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Sexual dimorphism in foot length ratios among North Indian adolescents☆

Kewal Krishan [a, *], Tanuj Kanchan [b], Neelam Passi [a], John A. DiMaggio [c]

[a] Department of Anthropology, Panjab University, Chandigarh 160 014, India
[b] Department of Forensic Medicine and Toxicology, Kasturba Medical College (Affiliated to Manipal University), Mangalore, India
[c] Forensic Podiatry Consulting Services, PLLC, 1450 Polaris Ln. SW, Bandon, OR 97411, USA

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ABSTRACT

Determination of sex along with other parameters of identification like stature, age and ancestry is one of the foremost criteria in establishing the biological profile of an individual. The present study was conducted to analyze the sex differences in the foot length ratios in a North Indian adolescent population. The study was conducted on 149 females and 154 males aged from 13 to 18 years. Foot length measurements were taken from pternion to the most anterior part of each toe and designated as T1, T2, T3, T4, and T5 respectively for first to fifth toes on both the feet in each participant using standard methods and techniques. A total of ten ratios (T1:T2, T1:T3, T1:T4, T1:T5, T2:T3, T2:T4, T2:T5, T3:T4, T3:T5, and T4:T5) were thus, obtained and the same were analyzed for sex differences using Student's t-test. Stature was measured in each participant and Pearson's correlation coefficients were calculated to find the correlation between various foot length ratios, age and stature. Receiver Operating Characteristic (ROC) curve was employed to test the sexing accuracy of the variables. P-value of less than 0.05 was considered as statistically significant. Foot length dimensions from each toe (T1 to T5) and stature were found to be significantly higher in males than females. The foot length ratios did not show any statistically significant correlation with stature. 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 ($p = 0.014$). Maximum sex differences were evident for foot length ratio between T1 and T4 (63.4%), and minimum for the ratio between T2 and T4 (56.5%). Though foot length measurements are significantly larger in males, its utility in sex differentiation may be limited owing to its direct correlation with stature of an individual. It has been observed that the foot length ratios are independent of stature and thus, can be considered a better sex determinant since they are not influenced by the body built of an individual. Apart from ratio between T2 and T4, only the foot length ratios with reference to first toe (T1:T2, T1:T3, T1:T4, T1:T5) were found to exhibit significant sex-differences. The present research concludes that the foot length ratios exhibit sex differences in the study population. However, its utility in forensic investigations may be limited owing to the lower sexing accuracy of foot length ratios.

1. Introduction

Forensic anthropology involves the examination and identification of unknown skeletal, dismembered and commingled remains in a legal context. This process focuses on establishing the biological profile of the deceased. There is a continuous need to discover new methods of establishing biological profile of the deceased in such cases. Determination of sex along with other parameters of identification like stature, age and ancestry is one of the foremost criteria in establishing the biological profile of an individual. These parameters of the biological profile can facilitate in narrowing down of the possible pool of victims during investigation process. Sex determination in forensic examinations has been considered as the simplest task as the external and internal genitalia can directly advise the sex of the deceased.[1] However, in highly decomposed and dismembered dead bodies, it becomes difficult to assess the sex of the deceased. Further, sex

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* Corresponding author. Tel.: +91 172 2534224 (office), +91 9876048205 (mobile).
E-mail addresses: gargkk@yahoo.com, kewalkrishan@pu.ac.in (K. Krishan).

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determination is essential in the evaluation of other parameters of biological profile such as the stature and the age owing to the sexual dimorphism exhibited and availability of sex dependent models for their estimation.[2] Therefore, without an accurate assessment of the sex of the deceased, stature and age estimation processes may be affected resulting in erroneous conclusions.[3,4] Hence, sex determination is considered a vital part of forensic investigations especially when dismembered and mutilated body parts are brought for examination.[5] Studies have been conducted on sex determination from various bones of the skeleton as well as from the body parts using anthropometry. In this regard, the researchers have used the dimensions of head and face,[6,7] hands,[8–10] pelvic dimensions,[11–13] long bones[14–16] as well as the feet[17–19] for determination of sex. However, a limited literature exists on the sexual dimorphism of feet in anthropological and forensic examinations.

Sex determination based on morphological features and anthropometric measurements is more challenging in adolescents when compared to adult population, due to the on-going physical growth in adolescents and sub-adult population. Human foot attains its full size and shape in the adolescent age than many other parts of the body that continue to grow till adulthood. The physical growth of the foot is completed by about 14 and 16 years respectively in females and males.[20] Thus, after these ages, the size of the feet of the adolescents is comparable with that of the adults. Sex determination from anthropometry of the feet has been attempted in a few studies. Agnihotri et al.[21] conducted a study on the feet of 250 adult males and females from Mauritius. They calculated foot index for determination of sex and concluded that the index more than 37 is suggestive of female individual and less than 37 a male. Moudgil et al.[22] also calculated foot index for determination of sex in a north Indian population. Though the index was found to be higher in females than males, it was observed that the sex cannot be determined accurately from the foot index. Another study conducted by Sen et al.[19] on the Rajbanshi population from West Bengal state of north India, showed significant sex differences in the foot dimensions. They devised multiple regression models for determination of sex; they however, concluded that the practical utility of the study is limited due to overlap of values in determination of sex. Krishan et al.[9] conducted a similar study on the feet of Rajput population of Himachal Pradesh of north India and devised foot index for sex determination. They devised sectioning point analysis for sex differences and concluded that the foot index is a poor sex indicator. Krishan et al.[18] devised a novel index called Heel-ball index for sex determination in north Indian adolescents. They found Heel-ball index to be larger in females than the males and suggested that the index can be utilized in determination of sex from the feet.

In mass disasters such as tsunamis, earth quakes, terrorists' attacks and other major incidents where a number of causalities are involved, there is always likelihood of recovering intact feet often protected by the shoes. The differences in the morphology of the feet of males and females are well-known.[23–25] However, it really becomes very difficult when cases pertaining to sexual dimorphism are brought for forensic examinations due to lack of systemic studies. Though a number of studies are conducted on the sexual dimorphism of finger length ratios especially index and ring finger ratio (2D:4D),[26–28] no such studies are available on the foot length ratios in literature. Many researchers have investigated the role of 2D:4D in certain psychological and biological characteristics of the persons. In the present study, it is proposed that similar sexual dimorphism may exist in foot length ratios also. The present study thus, is an attempt to evaluate the sexual dimorphism in foot length ratios in a North Indian population.

2. Material and methods

The present study was conducted on 303 north Indian participants (149 females and 154 males) aged between 13 and 18 years. Mean age of the participants was 15.7 ± 1.7 years. The sample for the present study was taken from the selected area of Tehsil Kalka in the District of Panchkula in Haryana state of north India as a part of Master's dissertation in Anthropology. As the research project was time-bound, the sample was taken according to the convenience and availability of the subjects for the study. Only healthy adolescents without any apparent physical deformity of the foot were taken for the study. Informed consent was taken from the participants before taking the anthropometric measurements.

Foot length measurements were taken from the landmark pternion (the most posteriorly projecting point on the heel when the participant stands erect) to the most distal part of each toe and designated as T1, T2, T3, T4, and T5 respectively for first to fifth toes on both feet in each subject using standard methods and techniques (Fig. 1). The methodology regarding foot length measurements and various landmarks involved in taking the measurements has been taken from the standard literature.[29,30]

T1 Length (d1.t-pte.): Distance from pternion (pte) to the most distal part of the first toe (d1.t).
T2 Length (d2.t-pte.): Distance from pte. to the most distal part of the second toe (d2.t).
T3 Length (d3.t-pte.): Distance from pte. to the most distal part of the third toe (d3.t).
T4 Length (d4.t-pte.): Distance from pte. to the most distal part of the fourth toe (d4.t).
T5 Length (d5.t-pte.): Distance from pte. to the most distal part of the fifth toe (d5.t).

Stature was measured in each participant using standard methods and techniques. Stature was measured as the vertical distance between the point vertex (highest point on the head when the head is held in the Frankfurt Horizontal plane) and the floor when the person stands in erect position without any headgear and footwear.

All the measurements were taken by a single observer (a trained physical anthropologist – NP) to avoid inter-personal or inter-observer error. As the present study is a part of a large anthropometric study[18,29,30] conducted in the area, the observer got a training in anthropometric techniques as a part of Master's degree examination in the Department of Anthropology, Panjab University, Chandigarh, India, before taking up the anthropometric data collection in the field.

Statistical analysis was performed using SPSS version 11.5. The side differences in the foot lengths at each toe were calculated and tested using paired t-test. Foot length measurements did not show any statistically significant right-left differences.[26,27] Hence, mean of right and left measurements was used in the study. All possible foot ratios between different foot length measurements were computed. A total of ten ratios (T1:T2, T1:T3, T1:T4, T1:T5, T2:T3, T2:T4, T2:T5, T3:T4, T3:T5, and T4:T5) were thus, obtained and the same were analyzed for sex differences. Stature and age were correlated with foot length ratios. Sex differences in foot ratios were analyzed using Student's t-test. Pearson's correlation coefficients were calculated to find the correlation between various measurements of the foot and foot length ratios with stature and age of the individuals. P-value of less than 0.05 was considered as statistically significant. Receiver Operating Characteristic (ROC) curve was employed to test the sexing accuracy of the variables. Area under the ROC curve (AUC) was considered as the measure of the sex discriminating power of the variables.