EJA

Eurasian Journal of Anthropology
ISSN: 2166-7411

Euras J Anthropol 15(1):1-14, 2025

Can footprint measurements be an alternative for foot measurements? A forensic anthropological approach

Saumya Seal[1], Devi Das[1], Suryakant Soni[2]

[1]Department of Anthropology, Panjab University, Chandigarh, India
[2]Department of Anthropology, Dr. Harisingh Gour University, Sagar, India

Article info

Received: 16 November 2024

Accepted: 21 April 2025

Key words

Forensic sciences, footprint dimensions, foot dimensions, anthropometric techniques, North-West India

For correspondence

Saumya Seal

Department of Anthropology, Panjab University, 160014, Chandigarh, India

ORCID: 0009-0009-1880-9194

E-mail: seal.saumya@gmail.com

Abstract

Footprints and foot measurements have recently gained importance as evidence in forensic case-works as the chances of recovering any pedal evidences from crime scenes or site of accidents are frequent. The present cross-sectional investigation aims to evaluate the morphometric differences between footprint and foot measurements and infer whether footprint evidences can be a replacement for foot morphometry, and vice versa. Age group of 17-26 years (128 males and 77 females) were selected as part of the research from Rajasthan state in North-West India. Seven linear anthropometric measurements were considered for both footprint and its subsequent foot measurement: T1-T5 lengths, breadths at ball region and heel region. Results inflicted 3rd toe dimensions of footprints showed the highest correlation with its corresponding foot measurement due to larger correlational and regression coefficient values. Further research on larger and diverse populations are recommended to validate the present findings and enhance forensic and anthropometric applications.

Introduction

A specialized field of forensic sciences is termed "forensic podiatry" that utilizes podiatry's principles to assist with criminal and legal investigations. In order to help identify suspects, connect people to crime scenes, and provide expert testimony in court, it entails analyzing foot, footprint, foot imprint, and footwear evidences by considering size, stride patterns, uncommon and distinctive features of the foot. In circumstances like natural disasters, terrorist attacks, homicides, or in any sort of crime scenes, the likelihood to recover pedal evidences are frequent (Staylas et al., 2005; DiMaggio and Vernon, 2011). Its growing importance highlights the intersection of science, medicine and law. Earlier human feet and other pedal evidences like footprints were not considered significant but gained importance recently with progressive developments in anthropometric methodologies, 3-D technology and machine learning algorithms (Seal and Soni, 2025). The biological profile of an unknown individual can be formulated from different foot evidences with reasonable accuracies due to its uniqueness among and even between populations (Hemy et al., 2013a). Studies have been conducted in the past on different ethnic populations around the world that has focused in establishing the identity of an unknown individual from foot and footprint measurements (Robbins, 1986; Krishan and Sharma, 2007; Krishan, 2008; Atamturk, 2010; Kanchan et al., 2010; Fawzy and Kamal, 2010; Sen et al., 2011; Hemy et al., 2013*a*,*b*; Basu and Bandyopadhyay, 2017; Seal et al., 2025). These studies examined population groups of different age groups. Additional research has explored samples of various ages from forensic and anatomical perspectives, comparing differences in human feet relative to growth in body size and weight (Robbins, 1986; Laskowski and Kyle, 1988; Atamturk and Duyar, 2008).

In forensic situations, foot evidences and footprints are rarely complete (Pickering and Bachman, 2009). Particularly for situations where partial or complete footprints are recovered, the present study investigates the potential of foot dimensions as a reliable alternative to its subsequent footprint parameters in forensic investigations, and whether they can be effectively substituted by one another. The aim of this research is to investigate the differences between foot measurements and footprint measurements using dermatoglyphic and anthropometric techniques in forensic context and assess how footprint measurements compare to foot dimensions in terms of accuracy and reliability for personal identification. By understanding the variations between the two, the study will evaluate the potential of foot measurements as a practical tool in criminal and legal investigations, especially when footprint evidences are recovered from the crime scene and vice versa.

Materials and methods

The present cross-sectional research was conducted in Rajasthan state in North-West India, and included 205 young adults (128 males and 77 females) aged 17 to 26 years, representing various several local endogamous population groups. The selected age range was based on evidence suggesting that the human foot typically attains its full size by the age of 14 to 16 years (Anderson et al., 1956). Participants were recruited through a purposive convenience sampling method, since this field-based study focuses on young adults from population groups within a selected geographic area in a limited time frame. Participants were considered eligible if they had ancestral ties to the study region extending back at least three generations. This criterion was applied to minimize potential genetic variation within ethnic groups that could impact the study's findings. Individuals with a known history of foot-related diseases, orthopedic deformities, injuries, or disorders were excluded from participation.

Seven anthropometric foot measurements were recorded following the methodology outlined by Robbins (1985) (Table 1). In addition, footprints were collected using dermatoglyphic techniques. For footprint collection, participants were instructed to thoroughly wash their feet with soap water. A clean glass plate, 8 mm thick, was evenly coated with quick-drying black duplicating ink using a footprint roller. Participants then placed their feet on the inked plate with gentle, controlled pressure, after which their inked foot was transferred onto a sheet of A3-sized white art paper placed on a uniform surface. Thus, in accordance with the methodology of Robbins (1985), further refined by Krishan (2008), seven measurements were extracted from the footprints using the same anatomical landmarks that were employed for direct foot measurements.

Table 1: Anthropometric measurements used in the present study

Measurements	Definition	Instrument used
Pternion-T1	It is the greatest distance between the heel's most posterior point to the anterior-most point of the first digit of the toe	Anthropometric rod compass
Pternion-T2	It is the greatest distance between the heel's most posterior point to the anterior-most point of the second digit of the toe	Anthropometric rod compass
Pternion-T3	It is the greatest distance between the heel's most posterior point to the anterior-most point of the third digit of the toe.	Anthropometric rod compass
Pternion-T4	It is the greatest distance between the heel's most posterior point to the anterior-most point of the fourth digit of the toe	Anthropometric rod compass
Pternion-T5	It is the greatest distance between the heel's most posterior point to the anterior-most point of the fifth digit of the toe	Anthropometric rod compass
Ball breadth	It is measured from the metatarsal lateral, which is the most lateral point on toe-5, and the metatarsal medial, which is the most medial point on the first metatarsophalangeal joint	Sliding caliper
Heel breadth	It is measured from calcaneal concavity medial to calcaneal tubercle laterale	Sliding caliper

Statistical analyses were conducted using the Statistical Package for Social Sciences (SPSS) software, version 26 (SPSS, Inc., Chicago, IL, USA). Descriptive statistics: including range, mean value, standard deviation (S.D.), skewness and kurtosis, were computed. A Shapiro-Wilk test was subsequently performed to assess the normality of the data. A paired t-test (for parametric variables) and Wilcoxon rank test (for non-parametric variables) was conducted to compare the foot measurements with their corresponding footprint measurements, determining the differences between the two sets of variables. For the correlation analysis, Pearson correlation coefficient (for parametric variables) and Spearman correlation coefficient (for non-parametric variables) was obtained to evaluate the relationships between footprint and foot measurements. To check the degree of association and consistency in the findings, linear regression equations were developed and Durbin-Watson tests were performed as part of the analyses.

Results and discussion

In developing and low-income countries like India, occurrence of crimes and accidental deaths are often high, naturally indicating high prevalence of podiatric evidences (Krishan, 2008). The present investigation found out positive differences between footprint and foot dimensions.

Table 2: Descriptive statistics to assess normality for bilateral male (*n* = 128) and female (*n* = 77) footprint measurements

Variables	Sex	Left					Right				
		Range (cm)	Mean (cm)	S.D.	Skewness	Kurtosis	Range (cm)	Mean (cm)	S.D.	Skewness	Kurtosis
FPT1	Male	20.4-27.7	24.81	1.15	-0.57	1.25	20.8-27.4	24.79	1.15	-0.31	0.25
	Female	20.0-24.8	22.44	0.98	0.21	-0.49	19.9-25.0	22.49	1.08	0.32	-0.74
FPT2	Male	20.5-28.0	24.71	1.12	-0.35	1.06	20.7-27.8	24.72	1.17	-0.22	0.35
	Female	19.7-25.1	22.33	1.14	0.16	-0.34	19.9-25.4	22.37	1.23	0.29	-0.60
FPT3	Male	20.0-27.2	23.90	1.14	-0.04	0.71	19.9-26.7	23.87	1.22	-0.17	0.17
	Female	19.1-24.5	21.64	1.12	0.36	-0.51	19.6-24.6	21.65	1.21	0.43	-0.65
FPT4	Male	19.1-25.7	22.65	1.06	-0.05	0.53	19.0-25.3	22.61	1.14	-0.16	0.10
	Female	18.2-23.0	20.46	1.01	0.56	-0.09	18.9-23.5	20.42	1.34	0.52	-0.26
FPT5	Male	18.1-23.4	20.96	0.95	-0.18	0.10	17.9-23.3	20.97	0.98	-0.28	0.27
	Female	16.8-21.5	18.89	0.90	0.81	-0.001	16.9-21.5	18.93	0.99	0.66	-0.42
FPBB	Male	7.9-11.7	9.75	0.65	-0.13	0.35	8.1-11.5	9.73	0.63	0.08	0.72
	Female	7.5-10.3	8.70	0.50	0.03	0.63	7.4-10.1	8.64	0.51	-0.20	0.71
FPHB	Male	4.3-6.6	5.37	0.43	-0.25	-0.18	4.4-6.2	5.44	0.39	-0.31	-0.25
	Female	4.3-6.0	4.91	0.36	-0.01	0.89	4.2-6.4	4.94	0.37	0.08	0.86

(refer to Table 2 for measurement abbreviations)

Descriptive statistical analysis of male and female footprint and foot measurements in bilateral sides depict significant differences in mean values of measurements (Table 2 and 3). Left side depict higher mean values in comparison to right side measurements while means of female foot dimensions are found to be significantly lesser than male dimensions. Our findings are similar to podiatric research done on varied populations all over the world by Ozden et al. (2005) and Zeybek et al. (2008) on Turkish sub-populations, Fawzy and Kamal (2010) on an Egyptian ethnic group and Moorthy et al. (2014) amongst a South Indian population. Shapiro-Wilk analysis to check frequency distribution and normality of the data reveals LT1, LT3, LT5, LHB, RT3, RBB and RHB to be parametric, i.e. the data is normally distributed (significance ≤ 0.05) and LT2, LT4, LBB, RT1, RT2, RT4 and RT5 to be non-parametric i.e. the data does not show normal distribution (significance > 0.05) (Table 4). This uneven distribution can possibly be ascribed to natural male-female differences in a population and hereditary, nutritional and environmental factors that products in comprehensive growth and development of an individual. Comparable outcomes can be inferred from research carried out on footprint and foot dimensions in the past by Jasuja et al. (1991) and Krishan et al. (2011) in a North Indian population, Sanli et al. (2005) in a Turkish population, Hemy et al. (2013*a*,*b*) in an Australian population where variable distribution of parametric and non-parametric variables was observed. The present study thus highlights the need to study different aspects of podiatry in populations around the world, as this can aid in addressing concerns related to forensic, anatomical, clinical and ergonomic contexts and while assessing differences in growth rates among individuals.

Table 3: Descriptive statistics to assess normality for bilateral male (*n* = 128) and female (*n* = 77) foot measurements

Variables	Sex	Left					Right				
		Range (cm)	Mean (cm)	S.D.	Skewness	Kurtosis	Range (cm)	Mean (cm)	S.D.	Skewness	Kurtosis
FDT1	Male	19.6-26.4	23.40	1.11	-0.36	0.50	19.3-25.7	23.13	1.03	-0.22	0.94
	Female	18.6-24.2	21.44	1.27	0.21	-0.49	18.7-24.1	21.30	1.35	0.32	-0.74
FDT2	Male	19.7-26.8	22.87	1.14	-0.09	0.46	19.6-26.2	22.74	1.10	0.008	0.24
	Female	17.4-23.8	20.92	1.41	0.16	-0.34	17.9-23.7	20.85	1.45	0.29	-0.60
FDT3	Male	18.2-25.2	22.00	1.18	-0.42	0.64	18.7-25.4	21.93	1.13	-0.08	0.38
	Female	17.1-23.4	20.14	1.47	0.36	-0.51	17.5-23.4	20.18	1.48	0.43	-0.65
FDT4	Male	16.8-23.4	20.61	1.24	-0.40	0.60	17.6-23.5	20.60	1.15	-0.06	0.05
	Female	16.1-22.7	18.86	1.52	0.56	-0.09	16.5-22.8	19.02	1.47	0.52	-0.26
FDT5	Male	16.1-23.6	19.04	1.31	0.01	0.30	16.1-22.0	18.99	1.00	0.22	0.61
	Female	15.2-21.0	17.37	1.49	0.81	-0.001	15.6-20.8	17.53	1.40	0.66	-0.42
FDBB	Male	8.0-11.8	9.95	0.62	-0.06	0.48	8.3-12.1	10.03	0.62	0.34	1.26
	Female	7.2-10.2	8.75	0.52	0.03	0.63	7.0-10.1	8.69	0.53	-0.20	0.71
FDHB	Male	4.8-7.0	6.11	0.41	-0.30	0.02	4.8-6.9	6.07	0.40	-0.30	-0.21
	Female	4.4-6.8	5.43	0.44	-0.01	0.89	4.5-6.6	5.44	0.41	0.08	0.86

(refer to Table 2 for measurement abbreviations)

Table 4: Shapiro-Wilk test to confirm normality of footprint and foot measurements on bilateral pooled data sample [male (*n* = 128) and female (*n* = 77)]

Variables	Side	Shapiro-wilk test	Significance
FPT1	Left	0.984	0.036
	Right	0.986	0.069
FPT2	Left	0.987	0.090
	Right	0.986	0.070
FPT3	Left	0.985	0.046
	Right	0.985	0.050
FPT4	Left	0.988	0.139
	Right	0.986	0.068
FPT5	Left	0.985	0.049
	Right	0.978	0.006
FPBB	Left	0.987	0.100
	Right	0.982	0.021
FPHB	Left	0.975	0.003
	Right	0.981	0.016
FDT1	Left	0.980	0.005
	Right	0.972	0.000
FDT2	Left	0.981	0.007
	Right	0.982	0.011
FDT3	Left	0.978	0.003
	Right	0.980	0.004
FDT4	Left	0.984	0.020
	Right	0.987	0.067
FDT5	Left	0.982	0.010
	Right	0.985	0.027
FDBB	Left	0.991	0.230
	Right	0.982	0.010

(refer to Table 2 for measurement abbreviations)

Table 5: Paired t-test/Wilcoxon ranked test to assess differences between bilateral footprint and foot measurements [male (*n* = 128) and female (*n* = 77)]

Variables	Males		Females	
	T-Value/ Z-Value	Significance (2-tailed)	T-Value/ Z-Value	Significance (2-tailed)
LFPT1-LFDT1	21.927	0.000	8.723	0.000
LFPT2-LFDT2	-9.815	0.000	-6.885	0.000
LFPT3-LFDT3	29.989	0.000	10.843	0.000
LFPT4-LFDT4	-9.706	0.000	-6.890	0.000
LFPT5-RFDT5	31.443	0.000	10.069	0.000
LFPBB-LFDBB	-4.462	0.000	-1.223	0.000
LFPHB-LFDHB	-16.347	0.000	-10.456	0.000
RFPT1-RFDT1	-9.709	0.000	-6.433	0.000
RFPT2-RFDT2	-9.726	0.000	-6.959	0.000
RFPT3-RFDT3	34.106	0.000	11.029	0.000
RFPT4-RFDT4	-9.674	0.000	-6.928	0.000
RFPT5-RFDT5	-9.607	0.000	-6.232	0.000
RFPBB-RFDBB	-6.336	0.000	-1.099	0.000
RFPHB-RFDHB	-15.130	0.000	-10.317	0.000

LFPT1 – Left footprint dimension toe 1, LFPT2 – Left footprint dimension toe 2, LFPT3 – Left footprint dimension toe 3, LFDT4 – Left footprint dimension toe 4, LFPT5 – Left footprint dimension toe 5, LFPBB – Left footprint dimension ball breadth, LFPHB – Left footprint dimension heel breadth, RFPT1 – Right footprint dimension toe 1, RFPT2 – Right footprint dimension toe 2, RFPT3 – Right footprint dimension toe 3, RFPT4 – Right footprint dimension toe 4, RFPT5 – Right footprint dimension toe 5, RFPBB – Right footprint dimension ball breadth, RFPHB – Right footprint dimension heel breadth, LFDT1 – Left foot dimension toe 1, LFDT2 – Left foot dimension toe 2, LFDT3 – Left foot dimension toe 3, LFDT4 – Left foot dimension toe 4, LFDT5 – Left foot dimension toe 5, LFDBB – Left foot dimension ball breadth, LFDHB – Left foot dimension heel breadth, RFDT1-Right foot dimension toe 1, RFDT2 – Right foot dimension toe 2, RFDT3 – Right foot dimension toe 3, RFDT4-Right foot dimension toe 4, RFDT5 – Right foot dimension toe 5, RFDBB – Right foot dimension ball breadth, RFDHB – Right foot dimension heel breadth

The degree of differences in footprint and foot measurements in males and females are presented in Table 5. Paired *t*-test (for parametric variables) and Wilcoxon ranked test (Z) (for non-parametric variables) were used to assess the level of difference between seven linear anthropometric measurements of bilateral footprints with their respective measurements. Statistically significant ($p < 0.05$) differences were observed among both sexes. Among males, bilateral T3 (34.106 for right side and 29.989 for left sides) showed highest differences in measurements followed by T5 (31.443) and T1 (21.927) of the left sides, while bilateral BB (-4.422 for left sides and -6.336 for right sides) showed least difference for comparison. Additionally, negative values inferred footprint measurements to be greater than foot measurements. In females, similar observations were made with bilateral T3 (11.029 for right side and 10.843 for left side) showed significant differences followed by T3 (10.843) of left sides. Ball breadths (-1.223 for left sides and -1.099 for right sides), T5 (-6.232) and T1 (-6.433) of right sides was found to have least difference. The findings revealed minimal variation in ball breadths, indicating a lower degree of discrepancy and comparative stability in contrast to other parameters. This consistency may make ball breadth dimensions a useful alternate parameter in scenarios in which footprints arelocated. However, their utility may be limited when viewed in isolation, as other metrics with greater differential variability may have unique discriminatory potential. Thus, additional confirmatory tests were performed to determine the reliable alternative parameter.

Table 6: Pearson test/Spearman's rho test to assess correlation between bilateral footprint and foot measurements [male (*n* = 128) and female (*n* = 77)]

Variables	Male		Female	
	Pearson/Spearman's correlation (r)	Significance (0.01 level)	Pearson/Spearman's correlation (r)	Significance (0.01 level)
LFPT1-LFDT1	0.796	0.000	0.634	0.000
LFPT2-LFDT2	0.792	0.000	0.638	0.000
LFPT3-LFDT3	0.812	0.000	0.587	0.000
LFPT4-LFDT4	0.772	0.000	0.596	0.000
LFPT5-LFDT5	0.752	0.000	0.586	0.000
LFPBB-LFDBB	0.697	0.000	0.660	0.000
LFPHB-LFDHB	0.284	0.000	0.410	0.000
RFPT1-RFDT1	0.772	0.000	0.587	0.000
RFPT2-RFDT2	0.808	0.000	0.646	0.000
RFPT3-RFDT3	0.854	0.000	0.645	0.000
RFPT4-RFDT4	0.824	0.000	0.632	0.000
RFPT5-RFDT5	0.720	0.000	0.606	0.000
RFPBB-RFDBB	0.630	0.000	0.641	0.000
RFPHB-RFDHB	0.300	0.000	0.414	0.000

r – Correlation coefficient (refer to Table 6 for measurement abbreviations)

Pearson's correlation (for parametric variables) and Spearman's rho (for non-parametric variables) tests found coefficient value (*r*) in males (0.854 - 0.284) was greater as compared to females (0.660 - 0.410). Third toe (RFPT3) for the right side showed highest correlation with its subsequent foot dimensions (RFDT3) in both males (0.854) and females (0.645). Heel breadths (0.300 in males and 0.414 in females) showed lesser correlation, in comparison to toe lengths (Table 6). Though Pearson's and Spearman's correlation (*r*) coefficients suggest that the 3rd toe's footprint measurements closely correspond to its corresponding foot dimensions for both genders, the contrast of the (*r*) value findings with t-test results highlights the complexity of identifying the consistent footprint parameter that can replace foot measurements. This complexity underscores the need for confirmatory statistical approaches, such as linear regression models, to provide a comprehensive understanding of the degree of association between the two parameters.

Linear regression analysis was performed considering footprint measurements as dependent variables and its corresponding foot measurements as independent variables (Table 7). The equations were derived according to the model $Y = b_0+(b_1*X)$, where (Y) represented the predicted value of the footprint measurement, (b_0) represented the intercept value, (b_1) represented the coefficient of the foot measurement and (X) represented the actual foot measurement. Higher adjusted regression coefficient (R^2) values across the seven variables suggest that foot measures more accurately account for the variation in footprint measurements among males (0.073 - 0.727) than among females (0.157 - 0.495). Specifically, the right side of T3 exhibited the highest R^2 value (0.727) in males, but in females, the left BB demonstrated the highest value (R^2 = 0.495). The lower standard error of estimate (SEE) in males (0.381 - 0.700) suggests that the generated regression models are relatively precise compared to females (0.343 - 0.768). The Durbin-Watson statistic, used to identify autocorrelation in residuals, remains within the range of 2 across all regression models, thereby affirming consistency in the analyses for both genders. It also indicates that the linear regression models are consistent across genders and sides and accurately represent

Table 7: Linear regression analysis between bilateral footprint measurements and foot measurements, with Durbin-Watson test for consistency analysis [male (*n* = 128) and female (*n* = 77)]

Variables	Side	Male					Female				
		Regression equations Y = $b_0+(b_1 * X)$	Adjusted R^2	R^2	SEE	Durbin-Watson	Regression equations Y = $b_0+(b_1 * X)$	Adjusted R^2	R^2	SEE	Durbin-Watson
FPT1-FDT1	Left	LFPT1 = 5.650+0.819(LFDT1)	0.630	0.633	0.700	1.625	LFPT1 = 11.916+0.491(LFDT1)	0.394	0.402	0.768	1.203
	Right	RFPT1 = 4.080+0.896(RFDT1)	0.645	0.648	0.690	1.717	RFPT1 = 12.964+0.447(RFDT1)	0.301	0.310	0.906	1.275
FPT2-FDT2	Left	LFPT2 = 6.404+0.801(RFDT2)	0.658	0.660	0.657	1.456	LFPT2 = 11.930+0.497(LFDT2)	0.364	0.373	0.916	1.112
	Right	RFPT2 = 4.995+0.869(RFDT2)	0.665	0.668	0.679	1.557	RFPT2 = 11.380+0.527(RFDT2)	0.381	0.389	0.971	1.283
FPT3-FDT3	Left	LFPT3 = 6.745+0.780(LFDT3)	0.656	0.659	0.670	1.583	LFPT3 = 12.633+0.447(LFDT3)	0.336	0.345	0.913	1.226
	Right	RFPT3 = 3.718+0.919(RFDT3)	0.727	0.729	0.638	1.593	RFPT3 = 10.954+0.530(RFDT3)	0.409	0.417	0.937	1.300
FPT4-FDT4	Left	LFPT4 = 8.346+0.693(LFDT4)	0.607	0.610	0.668	1.671	LFPT4 = 13.050+0.393(LFDT4)	0.341	0.350	0.823	1.234
	Right	RFPT4 = 5.668+0.822(RFDT4)	0.671	0.673	0.656	1.675	RFPT4 = 11.417+0.477(RFDT4)	0.378	0.387	0.889	1.452
FPT5-FDT5	Left	LFPT5 = 7.458+0.711(LFDT5)	0.561	0.565	0.631	1.765	LFPT5 = 12.881+0.346(LFDT5)	0.333	0.343	0.741	1.466
	Right	RFPT5 = 7.467+0.711(RFDT5)	0.525	0.529	0.677	1.668	RFPT5 = 12.104+0.387(RFDT5)	0.301	0.311	0.830	1.199
FPBB-FDBB	Left	LFPBB = 2.833+0.695(LFDBB)	0.441	0.445	0.486	1.753	LFPBB = 2.757+0.680(LFDBB)	0.495	0.502	0.360	1.725
	Right	RFPBB = 3.290+0.642(RFDBB)	0.392	0.397	0.498	1.421	RFPBB = 3.209+0.625(RFBB)	0.403	0.411	0.401	1.978
FPHB-FDHB	Left	LFPHB = 3.532+0.302(LFDHB)	0.073	0.080	0.422	1.484	LFPHB = 3.090+0.335(LFDHB)	0.157	0.168	0.331	1.593
	Right	RFPHB = 3.625+0.300(RFDHB)	0.083	0.090	0.381	1.329	RFPHB = 2.926+0.370(RFDHB)	0.160	0.171	0.343	1.831

($Y = b_0 + b_1 * X$) – Linear regression equation, R^2 – Regression coefficient, SEE – standard error estimate, (refer to Table 2 or measurement abbreviations) the relationship between foot and footprint dimensions. The findings support the regression model's dependability for both male and female participants and highlight gender-based differences in predictive relationships. Figure 1 and Figure 2 depicts the correlation between footprint dimensions and its subsequent foot dimensions with quadratic regression plots in males (n = 128) and females (n = 77) respectively. Findings cannot be compared *per se* since no research exists that explicitly correlates footprint dimensions with their corresponding foot measurements, highlighting a gap in research conducted in forensic domain till date.

Studies have been performed in the past by forensic and biological anthropology experts to establish biological profiling of pedal evidences for personal identification, but the present investigation is a novel approach to find out the degree of association between footprint and morphometric characteristics of foot. The present investigation infers males exhibit greater associative capability than females, and the parameter Toe-3 in footprints demonstrated considerable promise as a substitute for foot dimensions because it possessed the largest Pearson's value and regression coefficient (in males), but detailed researches on larger sample sizes, growth patterns and the implementation of Artificial Intelligence (AI) models is recommended on varied populations to check the validity of the information, especially for forensic and anthropological purposes--where precision plays a major role in making these estimates.

Conclusions

Forensic podiatrists rely on foot related evidences for personal identification and establishing biological profile of an unknown individual. Results inflicted 3rd toe measurements in footprints demonstrated statistical reliability as a substitute for foot dimensions. The study further suggests to conduct similar investigations on different populations to check the validity of the present research by comparing morphometric growth patterns of footprints and foot on larger sample sizes.

Disclosure statement

The authors are indebted to the participants and the local administration of Udaipurwati town, Rajasthan state, India for their support to the study.

Conflict of Interest

None to declare.

Ethical consideration and funding

The study strictly adheres to academic ethical guidelines laid down by Panjab University, Chandigarh, India. The authors also declare no financial grant was received from funding agencies, as the present study is part of a M.Sc. dissertation carried out by trained forensic anthropologists.

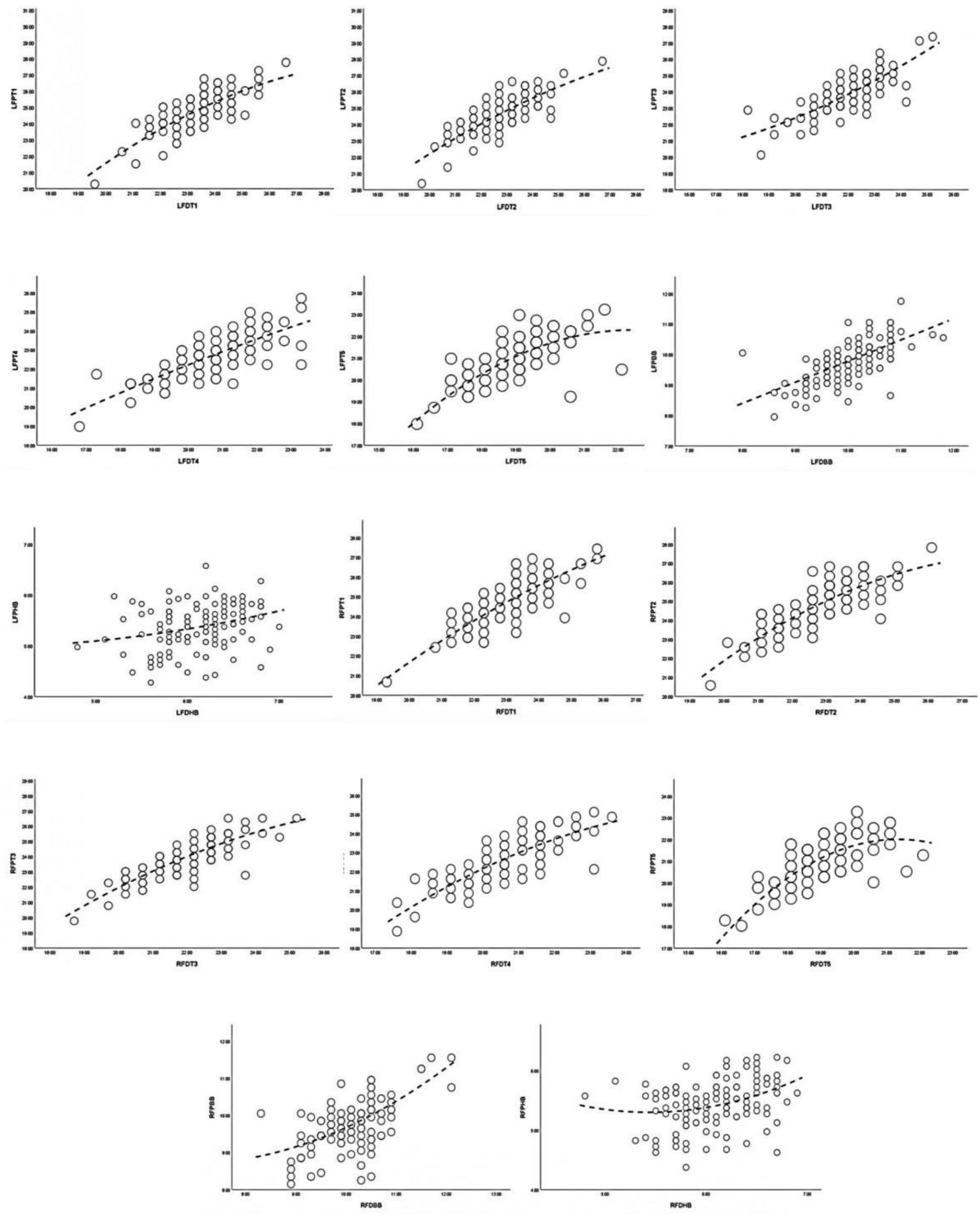

Figure 1: Correlation between footprint and foot measurements of male participants (*n* = 128) through quadratic regression plots

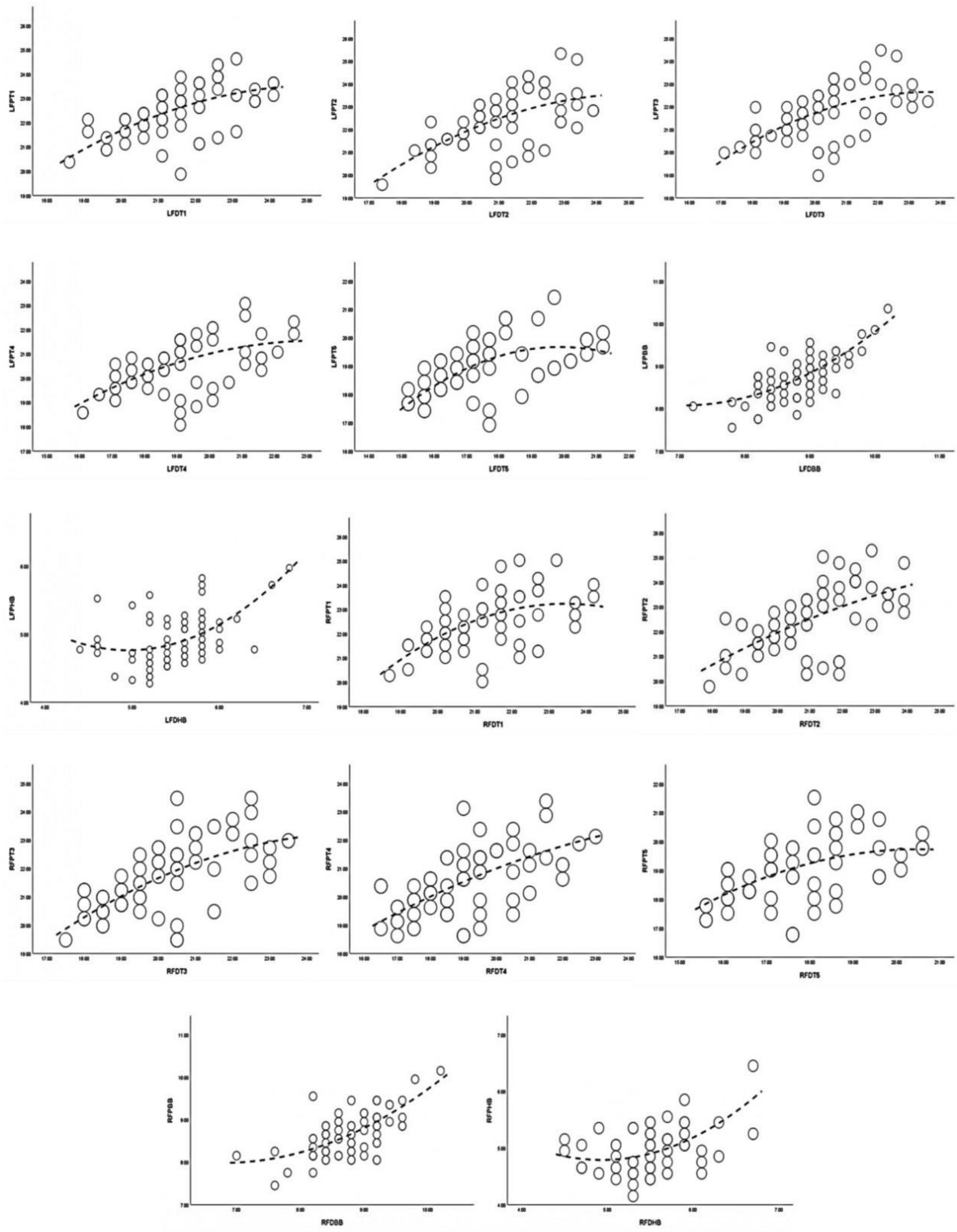

Figure 2: Correlation between footprint and foot measurements of female participants (*n* = 77) through quadratic regression plots

References

Anderson M, Blais M, Green WT. (1956) Growth of the normal foot during childhood and adolescence; length of the foot and interrelations of foot, stature, and lower extremity as seen in serial records of children between 1-18 years of age. Am J Phys Anthropol 14(2):287-308. https://doi.org/10.1002/ajpa.1330140221

Atamturk D. (2010) Estimation of sex from the dimensions of foot, footprints, and shoe. Anthropol Anz 68(1):21-29. https://www.jstor.org/stable/29543078

Atamturk D, Duyar I. (2008) Age-related factors in the relationship between foot measurements and living stature and body weight. J Forensic Sci 53(6):1296-1300. https://doi.org/10.1111/j.1556-4029.2008.00856.x

Basu N, Bandyopadhyay SK. (2017) Crime scene reconstruction—sex prediction from blood stained foot sole impressions. Forensic Sci Int 278:156-172. https://doi.org/10.1016/j.forsciint.2017.06.017

DiMaggio JA, Vernon W. (2011) Forensic Podiatry: Principles and Methods. First edition. USA: Humana Totowa NJ.

Fawzy IA, Kamal NN. (2010) Stature and body weight estimation from various footprint measurements among Egyptian population. J Forensic Sci 55(4):884-888. https://doi.org/10.1111/j.1556-4029.2010.01372.x

Gunn N. (1991) Old and new methods of evaluating footprint impressions by a forensic podiatrist. Br J Podiatr Med Surg 3:8-11.

Hemy N, Flavel A, Ishak NI, Franklin D. (2013) Estimation of stature using anthropometry of feet and footprints in a Western Australian population. J Forensic Leg Med 20(5):435-441. https://doi.org/10.1016/j.jflm.2012.12.008

Hemy N, Flavel A, Ishak NI, Franklin D. (2013) Sex estimation using anthropometry of feet and footprints in a Western Australian population. Forensic Sci Int 231(1-3):402-e1. https://doi.org/10.1016/j.forsciint.2013.05.029

Jasuja OP, Singh, J, Jain M. (1991) Estimation of stature from foot and shoe measurements by multiplication factors: a revised attempt. Forensic Sci Int 50(2):203-215. https://doi.org/10.1016/0379- 0738(91)90152-9

Kanchan T, Menezes RG, Moudgil R, Kaur R, Kotian MS, Garg RK. (2010) Stature estimation from foot length using universal regression formula in a North Indian population. J Forensic Sci 55(1):163-166. https://doi.org/10.1111/j.1556-4029.2009.01243.x

Krishan K. (2008) Estimation of stature from footprint and foot outline dimensions in Gujjars of North India. Forensic Sci Int 175(2-3):93-101. https://doi.org/10.1016/j.forsciint.2007.05.014

Krishan K, Sharma A. (2007) Estimation of stature from dimensions of hands and feet in a North Indian population. J Forensic Leg Med 14(6): 327-332. https://doi.org/10.1016/j.jcfm.2006.10.008

Krishan K, Kanchan T, Sharma A. (2011) Sex determination from hand and foot dimensions in a North Indian population. J Forensic Sci 56(2):453-459. https://doi.org/10.1111/j.1556-4029.2010.01652.x

Laskowski E, Kyle VL. (1988) Barefoot impressions: a preliminary study of identification characteristics and population frequency of their morphological features. J Forensic Sci 33(2):378-388. https://doi.org/10.1520/JFS11950J

Moorthy TN, Mostapa AMB, Boominathan R, Raman N. (2014) Stature estimation from footprint measurements in Indian Tamils by regression analysis. Egypt J Forensic Sci 4(1):7-16. https://doi.org/10.1016/j.ejfs.2013.10.002

Ozden H, Balci Y, Demirüstü C, Turgut A, Ertugrul M. (2005) Stature and sex estimate using foot and shoe dimensions. Forensic Sci Int 147(2-3):181-184. https://doi.org/10.1016/j.forsciint.2004.09.072

Pickering RB, Bachman D. (2009) The use of forensic anthropology. Taylor and Francis Group: CRC Press.

Robbins LM. (1985) Footprints—collection, analysis and interpretation. Springfield IL: Charles C. Thomas.

Robbins LM. (1986) Estimating height and weight from size of footprints. J Forensic Sci 31(1):143-152. https://doi.org/10.1520/JFS11868J

Seal S, Sahani R, Das D, Pal S, Guleria A, Chitara N, Rakesh M, Krishan K. (2025) Anthropometric measures to evaluate sex and stature from foot dimensions in a population of North-west India. Eur J Anat 29(2):181-191. https://doi.org/10.52083/UJQE5909

Seal S, Soni S. (2025) Sex Estimation Using Bare Footprint Dimensions: A Review of Literature. Pers Leg Forensic Sci 2(1):10004. https://doi.org/10.70322/plfs.2025.10004

Sen J, Kanchan T, Ghosh S. (2011) Sex estimation from foot dimensions in an indigenous Indian population. J Forensic Sci 56:S148-S153. https://doi.org/10.1111/j.1556-4029.2010.01578.x
Stavlas, P, Grivas TB, Michas C, Vasiliadis E, Polyzois V. (2005) 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(6): 424-428. https://doi.org/10.1053/j.jfas.2005.07.023
Weiner JS, Lourie JA. (1981) Practical Human Biology. United Kingdom: Academic Press.
Zeybek G, Ergur I, Demiroglu Z. (2008) Stature and gender estimation using foot measurements. Forensic Sci Int 181(1-3):54-e1. https://doi.org/10.1016/j.forsciint.2008.08.003