based on foot type classification. Ergonomics 2009;52:999-1008.
25. Hu A, Arnold JB, Causby R, Jones S. The identification and reliability of static and dynamic barefoot impression measurements: A systematic review. Forensic Sci Int 2018;289:156-64.
26. Vijayakumar K, Senthilkumar S, Bharambe V, Bokan R. A comparison of self-designed scanner device and AutoCAD image calibration method with gold standard classical ink foot print method: An analysis of arches of foot. IJMSIR 2020;5:171-8.
27. McCrory JL, Young MJ, Boulton AJ, Cavanagh PR. Arch index as a predictor of arch height. Foot 1997;7:79-81.
28. Staheli LT, Chew DE, Corbett M. The longitudinal arch. A survey of eight hundred and eighty-two feet in normal children and adults. J Bone Joint Surg Am 1987;69:426-8.
29. Zuil-Escobar J, Martínez-Cepa C, Martín-Urrialde J, Gómez-Conesa A. Medial longitudinal arch: Accuracy, reliability,

and correlation between navicular drop test and footprint parameters. J Manip Physiol Ther 2018;41:672-9.
30. Dunn JE, Link CL, Felson DT, Crincoli MG, Keysor JJ, McKinlay JB. Prevalence of foot and ankle conditions in a multiethnic community sample of older adults. Am J Epidemiol 2004;159:491-8.
31. Xiong S, Goonetilleke RS, Witana CP, Weerasinghe TW, Au EY. Foot arch characterization: A review, a new metric, and a comparison. J Am Podiatr Med Assoc 2010;100:14-24.
32. Nguyen US, Hillstrom HJ, Li W, Dufour AB, Kiel DP, Procter-Gray E, *et al.* Factors associated with hallux valgus in a population-based study of older women and men: The MOBILIZE Boston Study. Osteoarthritis Cartilage 2010;18:41-6.
33. Pourghasem M, Kamali N, Farsi M, Soltanpour N. Prevalence of flatfoot among school students and its relationship with BMI. Acta Orthop Traumatol Turc 2016;50:554-7.
34. Chougala A, Phanse V, Khanna E, Panda S. Screening of body mass index and functional flatfoot in adult: An observational study. Int J Physiother Res 2015;3:1037-41.
35. Cavanagh PR, Rodgers MM. The arch index: A useful measure from footprints. J Biomech 1987;20:547-51.
36. Redmond AC, Crane YZ, Menz HB. Normative values for the foot posture index. J Foot Ankle Res 2008;1:6.
37. Witana CP, Goonetilleke RS, Xiong S, Au EY. Effects of surface characteristics on the plantar shape of feet and subjects' perceived sensations. Appl Ergon 2009;40:267-79.