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Two-dimensional metric comparison between dynamic bare and sock-clad footprints for its forensic implications – A pilot study

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ABSTRACT

Footprints may be present at crime scenes as physical evidence. This pilot study compares two-dimensional measurements of bare and sock-clad footprints to determine if significant differences or similarities exist. Dynamic footprints were collected from 30 males and 20 females between the ages of 20 and 61 years old (mean of 28.2 years) using the Identicator Inkless Shoe Print Model LE 25P system. A midgait protocol was employed for obtaining footprints. The fifth and sixth footprint of gait were collected for the right and left foot, respectively, in both sock-clad and barefoot trials. The footprint measurements between sock-clad and bare footprints were compared. The results did not indicate any significant difference ($p > .05$) between bare and sock-clad foot length measurements for right or left feet. Significant differences were seen for the width measurements between bare and sock-clad footprints. These findings have forensic implications, particularly in criminal cases where it is unclear if a footprint impression is from a sock-clad foot or a bare foot. This study shows that such a determination is generally not necessary when utilizing two-dimensional measurements for length comparison between a bare and sock-clad footprint. However, if width measurements are being evaluated, the distinction between bare and sock-clad footprints should be considered.

1. Introduction

Two-dimensional bare footprints provide important information for a variety of scientific fields, such as anthropology, biomechanics, orthopedics, and forensic applications [1–7]. Investigative use of footprint evidence dates to 1862 in Scotland when Jessie McLachlan was linked to a murder by bloody footprints, leading to her conviction [8]. In the 1970s podiatrist Normal Gunn began analyzing footprint evidence and developed a scientific methodology to compare crime scene footprints to those of suspects [9–11]. Since then other experts have provided analysis and testimony of footprint evidence [12].

The distinct nature of bare footprints in forensics has been extensively researched [12–24]. The work of Kennedy et al. found the statistical chance of a random match of a bare footprint to be one in 1.27 billion [20]. Footprints found at crime scenes have evaluated suspect involvement by comparing the suspect's footprint with those at the crime scene [7–12]. Bare footprints associated with a crime may not possess the dermatoglyphic detail common with fingerprints [22,23,25]. As a result, footprint analysis in criminal matters often involves analysis of other factors, such as shape, size, pressure points, anatomical relationships, and other characteristics [12,26]. Footprints can also assist with estimating a suspect's weight, height, and sex [27–29]. Partial bare footprints also have forensic value [30].

While bare footprint research has been the most studied data, there have also been cases where sock-clad footprint evidence has been found at a crime scene [7,31]. Sock-clad footprints are defined as the plantar surface foot impressions made by sock-clad feet. Socks are typically designed to contour the foot, allowing the foot to fit in shoes. They provide comfort and warmth and reduce moister, impact forces, plantar pressure, stress and shear forces. Socks do not significantly affect the functioning foot's other biomechanical aspects [32–35]. Therefore, comparison between bare footprints and sock-clad footprints can be valuable to the analysis of sock-clad footprints in determining the veracity of the information that can be reliably interpreted from them. The present pilot investigation examines the linear methodologies to compare bare and sock-clad footprint exemplars to determine whether significant differences and/or similarities are present between these two.

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2. Materials and methods

2.1. Design

The study design was a quantitative test comparison. Linear measurements were obtained from various anatomical landmarks on the sampled bare and sock-clad footprints to determine if there are significant differences and/or similarities between the samples. Each participant signed an informed consent sheet, which disclosed the study's full use and purpose prior to their inclusion in the study.

2.2. Sample

The present research was taken as a preliminary research/pilot project. Since no previous study has been done on this pertinent issue in forensic podiatry, sample size calculations could not be done and a convenient sampling was used. The study participants were recruited from the Barry University School of Podiatric Medicine in Miami, Florida. A total of 30 males and 20 females participated in the study, providing a total of 100 dynamic footprints. The average age of the participant was 28.2 years, and the range was between 20 and 61 years old. 23 participants were Caucasian, 13 Asian, 9 Hispanic, and 5 African-American. Healthy participants without any apparent/obvious limb/foot abnormality or deformity were included in the study.

2.3. Materials used

The Identicator Inkless Shoe Print Model LE 25P system was used to obtain dynamic footprints. This device creates an image of footprint or shoeprint impression. The Identicator's coater measures 8 in. by 15 in. and its inkless impression sheets measure 7 in. by 14 in. (Fig. 1). The inkless system was cleaned with antibacterial wipes before and after each participant.

Participants were also provided with antibacterial wipes for their feet before and after the experiment. Although new socks were made available for each participant, the participants preferred their own socks for the experiment that differed in make and thickness. The area where participants walked during the recording of footprint impressions was swept and cleaned with antibacterial wipes or a Swiffer Wet Jet device before and after each participant.

2.4. Methods

2.4.1. Method for obtaining dynamic bare and sock-clad footprints

A midgait protocol was selected for obtaining footprints to reflect an individual's more natural walking style [36,37]. Participants were directed to a specific starting point on a hard, flat surface area, demarcated by a piece of tape. A hard, flat surface was chosen to avoid any three-dimensional irregularities that may arise with a soft surface, such as carpet [16]. Participants were instructed to place their big toe on the tape as their starting point. Each participant was instructed to walk ten steps, starting with the right foot, turn, and walk ten steps back in socks. Seven meters of walking surface were given for participants, which was adequate for participants to take full and natural strides. This walking procedure was repeated three times. No measurements were taken, but researchers marked the placement of the third and fifth step (right foot).

On the fourth trial, the Identicator inkless coater was placed at the third step, and the impression sheet was placed where the fifth step had occurred for the three previous trials. The chemically-sensitized impression sheets were secured with tape on the outermost two corners [16]. The participant was asked to repeat the ten steps, turn, and walk back to the starting point. This trial was repeated until an acceptable impression was captured on the impression sheet that included the entire footprint [12,38]. The same procedure was repeated for the left foot in socks, the right bare foot, and the left bare foot. For the left foot, the fourth and sixth steps in the gait cycle were used for the Identicator inkless coater and impression sheet, respectively.

Fig. 1. Collection of footprints using Identicator Inkless Shoe Print Model LE 25P system.

2.4.2. Analysis of dynamic bare and sock-clad footprints

Once 100 footprints had been obtained (50 right and 50 left footprints), the prints were scanned into PDF format using an HP Photosmart Premium C410 Series printer. To measure each exemplar, the Reel method (Fig. 2) was employed using GIMP software on an Apple Macbook Pro laptop. Because previous literature has noted asymmetry between a person's right and left foot, both feet from each participant were used in the pilot study [39–41]. The Reel measurement system was chosen based on its high intra-rater reliability. The Reel method has an intra-class correlation coefficient of 0.98 to 0.99 and a standard error of measurement of 95% in a controlled setting. Scientific literature has demonstrated that height and weight were inconsequential factors concerning the reliability of this method. This high reliability indicates that the Reel method is a satisfactory baseline measurement system to analyze two-dimensional footprints [42]. Literature contends that this measurement system can be applied as a baseline technique for comparing sock-clad versus bare footprints [16].

Seven length and width measurements using standard anatomical landmarks were taken from each footprint. A central axis, a measurement for each toe (A1 to A5), the ball of the foot width (metatarsophalangeal joint; MPJ) width, and heel (Calcanea; CALC) width of the foot measurements were obtained based on the Reel linear measurements [34]. The heel width (CALC) and ball width (MPJ) measurements were from the most medial to the most lateral aspects of the print. For the toe lengths, the inner and outermost tangents were identified and bisected to form a central axis. A horizontal line from the most posterior aspect of the heel was drawn through the central axis. From this intersection, the distal aspect of toes 1–5 were measured. Figs. 3 and 4 show the labelled bare footprint and sock-clad footprint respectively.

2.5. Statistical analyses

The data obtained was statistically analyzed using SPSS version 16.0. Descriptive statistics were obtained for the different measurements on the bare and sock-clad footprints on the right and left sides. Paired *t*-test was performed to find the side (right-left) differences in the various measurements on the bare and sock-clad foot. Student's test was performed to study the differences between different measurements on the bare and socked footprints on the right and left side.

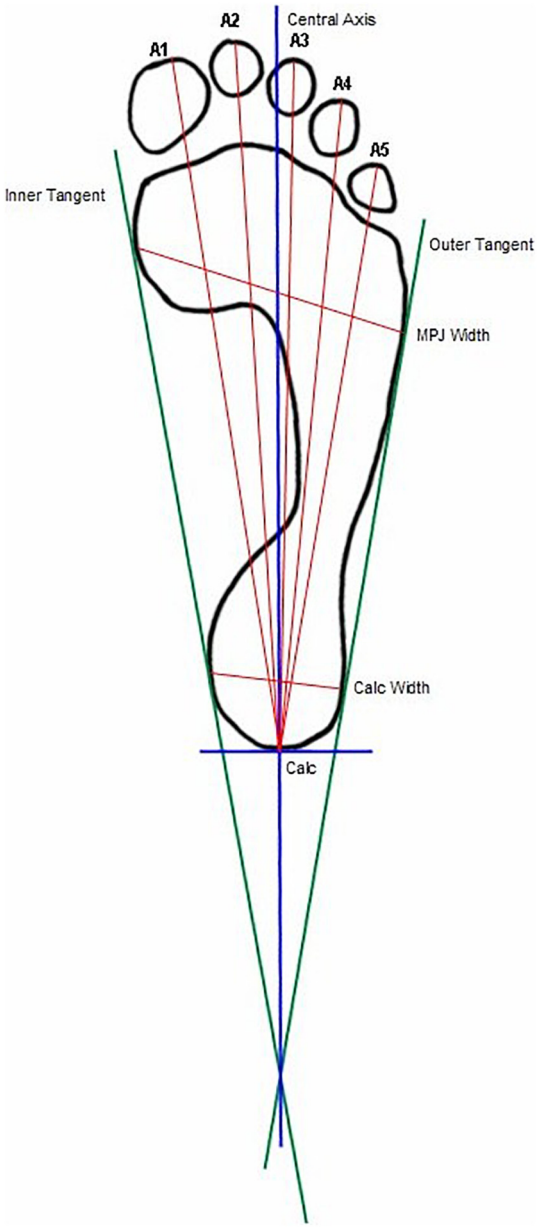

Fig. 2. Length and width measurements as defined by the Reel method.

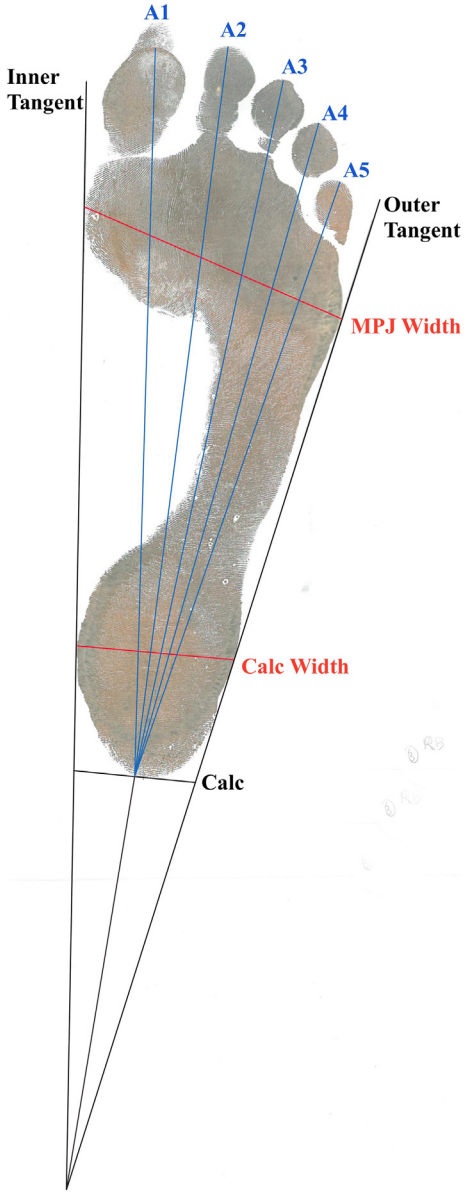

Fig. 3. Length and breadth measurements on bare footprint.

3. Results

Descriptive statistical measurements on the right and left bare foot and sock-clad prints are shown in Tables 1 and 2, respectively. Among the bare and sock-clad foot length measurements, mean dimensions were largest for A1 followed by A2, A3, A4, and A5. Among the foot width measurements, MPJ measured more than CALC in both the right and left foot.

No significant differences ($p > .05$) were observed between right and left bare footprint or sock-clad footprint measurements included in the study. The details of bilateral differences in the measurements on the bare and sock-clad foot are shown in Table 3.

No significant differences ($p > .05$) were observed between the various length measurements of bare and sock-clad footprint on either right or left side. Statistically significant differences ($p < .05$) were however, observed between width measurements of the bare and socked footprints. Specifically, statistically significant differences were observed for the width of the ball of the foot on right and left sides and width of the heel of the foot on the right side. Table 4 details the differences between bare and sock-clad footprint measurements on the right and left side.

4. Discussion

Previous research has established that bare footprints are distinctive and may approach uniqueness [12,13,18,24]. The question of whether bare footprint distinctiveness can be extrapolated to sock-clad footprints was raised in a homicide case in Wisconsin in 2015 [7]. Because of the absorbent nature of socks, literature suggests the chance for a footprint at a crime scene is more likely when the criminal is sock-clad than barefoot. This absorbency of socks allows for a longer trail of footprints to occur than would be expected from a bare foot. Uetake showed that in some instances socks soaked in paint created usable footprints for research for a distance of 50 m [43]. Also, sock-clad footprints may occur during crimes involving assault, as the perpetrator's shoes may fall off or if the assault is sexual in nature the perpetrator may remove only his shoes. These examples show the value in being able to compare bare and sock-clad footprints.

Through a Medline and Scopus search, the only previous research

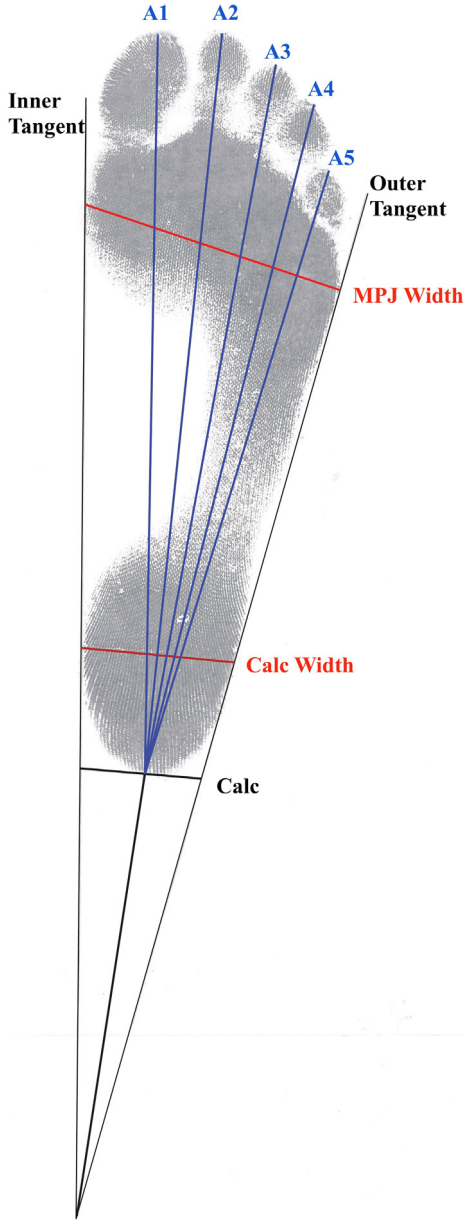

Fig. 4. Length and breadth measurements on sock-clad footprint.

addressing the comparison of bare and sock-clad footprints that the authors found was a study by Smerecki and Lovejoy [26]. Smerecki and Lovejoy suggested, "footprints made through socks or stockings can leave an anatomical morphology that can be examined to yield a high degree of identification." Their study compared bare and sock-clad footprints by linear measurements and morphological factors [26]. These factors include: the terminal phalanges of toes 2 to 5 relative position, the degree of great toe deviation, the anterior border of the ball of foot's four stem spaces form and pattern, and presence or absence of satellites along the stem axes of digits 2–5 [26]. The current study addresses the comparison of bare and sock-clad footprints employing a linear dimension methodology that has shown reliability [16]. The results indicate no significant differences were observed in linear length measurements of bare and sock-clad footprints. Significant differences between bare and sock-clad footprints were found for ball of the foot and heel width measurements.

Investigators and prosecutors may question whether a footprint at a crime scene was made by a sock-clad or bare foot. Depending on the quality of the footprint at the scene, this distinction may not be possible. This study shows that forensic footprint investigators might assume no difference between bare and sock-clad footprints when using two-dimensional length methodology. Moreover, the findings suggest that linear length dimension research, methodologies and techniques are transferable between barefoot and sock-clad footprints. However, the distinction between bare and sock-clad footprints should be considered when comparing width measurements and as such, linear width dimension research, methodologies and techniques between bare and sock-clad footprints may differ.

The results of this study warrant further investigation into this topic using a larger sample in different population groups. The potential exists for a person to wear an unusually thick or thin sock, which may create a significant difference between sock-clad and bare footprint measurements. Examining how different sock materials affect the two-

Table 1
Descriptive statistics of measurements on the bare foot.

	N	Minimum	Maximum	Mean	S.D.
Right foot					
MPJ	50	7.85	10.92	9.5152	0.74548
CALC	50	3.97	6.36	5.0242	0.4757
A1	50	21.49	28.48	25.0256	1.65805
A2	50	21.51	28.17	24.9612	1.68399
A3	50	20.75	26.94	24.0162	1.68577
A4	49	19.57	25.77	22.7306	1.57633
A5	40	18.38	23.47	21.0413	1.45403
Left foot					
MPJ	50	7.99	11.01	9.4844	0.75375
CALC	50	4.22	6.23	5.0242	0.46031
A1	50	20.78	28.5	24.9722	1.72476
A2	50	21.16	28.15	24.9556	1.71681
A3	50	20.4	27.38	24.0336	1.66033
A4	50	19.33	26.39	22.7664	1.56874
A5	43	17.87	23.7	21.0595	1.42867

MPJ – Width of the ball of the foot (cm), CALC – Width of the heel of the foot (cm), A1 – Foot length from the base of the heel to the apex of the 1st toe (cm), A2 – Foot length from the base of the heel to the apex of the 2nd toe (cm), A3 – Foot length from the base of the heel to the apex of the 3rd toe (cm), A4 – Foot length from the base of the heel to the apex of the 4th toe (cm), A5 – Foot length from the base of the heel to the apex of the 5th toe (cm), S.D. – Standard Deviation.

Table 2
Descriptive statistics of measurements on the socked foot.

	N	Minimum	Maximum	Mean	S.D.
Right foot					
MPJ	50	7.5	10.7	9.2584	0.80918
CALC	50	3.9	6.49	4.9056	0.50902
A1	50	20.92	28.19	25.0562	1.73551
A2	50	21.31	27.9	24.9794	1.7866
A3	45	20.51	27.41	24.1573	1.69839
A4	45	19.07	26.02	22.6816	1.63496
A5	36	17.62	23.85	20.8478	1.58457
Left foot					
MPJ	50	7.81	11.09	9.2884	0.77125
CALC	50	4.04	6.15	4.9728	0.47671
A1	50	20.33	28.53	25.0528	1.79302
A2	50	20.94	28.25	25.0438	1.7785
A3	46	20.42	27.87	24.1717	1.71376
A4	46	19.48	26.63	22.7585	1.57888
A5	37	17.86	23.71	21.0495	1.46984

MPJ – Width of the ball of the foot (cm), CALC – Width of the heel of the foot (cm), A1 – Foot length from the base of the heel to the apex of the 1st toe (cm), A2 – Foot length from the base of the heel to the apex of the 2nd toe (cm), A3 – Foot length from the base of the heel to the apex of the 3rd toe (cm), A4 – Foot length from the base of the heel to the apex of the 4th toe (cm), A5 – Foot length from the base of the heel to the apex of the 5th toe (cm), S.D. – Standard Deviation.

Table 3
Bilateral differences in the measurements on the bare and socked foot.

	Bare foot (right versus left)		Socked foot (right versus left)	
	t-value	p-value	t-value	p-value
MPJ	0.734	0.466	0.659	0.513
CALC	0	1	1.845	0.071
A1	0.81	0.422	0.034	0.973
A2	0.073	0.942	0.635	0.528
A3	0.217	0.829	0.193	0.848
A4	0.649	0.52	0.686	0.496
A5	0.528	0.601	0.748	0.460

MPJ – Width of the ball of the foot (cm), CALC – Width of the heel of the foot (cm), A1 – Foot length from the base of the heel to the apex of the 1st toe (cm), A2 – Foot length from the base of the heel to the apex of the 2nd toe (cm), A3 – Foot length from the base of the heel to the apex of the 3rd toe (cm), A4 – Foot length from the base of the heel to the apex of the 4th toe (cm), A5 – Foot length from the base of the heel to the apex of the 5th toe (cm).

Table 4
Differences between bare and socked foot measurements on right and left side.

	Right (bare versus socked)		Left (bare versus socked)	
	t-value	p-value	t-value	p-value
MPJ	6.665	< 0.001*	4.045	< 0.001*
CALC	3.188	0.002*	1.576	0.121
A1	0.383	0.703	1.305	0.198
A2	0.231	0.818	1.282	0.206
A3	0.086	0.932	0.106	0.916
A4	0.752	0.456	0.951	0.347
A5	1.093	0.283	0.309	0.759

MPJ – Width of the ball of the foot (cm), CALC – Width of the heel of the foot (cm), A1 – Foot length from the base of the heel to the apex of the 1st toe (cm), A2 – Foot length from the base of the heel to the apex of the 2nd toe (cm), A3 – Foot length from the base of the heel to the apex of the 3rd toe (cm), A4 – Foot length from the base of the heel to the apex of the 4th toe (cm), A5 – Foot length from the base of the heel to the apex of the 5th toe (cm).

* Statistically significant.

dimensional measurements and the extrapolation with bare footprint standards may an avenue for further research.

Sock-clad footprints would generally not be expected to show skin features or abnormalities, such as dermal ridges, creases, pits, and other irregularities, though thin socks may reveal such findings. Alternatively, comparing sock-clad crime scene footprints to suspect sock-clad footprints may show sock-induced similarities, such as a sock bunching up under toes in a particular manner. This study did not consider these possibilities.

This study was limited in that it was carried out under control conditions and the sample population was relatively small and limited to students at a particular college. Future research could assess a larger and/or broader population and may consider more 'real-world' scenarios or environments. Another limitation of the study is that participants were allowed to use their own socks for the study. This was done for hygienic reasons and comfort of the participants. However, this might have caused differences in measurements of the sock-clad footprints. While this is more consistent with 'real-world' scenarios, future research should consider giving participants new socks of the same brand and style. The controlled make and thickness of the socks could allow for more consistency in measurements.

5. Conclusion

This pilot study analyzed the differences and/or similarities between length and width linear measurements of bare and sock-clad footprints utilizing the Reel linear measurement methodology. No significant differences between the various length measurements of bare and sock-clad footprints on either right or left side were found. Significant differences were found between various width measurements of bare and sock-clad footprints. No significant differences were found between right and left side footprints. This study establishes that a footprint found at crime scene does not require bare or sock-clad distinction when utilizing the length measurements of the Reel method comparison to a suspect's footprint. Further, this study implies that experts may apply the standards and research developed from bare footprints to sock-clad footprints for linear length measurement scenarios. Width measurements need a determination of whether the footprint is bare or sock-clad, and experts should apply width standards developed from bare footprints to sock-clad footprints with caution. However, since the study is limited to a small, opportunistic sample of participants, a larger and more 'real-world' pool of participants is warranted in future studies to confirm the observations made in the present study.

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References

[1] M.R. Bennett, S.A. Morse, Human Footprints: Fossilised Locomotion? Springer, Springer International Publishing, Cham, 2014.
[2] L.T. Staheli, D.E. Chew, M. Corbett, The longitudinal arch. A survey of eight hundred and eighty-two feet in normal children and adults, J. Bone Jt. Surg. Am. 69 (1987) 426–428.
[3] P. Stavlas, T.B. Grivas, C. Michas, E. Vasiliadis, V. Polyzois, The evolution of foot morphology in children between 6 and 17 years of age: a cross-sectional study based on footprints in a Mediterranean population, J. Foot Ankle Surg. 44 (2005) 424–428.
[4] S.C. Wearing, A.P. Hills, N.M. Byrne, E.M. Hennig, M. McDonald, The arch index: a measure of flat or fat feet? Foot Ankle Int. 25 (2004) 575–581.
[5] E.A. Welton, The Harris and Beath footprint: interpretation and clinical value, Foot Ankle 13 (1992) 462–468.
[6] J.C. Cobey, E. Sella, Standardizing methods of measurement of foot shape by including the effects of subtalar rotation, Foot Ankle 2 (1981) 30–36.
[7] M. Nirenberg, Meeting a forensic podiatry admissibility challenge: a Daubert case study, J. Forensic Sci. 61 (2016) 833–841.
[8] J. Hamilton, Scottish Murders: From Burke and Hare to Peter Tobin, Waverly Books, 2013.
[9] W. Vernon, The development and practice of forensic podiatry, J. Clin. Forensic Med. 13 (2006) 284–287.
[10] J.A. Dimaggio, The role of feet and footwear in medicolegal investigations, in: J. Rich, D.E. Dean, R.H. Powers (Eds.), Forensic Medicine of the Lower Extremity, Humana Press, Totowa, NJ, 2005, pp. 375–400.
[11] N. Gunn, Old and new methods of evaluating footprint impressions by a forensic podiatrist, Br. J. Podiatr. Med. Surg. 3 (1991) 8–11.
[12] W. Vernon, J.A. Dimaggio, Forensic Podiatry: Principles and Methods, 2nd ed., CRC Press, Boca Raton, FL, 2017.
[13] K. Krishan, Individualizing characteristics of footprints in Gujjars of north India, Forensic Sci. Int. 169 (2007) 137–144.
[14] W. Vernon, N. Simmonite, S. Reel, S. Reidy, An investigation into the cause of the inner dark areas and outer lighter areas (ghosting) seen in dynamically-created two-dimensional bare footprints, Sci. Justice 57 (2017) 276–282.
[15] J.G. Burrow, A Comparison between Manual and Digital Measurements in Exemplar Bare Footprint Analysis, Int. J. Forensic Sci. 2 (2017) 000116Available at: https://medwinpublishers.com/IJFSC/IJFSC16000116.php?id=25.
[16] S. Reel, S. Rouse, W. Vernon, P. Doherty, Reliability of a two dimensional footprint measurement approach, Sci. Justice 50 (2010) 113–118.
[17] J.G. Burrow, Bare footprint analysis comparing two collection methods adopting the reel measurement system and adobe photoshop, Forensic Res. Criminol. Int. J. 2 (2) (2016) 00050, https://doi.org/10.15406/frcij.2016.02.00050.
[18] R.B. Kennedy, Ongoing research into barefoot impression evidence, in: J. Rich, D.E. Dean, R.H. Powers (Eds.), Forensic Medicine of the Lower Extremity: Human Identification and Trauma Analysis of the Thigh, Leg and Foot, The Humana Press Inc, Totowa, NJ, 2005, pp. 401–413.
[19] R.B. Kennedy, Uniqueness of bare feet and its use as a possible means of identification, Forensic Sci. Int. 82 (1996) 81–87.
[20] R.B. Kennedy, S. Chen, I.S. Pressman, A.B. Yamashita, A.E. Pressman, A large-scale

statistical analysis of barefoot impressions, J. Forensic Sci. 50 (2005) 1071–1080.
[21] R.B. Kennedy, I.S. Pressman, S. Chen, P.H. Petersen, A.E. Pressman, Statistical analysis of barefoot impressions, J. Forensic Sci. 48 (2003) 55–63.
[22] G.E. Laskowski, V.L. Kyle, Barefoot impressions—a preliminary study of identification characteristics and population frequency of their morphological features, J. Forensic Sci. 33 (1988) 378–388.
[23] S.R. Qamra, B.P. Sharma, P. Kaila, Naked foot marks—a preliminary study of identification factors, Forensic Sci. Int. 16 (1980) 145–152.
[24] T. Kanchan, K. Krishan, S. Shyam Sundar, K.R. Aparna, S. Jaiswal, Analysis of footprint and its parts for stature estimation in Indian population, Foot 22 (2012) 175–180.
[25] W. Vernon, The foot, in: T. Thompson, S. Black (Eds.), Forensic Human Identification: An Introduction, CRC Press, Boca Raton, FL, 2007, pp. 303–320.
[26] C.J. Smerecki, C.O. Lovejoy, Identification via pedal morphology, Int. Crim. Police Rev. 40 (1985) 186–190.
[27] K. Krishan, T. Kanchan, J.A. DiMaggio, Emergence of forensic podiatry—a novel sub-discipline of forensic sciences, Forensic Sci. Int. 55 (2015) 16–27.
[28] D.V. Oberoi, A. Kuruvilla, K.M. Saralaya, A. Rajeev, B. Ashok, K.R. Nagesh, N.G. Rao, Estimation of stature and sex from footprint length using regression formulae and standard footprint length formulae respectively, J. Punjab Acad. Forensic Med. Toxiol. 6 (2006) 5–8.
[29] K. Krishan, Establishing correlation of footprints with body weight—forensic aspects, Forensic Sci. Int. 179 (2008) 63–69.
[30] S.L. Barker, J.L. Scheuer, Predictive value of human footprints in a forensic context, Med. Sci. Law 38 (1998) 341–346.
[31] W.G. Kerr, Seen at the scene—plantar dermatoglyphic use in identification and detection, Br. J. Podiatry 3 (2000) 57–60.
[32] D.H. Richie, Athletic socks, Athletic footwear and orthoses in sports medicine, Springer, Cham, 2017, pp. 91–105.
[33] H.J. Murray, A. Veves, M.J. Young, D.H. Richie, A.J. Boulton, Role of experimental socks in the care of the high-risk diabetic foot: a multicenter patient evaluation study, Diabetes Care 16 (1993) 1190–1192.
[34] T. Blackmore, D. Jessop, S. Bruce-Low, J. Scurr, The cushioning properties of athletic socks: an impact testing perspective, Clin. Biomech. 28 (2013) 825–830.
[35] X.-Q. Dai, Y. Li, M. Zhang, J.T.-M. Cheung, Effect of sock on biomechanical responses of foot during walking, Clin. Biomech. 21 (2006) 314–321.
[36] M. Morlock, T. Mittlmeiser, First step method vs. full gait method – results of a comparison, Eur. J. Phys. Med. Rehab. 2 (Suppl. 1) (1992) 33–34.
[37] S.C. Wearing, S.R. Urry, J.E. Smeathers, D. Battistutta, A comparison of gait initiation and termination methods for obtaining plantar foot pressures, Gait Posture 10 (1999) 255–263.
[38] S. Reel, S. Rouse, W. Vernon, P. Doherty, Estimation of stature from static and dynamic footprints, Forensic Sci. Int. 219 (2012) 283.e1–283.e5.
[39] W.A. Rossi, The high incidence of mismated feet in the population, Foot Ankle 4 (1983) 105–112.
[40] I.A. Fawzy, N.N. Kamal, Stature and body weight estimation from various footprint measurements among Egyptian population, J. Forensic Sci. 55 (2010) 884–888.
[41] K. Krishan, Estimation of stature from footprint and foot outline dimensions in Gujjars of North India, Forensic Sci. Int. 175 (2008) 93–101.
[42] R. Mukhra, K. Krishan, T. Kanchan, Bare footprint metric analysis methods for comparison and identification in forensic examinations: a review of literature, J. Forensic Legal Med. 58 (2018) 101–112.
[43] T. Uetake, Can we really walk straight? Am. J. Phys. Anthropol. 89 (1992) 19–27.