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Original Article

Age, Sex and Stature Estimation from Footprint Dimensions

Paurbhi Singh[1*], Baljeet Yadav[2]

[1] *Department of Biotechnology, Babasaheb Bhimrao Ambedkar University, Lucknow, India*

[2] *Institute of Forensic Science and Criminology, Bundelkhand University, Jhansi, India*

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Abstract

The present study was carried out to evaluate the utility and reliability of footprint dimensions in age, sex and stature determination in the North Indian population.

This study was carried out using a sample of 400 people (146 female and 254 male) aged 10-65 years in Uttar Pradesh, a North Western state of India. Footprints of both feet were taken bilaterally, and thus a total of 800 prints were obtained. A cluster of 7 measurements were taken carefully with the help of a scientific scale ruler. Five measurements were length dimensions from the most anterior part of each toe (T1–T5) to the mid rear heel point, and two were breadth dimensions from both left and right footprints: breadth at ball (BBAL), breadth at heel (BHEL). In addition, 2 indexes were recorded: heel-ball Index (HBI) and footprint index (FPI). All data were analyzed statistically using Student's t-test, regression coefficient and Pearson's correlation for the estimation of sex on the basis of footprint dimensions.

The T1 in left footprints was greater than right footprints in males, while T1 and BBAL were both found to be greater in left footprints than right footprints in females. All the seven foot dimensions were higher in males than females.

There were statistically significant differences observed in all footprint dimensions between the male and female footprints except LFPI, LHBI, and RHBI.

Keywords: Forensic Science, Footprints, Age, Stature, Sex estimation, India

* Corresponding Author: Paurbhi Singh
Email: paurbhisingh@gmail.com

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تقدير العمر والجنس والقامة من خلال أبعاد طبعة القدم

المستخلص

أجريت الدراسة الحالية من أجل تقييم إمكانية استخدام أبعاد طبعة القدم في تحديد كل من العمر والجنس والقامة عند سكان شمال الهند، والتي يمكن أن تساعد في التحقيقات عن طريق تضييق القائمة المحتملة للأشخاص المشتبه بهم.

أجريت هذه الدراسة باستخدام عينات من 400 شخص تتراوح

أعمارهم بين 65-10 سنة (146 من الإناث و 254 من الذكور) وذلك في ولاية أوتّار براديش (Uttar Pradesh)، وهي ولاية من ولايات الحزام الشمالي الغربي في الهند. وأخذت طبعة كلا القدمين من كل شخص على حدة، وبالتالي تم الحصول على 800 عينة طبعة قدم. وقد أخذ ما مجموعه سبعة قياسات هي كالتالي: خمسة قياسات للمسافة من الطرف الأمامي لكل إصبع حتى آخر نقطة من منتصف محيط الكعب وهي على التوالي (T1, T2, T3, T4, T5)، و عرض مقدمة القدم BBAL ، وعرض الكعب BHEL، ومؤشرين هما نسبة عرض الكعب إلى عرض مقدمة القدم (HBI) ومؤشر طبعة القدم(FPI)، وتم ذلك بكل عناية ودقة باستخدام مسطرة فولاذية مدرجة، وتم تحليل جميع البيانات إحصائياً باستخدام اختبار – ت t-test ، وكذلك معامل الانحدار ومعامل بيرسون للارتباط، وذلك لتحديد جنس المشتبه بهم استناداً إلى اختلاف أبعاد القدم بين الذكور والإناث .

بينت النتائج أن المسافة من طرف الأصبع الأكبر للقدم عن منتصف الخط المحيط للكعب T1 كان أكبر في طبعات الأقدام اليسرى مقارنة بطبعات الأقدام اليمنى عند الذكور، فيما عند الإناث كانت قيم كل من T1 وBBAL على حد سواء أكبر في بصمات الأقدام اليسرى مقارنة ببصمات الأقدام اليمنى. وكانت جميع أبعاد القدم أكبر بكثير عند الذكور منها وبفروق ذات دلالة إحصائية مقارنة بالإناث.

يستخلص من هذا البحث أنه هناك فروق ذات دلالة إحصائية بين الذكور والإناث في جميع أبعاد بصمة القدم باستثناء كل من LFPI، LHBI، وRHBI .

الكلمات المفتاحية: علوم الأدلة الجنائية، الاستعراف، بصمة القدم، تقدير، العمر، الجنس، القامة، الهند.

1. Introduction

Age, sex and stature are primary characteristics used to establish the biological profile of an individual. The science and technology of measuring and statistically analyzing physical and behavioral characteristics of an individual for the purpose of identification is known as biometrics. There are many biometric identifiers used for the identification or verification of a person's identity. An individual may be identified by fingerprints, voice, palm prints, hand geometry, iris patterns, retina characteristics, signatures, DNA types, keystroke dynamics and gait.[1]

Among all the biometric identifiers, fingerprint-based identification is the oldest and the most widely used method, which has been successfully and universally applied for human identity testing. Every human being is known to have a unique, immutable friction ridge pattern (fingerprints) that is not shared by any other living or dead individual, not even among identical or monozygotic twins. The uniqueness of a fingerprint is attributed to the pattern of ridges, furrows and minutiae points present on fingers.

In facial recognition, a digital video camera image is used to scan certain distinctive facial features such as geometric distance between eyes, contour of the eye sockets, nose, and chin. These measurements are stored in a database and then used to compare with a subject or suspect standing before a camera. In iris recognition, iris patterns are taken by a special gray-scale camera [2-3].

Stature is one of those identifying characteristics which have also been used for many years in crime investigations. There is always a proportional relationship between each part of the body and stature [4].

In hand and foot geometry, the length and the width of the fingers and feet are required. The identification of a person with the help of footprint analysis is an emerging biometric technique [5]. Footprints are the impressions which are left behind by a person when he walks and is a general term used for bare footprints [6]. Usually, criminals remove their footwear to gain better grip in climbing walls or to avoid noise etc., [7]. When a criminal enters or exits a crime scene barefooted, footprints are frequently found on surfaces like floors, windows, and ceramic tiles and sometimes on carpets if feet are muddy or soiled with paint or

blood. [1]

Footprints are the second most common evidence type found at the crime scene [8]. Individual characteristics of a footprint recorded at a crime scene can help forensic investigators in establishing the identity of the person who deposited them or narrow down a long list of suspects [9-11].

This study was carried out to verify the utility and reliability of footprint dimensions in age, sex and stature determination in a North Indian population, which may help in criminal investigation by narrowing down the probable list of suspects.

2. Materials and Methods

2.1 Study subjects

This study was carried out using a sample of 400 people (146 female and 254 male) aged 10-65 years in Uttar Pradesh, a North-Western state of India. Participation in the study was voluntary and entirely based on written informed consent. The participants were free from any orthopedic disease and deformity of the lower limbs. Footprint measurements of both feet were taken bilaterally and thus a total of 800 prints were obtained. Before the sample collection, information such as sex, age, and place of origin of each volunteer was obtained and recorded.

2.2 Procedure for collection of footprints:

A small amount of black duplicating ink was placed on a well cleaned glass plate with the help of a footprint roller, the ink was uniformly spread over the glass plate (Figure-1). Before taking the footprints, participants were asked to wash their feet with soap and dry them in order to obtain clear prints. The participants were then requested to step onto the glass plate, applying minimal pressure. The inked foot was then then transferred onto a plain white sheet of A4 paper, which was kept aside on a smooth, hard and flat surface. Before the foot was lifted off the paper, a sharp pointed pencil tip was used to mark 3 important points which helped in taking all measurements of the foot: mid rear heel point, lateral metatarsal point and median metatarsal point. Using the above method, both the left and right foot were recorded onto two separate A-4 papers for each participant.

Footprint collection procedures vary from surface to surface. For example, muddy surfaces require a cast to lift footprints. However, measurements of the footprints cannot vary for the same person. Surface differences might affect difficulty in collecting the prints, but the dimensions of the footprints will always be the same.

For measuring their height, volunteers were asked to remove bulky clothes, including thick-soled shoes and hair

Figure 1- *Procedure for collection of footprints. 1) Procedure of inking the glass slab. 2) Taking footprint on paper*

ornaments, and to stand still against a wall facing outwards and looking straight ahead. A standard steel measuring tape was used. Height measurements were taken from the top point of head (vertex) to the floor.

2.3 Footprint measurements

A total of 7 measurements were taken carefully with the help of a standard steel scale: 5 were length dimensions and 2 were breadth dimensions from both left and right footprints (Figure-2). All measurements were recorded in centimeters (cm).

Length Dimensions:

T1-T5 Length: the most anterior point of the heel (pternion) to the most projecting point of each toe (Acropodian). The same procedure was repeated for both right and left footprints.

Breadth Dimensions:

1. Breadth at Ball (BBAL): the maximum breadth between the medial margin of the head of the metatarsal print and lateral margin of the fifth metatarsal print.
2. Breadth at Heel (BHEL): the widest part of the heel.

Some additional variables were also recorded for each footprint:

a. Footprint Index: maximum footprint breadth/maximum footprint length X 100
b. Heel-Ball Index: BHEL/BBAL x 100
c. BL (Base Line): perpendicular to the heel at the rear edge of the footprint.

2.4 Statistical analysis

Data analysis was performed using Statistical Package for Social Sciences (SPSS) version 20 for Windows (IBM Company). Data were summarized as Mean ± SD. Means were compared by paired and unpaired t-tests, respectively. Linear regression correlation coefficient (R) was used to calculate correlation between age and index parameters, and stature and index parameters. A two-tailed $p < 0.05$ was considered statistically significant.

3. Results

The descriptive statistics for footprint measurements of 400 volunteers is shown in Table-1. There were 254 (63.5 %) males and 146 (36.5) females, with a mean ± SD age of 26.91 ± 12.432 (10 – 65) years. Footprint dimensions were recorded from all the 400 volunteers. All parameters (T1–T5 length, BBAL, BHEL, HB index and FP index) of the left and right foot were taken and their minimum and

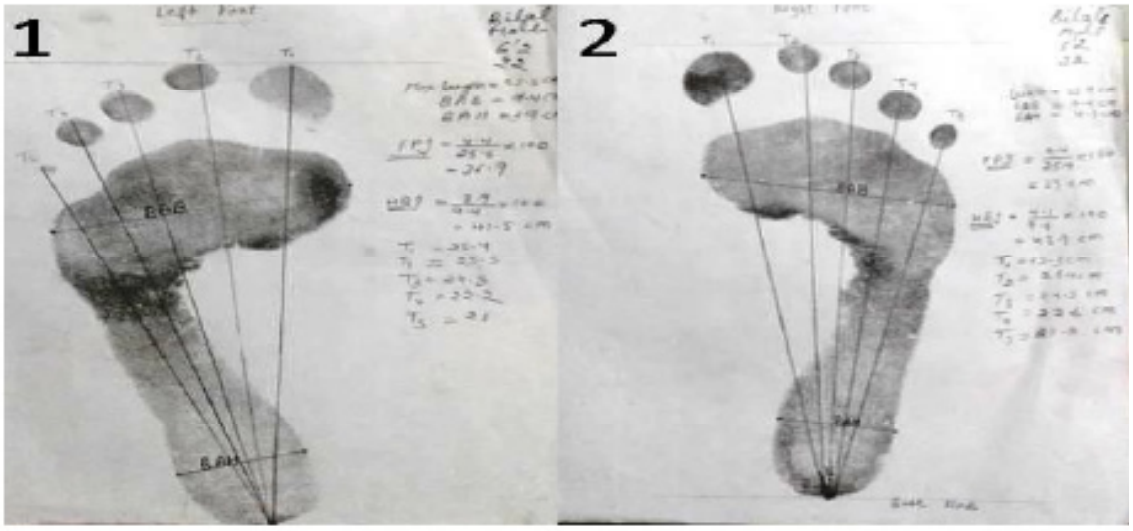

Figure 2- *Measurements of left (1) and of right (2) footprints*

maximum range was also determined.

The mean ± SD data of left and right footprint dimensions and indexes for both males and females are shown in Table-2. The left and right footprint dimensions were compared using paired t-test for significance. No statistically significant differences were found in footprint dimensions between the left and right foot both in males and females, except T1, which was significantly greater in the left footprint than right footprint in males ($p < 0.001$) as well as females ($p < 0.042$). In addition BBAL was significantly greater ($p < 0.001$) in the left footprint than the right footprint ($p < 0.05$) in females.

Table-3 shows a comparison of mean ± SD footprint dimensions and indexes between the left footprint and right footprint variables in male and female volunteers. The data were compared using unpaired t-test for significance. All the left footprint and the right footprint dimensions (T1-T5, BHEL and BBAL) were significantly higher in males than females ($p < 0.001$), except Footprint and Heel ball indexes. The left footprint index was slightly greater in females (36.86 ± 3.50) than males (36.72 ± 3.563), p

Table 1- *Descriptive statistics of footprint measurements (cm) and variables in our studied volunteers (n = 400).*

Footprint variables	Minimum	Maximum	Mean	S.D.
Left footprint variables				
T1	17.40	26.70	22.6230	1.6459
T2	17.50	27.30	22.4180	1.6886
T3	17.10	26.30	21.6320	1.6762
T4	15.70	24.70	20.4910	1.5794
T5	14.50	22.40	18.9560	1.4084
BHEL	3.00	6.00	4.3615	0.5207
BBAL	6.70	10.00	8.4020	0.6925
FP Index	17.90	50.50	36.7901	3.5369
HB Index	33.33	89.80	51.7953	6.0901
Right footprint variables				
T1	16.90	26.30	22.4595	1.6203
T2	16.80	27.00	22.4090	1.6917
T3	16.30	26.50	21.6305	1.6718
T4	15.30	24.50	20.4600	1.5609
T5	14.00	22.40	18.9825	1.4272
BHEL	2.80	6.00	4.3865	0.5399
BBAL	6.40	10.10	8.3510	0.7375
FP index	18.00	61.40	36.8081	4.0496
HB index	12.50	66.60	52.1522	6.0515

T1-T5, Length (cm) between the most anterior point of the heel (pternion) and the most projecting point of the toe (Acropodian); BHEL, Breadth at Heel; BBAL, Breadth at Ball; FP index. Footprint index; HB index, Heel ball index

Table 2- *Descriptive statistics and differences between left-right footprint dimensions in male (n = 254) and female (n = 146) volunteers.*

Variables	Male (*n* = 254) (63.5%)		*p*-value	Female (*n* = 146) (36.5%)		*p*-value
	Left (mean ± S.D.)	Right (mean ± S.D.)		Left (mean ± S.D.)	Right (mean ± S.D.)	
T1	23.31 ± 1.483	23.11 ± 1.480	<0.001*	21.42 ± 1.162	21.32 ± 1.170	0.042*
T2	23.06 ± 1.487	23.01 ± 1.515	0.177	21.28 ± 1.401	21.34 ± 1.442	0.169
T3	22.28 ± 1.452	22.25 ± 1.518	0.402	20.50 ± 1.422	20.54 ± 1.344	0.275
T4	21.10 ± 1.386	21.05 ± 1.39	0.198	19.419 ± 1.298	19.419 ± 1.265	1.000
T5	19.50 ± 1.272	19.51 ± 1.321	0.851	18.00 ± 1.093	18.06 ± 1.105	0.151
BHEL	4.51 ± 0.503	4.55 ± 0.515	0.053	4.09 ± 0.438	4.09 ± 0.446	0.798
BBAL	8.637 ± 0.648	8.634 ± 0.679	0.912	7.99 ± 0.566	7.85 ± 0.552	<0.001*
FP index	36.72 ± 3.563	37.19 ± 3.441	0.077	36.89 ± 3.500	36.14 ± 4.873	0.056
HB index	52.1 1 ± 5.421	52.17 ± 6.26	0.879	51.24 ± 7.091	52.11 ± 5.675	0.108

T1-T5, Length (cm) between the most anterior point of the heel (pternion) and the most projecting point of the toe (Acropodian); BHEL, Breadth at Heel; BBAL, Breadth at Ball; FP index. Footprint index; HB index, Heel ball index

Table 3- *Comparison of means, standard deviation and differences in footprint measurements (cm) according to gender.*

Variables	Male (*n* = 254) (mean ± S.D.)	Female (*n* = 146) (mean ± S.D.)	*p*-value
Left footprint variables			
T1	23.31 ± 1.483	21.42 ± 1.162	<0.001
T2	23.06 ± 1.487	21.28 ± 1.401	<0.001
T3	22.28 ± 1.452	20.50 ± 1.422	<0.001
T4	21.10 ±1.386	19.419 ± 1.298	<0.001
T5	19.50 ± 1.272	18.00 ± 1.093	<0.001
BHEL	4.51 ± 0.503	4.09 ± 0.438	<0.001
BBAL	8.637 ± 0.648	7.99 ± 0.566	<0.001
FP index	36.72 ± 3.563	36.89 ± 3.500	0.648
HB index	52.11 ± 5.421	51.24 ± 7.091	0.170
Right footprint variables			
T1	23.11 ± 1.480	21.32 ± 1.170	<0.001
T2	23.01 ± 1.515	21.34 ± 1.442	<0.001
T3	22.25 ± 1.518	20.54 ± 1.344	<0.001
T4	21.05 ± 1.39	19.419 ± 1.265	<0.001
T5	19.51 ± 1.321	18.06 ± 1.105	<0.001
BHEL	4.55 ± 0.515	4.09 ± 0.446	<0.001
BBAL	8.634 ± 0.679	7.85 ± 0.552	<0.001
FP index	37.19 ± 3.441	36.14 ± 4.873	0.013
HB index	52.17 ± 6.26	52.11 ± 5.675	0.923

T1-T5, Length (cm) between the most anterior point of the heel (pternion) and the most projecting point of the toe (Acropodian); BHEL, Breadth at Heel; BBAL, Breadth at Ball; FP index. Footprint index; HB index, Heel ball index

Table 4- *Estimation of stature (cm) from FP index (Left and Right) and HB index (Left and Right) according to gender.*

Parameters	Male (n = 254)			Female (n = 146)		
	Regression Coefficient (R)	R^2	p-value	Regression Coefficient (R)	R^2	P-value
LFP index	0.254	0.065	<0.001*	0.178	0.032	0.031*
LHB index	0.080	0.006	0.201	0.163	0.026	0.050
RFP index	0.046	0.002	0.462	0.040	0.002	0.629
RHB index	0.101	0.010	0.110	0.215	0.046	0.009*

LFP, left footprint index; LHB, left heel ball index; RFP, right footprint index; RHB, right heel ball Index

Table 5- *Mean and standard deviation of FP and HB Indexes (cm) in male and female volunteers according to age.*

Variables	Age range (Years)	Males			Females		
		n	Mean	S.D.	n	Mean	S.D.
RFP index	10 - 18	84	37.7893	2.10723	20	37.5800	1.71789
	19 - 30	98	36.6592	3.26302	82	35.5195	6.04409
	31 - 45	52	37.2619	5.42460	28	36.7514	2.45963
	46 - 55	16	36.9762	1.54409	10	35.3600	3.28674
	56 - 65	4	37.5500	.17321	6	38.3400	3.16642
	Total	254	37.1903	3.44192	146	36.1430	4.87387
RHB index	10 - 18	84	51.4452	7.54453	20	51.0900	4.53093
	19 - 30	98	51.9792	5.43167	82	51.7280	5.84404
	31 - 45	52	53.5642	5.84257	28	53.8800	5.51572
	46 - 55	16	52.7875	5.49362	10	55.6240	3.59887
	56 - 65	4	51.7500	1.32791	6	46.7000	5.59929
	Total	254	52.1744	6.26826	146	52.1136	5.67558
LFP index	10 - 18	84	36.8621	3.81821	20	37.1500	3.15203
	19 - 30	98	36.5841	3.85397	82	36.3051	3.70889
	31 - 45	52	36.8012	3.21996	28	37.6071	3.05475
	46 - 55	16	36.6375	1.32960	10	36.7420	2.70067
	56 - 65	4	36.9000	.80829	6	41.0833	1.15268
	Total	254	36.7288	3.56316	146	36.8968	3.50049
LHB index	10 - 18	84	50.9912	4.92128	20	52.2800	4.31077
	19 - 30	98	52.3343	5.28508	82	51.5312	8.07760
	31 - 45	52	53.5588	6.34180	28	51.2843	4.86683
	46 - 55	16	51.7125	5.19934	10	51.8480	5.57156
	56 - 65	4	53.0000	3.46410	6	42.6767	7.24666
	Total	254	52.1121	5.42180	146	51.2442	7.09148

S.D., standard deviation; RFP, right footprint index; LFP, left footprint index; RHB, right heel ball Index; LHB, left heel ball index

Table 6- *Estimation of age from FP index (Left and Right) and HB index (Left and Right) according to gender.*

Variables	Male (n = 254)			Female (n = 146)		
	Regression Coefficient (R)	R^2	p-value	Regression Coefficient (R)	R^2	P-value
LFP index	0.041	0.002	0.520	0.200	0.040	0.015*
LHB index	0.140	0.020	0.026*	0.104	0.011	0.213
RFP index	0.001	0.000	0.989	0.053	0.003	0.529
RHB index	0.090	0.008	0.151	0.104	0.011	0.213

LFP, left footprint index; LHB, left heel ball index; RFP, right footprint index; RHB, right heel ball index

= 0.648. On the other hand, the right footprint index was significantly higher in males (37.19 ± 3.441) than females (36.14 ± 4.873), p = 0.013. The heel ball index of both left footprints (52.11 ± 6026 vs. 51.24 ± 7.091) and right footprints (52.17 ± 6.26 vs. 52.11 ± 5.675) was slightly higher in males than females, p = 0.170 and 0.923, respectively (Table-3).

There was a partial positive linear correlation between the footprint index and stature of a person in males as well as females (Table-4). In addition, a partial positive linear correlation was also present between the heel ball index and stature, both in males and females. A significant correlation was found in the left footprint index in males and left footprint index and right heel ball index in females (Table-4).

Table-5 shows the mean and standard deviation of heel ball index (HB) and footprint (FP) index of left and right footprints in 254 males and 146 females according to different age groups. To determine the age of an individual, differences in HB and FP indexes were calculated.

Various linear equations from the footprint dimensions and footprint indexes were derived for the estimation of age and sex in male and female volunteers:

Estimation of Stature for Male/Female

Estimation of Stature from Left footprint index (Male) Y=4.006+0.035*X

Estimation of Stature from Right footprint index (Male) Y=5.058+0.007*X

Estimation of Stature from Left heel ball index (Male) Y=5.690+(-0.007)*X

Estimation of Stature from Right heel ball index (Male) Y=5.722+(-0.008)*X

Estimation of Stature from Left footprint index (Female) Y=5.819+(-0.017)*X

Estimation of Stature from Right footprint index (Female) Y=5.280+(-0.003)*X

Estimation of Stature from Left heel ball index (Female) Y=4.778+0.008*X

Estimation of Stature from Right heel ball index (Female) Y=4.506+0.013*X

Estimation of Age for Male/Female:

Estimation of Age from Left footprint index (Male) Y=31.270+(-0.141)*X

Estimation of Age from Right footprint index (Male) Y=26.207+(-0.003)*X

Estimation of Age from Left heel ball index (Male) Y=9.444+0.320*X

Estimation of Age from Right heel ball index (Male) Y=16.787+0.178*X

Estimation of Age from Left footprint index (Female) Y=2.104+0.711*X

Estimation of Age from Right footprint index (Female) Y=23.504+0.134*X

Estimation of Age from Left heel ball index (Female)

Y=37.674+(-0.182)*X

Estimation of Age from Right heel ball index (Female)
Y=16.506+0.227*X

There was a partial positive linear correlation between the footprint index and age of a person for males and females, respectively (Table-6). A partial positive linear correlation was found between the heel ball index and age of a person for males and females. A significant correlation was found in left heel ball index for males and left footprint index for females (Table-6).

4. Discussion

Researchers in the past have conducted several studies on feet with regard to their utility in forensic identification by estimating stature and sex from foot dimensions [12-20]. Hand and foot dimensions have also been correlated for personal identification in mass disasters. The present study sought to verify the utility and reliability of footprint dimensions in age, sex and stature determination in a North Indian population.

Krishan et al. [12] reported that foot measurements from each toe (T1 to T5) have a strong relationship with stature and are significantly higher in males than females. Statistically significant sex differences were exhibited by ratios between T1 and T2 ($p = 0.002$), T1 and T3 ($p = 0.001$), T1 and T4 ($p < 0.001$), T1 and T5 ($p = 0.001$), and T2 and T4 ($p = 0.014$). Hence, foot length measurements were significantly larger in males. Their research, therefore, concluded that the foot length ratios exhibit sex differences. However, according to Jubilant et al. [13], some footprint dimensions (i.e. T2, T3, T4 and T5) showed statistically significant bilateral asymmetry present only in males. With all dimensions subjected to stepwise discriminant function analysis, 80.3% and 77% of cases could be correctly classified, combining both T5 and BAH for left footprints and T1, BAB and BAH for left footprints, respectively. The present study has shown that T1 was significantly greater in the left footprint than the right footprint ($p < 0.001$) in both sexes, and all other measurements of other toes (T_2-T_5) were not significant.

Fessler et al. [14] showed that female foot length was consistently smaller than male foot length correlation coefficients between stature and all the foot measurements being highly significant and positively correlated.

Jitender et al. [15] showed that stature estimation from foot length was more reliable in female subjects than male subjects. According to Sween et al. [16], the length and breadth of footprints is greater in males than females: males had an average foot length about 2.59 cm greater than females. Ukoha et al. [17] reported that footprint dimensions are strongly correlated with stature and can be used for predicting stature in forensic examinations.

Jubilant et al. [13] showed that footprint dimensions allowed 69.8%-80.3% of cases to be correctly classified into their sex groups. Sween et al. [16] reported that foot breadth was about 0.9 cm greater in males compared to females. However, in the investigation of Kanchan et al. [18], right–left differences in footprint breadth at Ball (BBAL) and footprint breadth at Heel (BHEL) were not found to be statistically significant, except for the BBAL in females, which was found to be larger on the left side, similar to the findings in the present study.

Rahman et al. [19] documented that footprint ratio has a significant difference in the mean values for both feet in both sexes. The percentage accuracy of establishing sex by this method is 80%, which was quite significant. Sween et al. [16] found that footprint index is higher in females than males.

Jubilant et al. [13] reported that all the footprint dimensions, except HB index, were significantly greater in males than females ($p < 0.001$). However, Kanchan et al. [18] concluded that footprint measurements at the ball and heel

can be used in determining the sex of an individual, but that the HB index cannot be utilized in sex determination from footprints. Similarly, in the present study, the HB index may not be utilized in sex determination from footprints. However, there were significant and positive correlations between stature and the right Heel ball index both in males and females. Also with the age, the left Heel ball index was found to be significant in males.

In the study of Devesh et al. [20], a highly significant degree of correlation was found between footprint lengths and stature of both sexes. Hairunnisa et al. [21] provided a regression equation from the outlines of partial or complete footprints in Ibans in east Malaysia. Devesh et al. [20] developed a regression formula to predict stature separately for males and females and the combined data along with the standard error of estimate. The results obtained are found to show less error in predicting stature as compared to other conventional methods used earlier.

In the present study, we analyzed 4 parameters: Left footprint index, right footprint index, left heel ball index and right heel ball index to determine the difference in their mean and standard deviation to ascertain the approximate age of individuals. There was no significant value found for age estimation from the footprints, but there was a partial positive linear correlation between footprint index and age for males and females. We also found a partial positive linear correlation between the Heel ball index and age for males and females. Hence, in the present study, all the values (T1, T2, T3, T4, T5, BBAL, BHEL, Right Heel Ball index) showed statistically significant differences, except left footprint index, left heel ball index and right heel ball index between the male and female footprint dimensions ($p < 0.001$ and $p < 0.05$).

There was a partial positive linear correlation between the footprint index and stature of a person for males and females, respectively. We also found a partial positive linear correlation between the heel ball index and stature of a person, for both males and females.

5. Conclusion

In this study, we have analyzed different foot dimensions such as toe measurements, breadth at ball and heel in order to discover the link between these measurements and stature. From the toe measurements, T1 was greater in left footprints than right footprints of males and T1 and BBAL both were found to be greater in left footprints than right footprints. All the foot dimensions are significantly greater in males than females.

There were statistically significant differences observed between the male and female footprint dimensions, except LFPI, LHBI and RHBI. A significant correlation was found for stature estimation in left footprint index for males and left footprint index and right HB index for females.

For estimation of age, a significant correlation was found in left HB index for males and left footprint index for females, and the left HB index was significant for males.

The study concludes that though footprint dimensions, we can gain a useful estimation of the age, sex and stature of an individual, which helps us to establish the biological profile of criminals or victims.

Conflict of interest

Authors declare no conflict of interest.

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