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Gender Identification Using Foot Dimensions: A Forensic Exploration

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Abstract

Background: Foot morphometry is an important tool in gender identification in forensic investigations. Personal identification from feet is very pertinent as foot impressions are sometimes reported at crime scenes or feet are often recovered from the site of mass disasters. The present study has been aimed towards gender identification using specific foot measurements and feet impressions.

It is based on the foot measurements and foot prints measurements carried out among 100 individuals including 50 males and 50 females residing in Delhi. Measurements namely foot length, foot breadth was taken and the foot Index was evaluated. Also, from the foot prints, breadth at the heel and breadth at the ball were measured and the heel- ball index was calculated.

Results: Student t-test revealed the significant differences for foot measurement between males and females.

Conclusion: Sexual dimorphism is more apparent from foot measurements and indices, while inter-digital angles may not be very specific for the same purpose. However, further studies needed on larger samples and on different age and ethnic groups for precise gender identification.

Keywords: Anthropometry; Forensic anthropology; Foot index; Heel-ball index; Personal identification

Introduction

Forensic Anthropology is the science that deals with application of anatomical details of human(s), whether dead or alive, for the identification of an individual. Identification of human bony remains and any other human parts is of great importance for legal as well as for humanitarian reasons [1]. In cases of mass disasters or missed persons, identification of the dead hold significance especially for information of his/her surviving relatives [2].

Forensic anthropologists, plays an important role in identification of mass burials of humans. Forensic anthropologist identifies dead bodies from human remains including foot. From the feet, we can analyze foot characteristics of the deceased [3-5].

A footprint is an impression of the weight-bearing areas of the plantar surface of the foot. Footprints can be found at different places associated with crime scene including rain covered surfaces, newly waxed floors, freshly cemented surfaces, moistened surfaces, dust, mud, sand, oil, paint and blood at murder scenes [6].

Footprints can be found at crime scenes because offenders often remove their footwear, either to avoid noise or to gain a better grip in climbing walls etc. while entering or exiting [7]. Foot prints of an individual are unique to that individual and comparison of the footprints linked to a crime can be compared with a suspect's footprints for inclusion or exclusion of the suspect for any involvement in that crime.

Sex, ethnicity, age, and stature estimation are four important parameters in forensic identification [8]. Globally as well as in Indian context, there is a lack of forensic databases for sex determination from footprints. Present paper was conceptualized with an objective to make a comparative account of gender on foot dimensions and footprints with a forensic perspective.

Methodology

All the study participants were students of Delhi University, pursuing their graduation or post-graduation. The study was carried out on 100 individuals (50 males, 50 females) of Indian origin of the age group 18-22 years. Healthy individuals without any deformity of the foot were included in the study.

The Determination of the ethnicity of the footprint may not be possible and hence, study samples in the present study were comprised of a mixed population. Footprints were obtained from both feet of the study participants using standard techniques. Thus, a total of 200 footprints were obtained. Measurements like foot length (FL) and foot breadth (FB) were taken using standardized technique.

Foot impressions were then taken on paper, using fingerprint ink, which were further evaluated to determine breadth at the heel (BHEL) and breadth at the ball (BBAL). The impressions taken were then assessed to determine the central axis of the foot. Once known, angles between the 2nd toe with the central axis and angle between the 4th toe and the central axis were evaluated for comparison.

The participants belonged to various socio-economic backgrounds. Participation in the study was voluntary and it was entirely based on written informed consents which was taken prior to start the data collection. All the study participants had variable diet preferences,

some preferring strictly vegetarian diet, while a few stuck to both vegetarian and non-vegetarian foods.

To avoid the inter-observer error, the measurements were performed by one observer and it was recorded to the nearest 0.1 centimeter. Reproducibility coefficient was calculated prior to start the data collection in order to standardize the techniques to be used. Later, 100 respondents were measured and evaluated during February, 2017 to March, 2017.

Foot length was measured as the straight distance measured from the pternion to acropodion using a rod compass. Whereas the foot breadth was measured as the straight distance between metatarsal tibialis and metatarsal fibularis using a sliding caliper. Various landmarks have been identified using standard techniques given by [9]. The procedures followed were in accordance with the ethical standards of the responsible ethical committee of the institute. The foot length and foot breadth were taken on the fleshed foot.

Whereas the measurements namely breadth at the heel and breadth at the ball were measured on the foot prints. The central axis was also marked on the foot print to assess few specific angles. The foot prints were collected using the standard black fingerprint ink and a white tile. The ink was spread on a white tile uniformly.

Once the footprints were taken, the landmarks were marked on the print. Using a ruler, with gradations in centimeters, the distance between the two landmarks was measured. The breadth at the heel (BHEL) was measured as the distance between calcaneal concavity medial and calcaneal tubercle lateral [10].

The breadth at the ball (BBAL) was taken as the distance between medial metatarsal point and lateral metatarsal point. The breadth of the footprint at ball (BBAL) and the breadth of the footprint at heel (BHEL) were measured on the footprints. After taking all the measurements, the foot index and heel ball index were calculated using the formulas as follows:

Foot Index (FI)=[Foot Breadth/Foot Length] × 100

Heel-Ball Index (HBI)=[Breadth at Heel (BHEL)/Breadth at Ball (BBEL)] × 100

The shape of the foot is determined by studying the relationship between foot index (FI) and standard deviation (S.D). The foot shape is categorized as 'slender' 'standard' and 'broad' foot type [11]. Data was collected in excel sheet using Microsoft excel 2010 and the statistical analysis package (SPSS) version 21 was used for the analysis of data. The significance of the sex differences among male and female footprints was tested using student's t-test.

Results and Discussion

The means, standard deviation and differences between left and right footprint dimensions in both males and females are shown in Table 1. In females, no statistically significant differences were observed between the left and right footprint dimensions ($p>0.05$). In males, however, most of the dimensions were significantly greater in the left footprints than right footprints ($p<0.001$).

Significant gender differences for the right foot were obtained for most of the foot measurements namely foot length, foot breadth, BHEL, BBAL at $p<0.001$, and the angle at 4th toe ($p<0.05$). For the left foot, significant gender differences were obtained for foot length at $p<0.05$ whereas for foot breadth, foot index, BHEL, BBAL, and the angle at 4th Toe at $p<0.001$ (Table 1).

	Right Foot			Left foot		
Variables	Males (Mean ± S.D.)	Females (Mean ± S.D.)	t-Test value	Males (Mean ± S.D.)	Females (Mean ± S.D.)	t-Test value
Foot Length	22.92 ± 2.47	21.24 ± 2.37	3.30***	22.77 ± 2.35	21.25 ± 2.33	3.12**
Foot Breadth	9.71 ± 0.49	8.77 ± 0.41	10.21***	9.72 ± 0.45	8.81 ± 0.41	11.28***
BHEL	5.10 ± 0.46	4.61 ± 0.32	6.86***	4.98 ± 0.49	4.49 ± 0.40	5.90***
BBAL	9.17 ± 0.45	8.25 ± 0.42	11.18***	9.11 ± 0.49	8.36 ± 0.35	8.74***
Angle At 2nd Toe	2.34 ± 1.27	1.94 ± 1.26	1.61	2.44 ± 1.45	2.08 ± 1.25	1.43
Angle At 4th Toe	6.04 ± 1.29	6.94 ± 1.74	2.91**	6.20 ± 1.77	7.46 ± 1.64	6.30***
Foot Index	42.75 ± 4.71	41.80 ± 5.31	1.05	42.70 ± 77.9	41.50 ± 5.23	7.82***
Heel-Ball Index	55.56 ± 4.53	55.89 ± 3.72	0.02	54.75 ± 5.96	53.65 ± 4.42	1.33
**p<0.05; ***p<0.001						

Table 1: Foot comparison across genders.

The foot length, foot breadth, breadth at the heel and breadth at the ball of the right and left foot were higher among males. However, the angle between the central axis of the foot and the axis of the 4th toe was significantly higher among females.

In the right foot, the foot index and Heel-Ball Index did not have any significant differences between males and females (Figure 1). However, in left foot, the angle between the central axis of the foot and the axis of the 2nd toe was higher for males than females.

For left foot the angle between the central axis and the axis of the 4th toe was higher for females than males whereas the foot index and heel-ball index were higher for males than females (Figure 2).

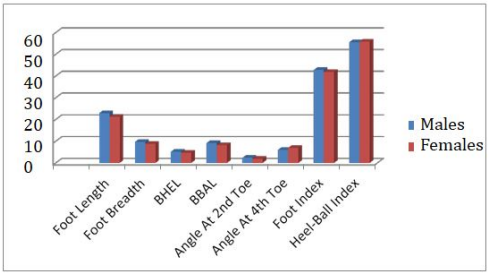

Figure 1: Comparison of the right foot across gender.

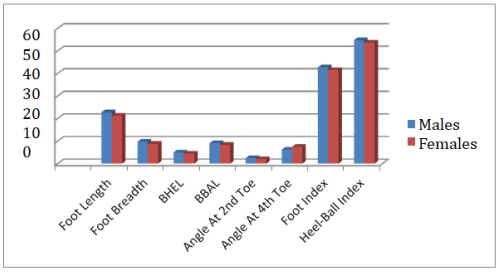

Figure 2: Comparison of the left foot across gender.

It was observed that the footprint dimensions were significantly higher in males as compared to their counterpart females. However, they found non-significant gender differences for heel-Ball Index (HBI) [12]. It was found that foot length and foot breadth was higher among Jat community males as compared to Jat females [13]. They concluded that indices have a higher value in females even though the individual measurements were lower among them. Significantly higher foot length and foot breadth, among males than females have been reported by others investigators also [14-17]. Feet of males differ from female feet in shape characteristics, especially at the arch, the lateral side of the foot, the hallux and the ball of the foot.

Higher foot index (FI) was reported among males than females, thus making sexual dimorphism more ostensible. It was reported that the inter-digital distance was higher for males than females. Hence, the axis passing through the 4th and the 2nd toe would also be greatly deviated from the central axis, thereby, giving significant variation between the axes [18]. The BHEL was more for the left foot in males than the right foot. BBAL was significantly higher in the right foot of males [10]. However, in present study, BHEL and BBAL were significantly higher for the right foot than left foot in males as well as among females as also reported [12]. Foot shapes have been categorized as slender, standard and broad type using mean foot index and standard deviation [11]. In the present study the 'standard' foot shape was most common in the right foot and slender shape in left foot among males. The 'standard' type foot shape was found to be most common in both right and left foot of the females. However it was reported broad feet among males and slender feet among females [16]. The present study is limited by its relatively small sample size, thus the results cannot be generalized. Nonetheless, these preliminary results further confirms gender differential in foot dimension and it provide the baseline for elaborated studies in the future.

Conclusion

Foot dimensions i.e. foot length, foot breadth, BHEL, BBAL, angle between central axis and 2nd toes, angle between central axis and 4th toe and foot index were reported to be higher for both the feet among males than females. However, the heel ball index (HBI) was higher among females in the right foot and higher among males in the left foot. Thus, sexual dimorphism is more apparent from foot measurements and indices, while inter-digital angles may not be so specific for the same purpose. However, further studies on larger samples and on different age groups and ethnic groups may prove informative and convincing for more accuracy in gender identification.

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