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Osteometric analysis for sexing of modern sternum – An autopsy study from South India

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ABSTRACT

Estimation of sex is considered as one of the essential parameters in forensic anthropology and requires foremost attention in the analysis of commingled and unidentified remains. In India, there is a paucity of population specific morphometric standards for identifying sex from unknown human remains in different population groups. The present research is an osteometric analysis to study the sexual dimorphism of the sternum of South Indian origin using statistical considerations. The study sample constituted of adult autopsied sternums of known age and sex. Five linear measurements (length of the manubrium, mesosternum, manubrium and mesosternum together, and width at 1st and at 3rd sternebra) were examined during the study. Three indices (manubrio-corpus Index, ratio of the length of the mesosternum and manubrium, and sternubrial-width index) were computed from the length and width measurements of the sternum. Statistical analysis was done using SPSS computer software and Student's *t*-test was applied to find the sex differences in these variables. While statistically significant sex differences were observed for all the five linear measurements of the sternum, none of the sternal indices showed statistically significant sex differences. Discriminant function and logistic regression analysis were performed to derive the predicting models for estimation of sex from the different variables. The predictability of sternal measurements in sexing using univariate models ranged between 67.5% for the width at 3rd sternebra and 74.4% for the combined length of manubrium and mesosternum. The classification accuracy rates of sternal measurements were observed to be higher when multivariate analysis was performed. Length of manubrium and mesosternum together along with width at 1st sternebra yielded maximum accuracy of 79.5% (discriminant function analysis) and 81.2% (logistic regression analysis) in sexing of male and female sternum. The present research concludes that the application of sternum in sex estimation should be restricted to cases when other more reliable bones for sexing are not available to the investigators.

1. Introduction

Forensic Anthropology is considered as one of the important sub disciplines of forensic sciences that deals with identification of unknown human remains in a legal context. Determination of ancestry, sex, age, and stature contributes to establishing the biological profile of an individual. Estimation of sex forms the foremost criteria in the analysis of commingled and skeletal remains as it potentially narrows down the pool of possible victim matches during investigation process [1]. Though sex can be estimated from different bones of the human skeleton; pelvis and cranium are considered more reliable in the estimation of sex during the examination of skeletal remains [2]. Stewart stated that the sexing accuracy of entire skeleton, pelvis, or one hip bone is 90–95%, and accuracy from skull alone is 80% [3,4]. The entire skeleton may not always be recovered for forensic examinations, and hence, individual bones of the human skeleton need to be evaluated as potential indicators of sex. Different studies have confirmed that sex can be estimated from cranium [5–7], mandible [8,9], ribs [10], vertebral column [11,12], sternum [13–15], pelvis [16], long bones [17,18], and the bones of hands and feet [19–21]. The accuracy of these bones in sex estimation is shown to vary for different bones, and amongst populations.

Sternum is considered to be a useful bone in forensic anthropological analysis with high rate of recovery than other parts of the human skeleton [13]. Besides its sexing potential, sternum has also

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been used in estimating age as well as stature in forensic examinations [22–25]. The earliest known studies on estimation of sex from sternum were conducted by Krause [26], Wenzel [27], Dwight [28], and Hyrtl [29,30]. Observations of these studies led to the formulation of Hyrtl's Law, which states that "the manubrium of the female sternum exceeds half the length of the body, while the body in the male sternum is, at least, twice as long as the manubrium" [13]. Studies on the sexing potential of sternum have followed osteometric [13–15] and radiographic techniques [31]. Besides, sternal indices have been derived [32] for their applicability in estimation of sex. These studies have utilized different statistical approaches such as simple proportions, limiting points, identification points, demarking points, and discriminant function analysis for sexing the sternum. Though these studies have reported that sex can be estimated from various measurements of the sternum, the accuracy is shown to vary in different populations of the world. Franklin et al. [33] observed an accuracy of 72.2–84.5% in sex estimation of Australian sternum, Bongiovanni and Spradley [13] reported an accuracy of 80.0% and 88.24% in males and females respectively on American whites and blacks, Hunnargi et al. [34] found the reliability of sternum as 85.3% and 77.5% in males and females respectively in a Maharashtrian population of India, while Macaluso Jr. [15] provides accuracy ranging from 68.4% to 83.5% in a South African sample. A need to derive standards for different populations is emphasized as the variations in the sexual dimorphism are population specific [13,35].

Multiple ethnic populations reside in India [36] and the sexual dimorphism of sternum in South Indian population remains unexplored as yet. A need to develop sex specific population standards for different population groups is emphasized in India as the standards developed on one population group cannot be applied on the other. The present study is thus, aimed to study the sexual dimorphism of the sternum based on its osteometric analysis in South Indian population, observe the degree of accuracy for the different variables, and generate the standards for estimation of sex using statistical considerations.

2. Materials and methods

The sample for the present study included 117 adult sternums of known age and sex (67 males and 50 females), which were kept as South Indian origin samples at the Department of Forensic Medicine, JSS Medical College, Mysore, South India. Males in the study sample were aged between 25 and 74 years, and the females, between 20 and 80 years. Mean age of the males and females was 45.9 years and 39.1 years, respectively. The sternums that were free from any fracture or other deformities were obtained after autopsy and a thorough maceration of each sternum was performed. Osteometric analysis was performed on each sternum using vernier calipers graduated to the last 0.01 mm. All the measurements were taken by the first author (HVC).

2.1. Measurements and techniques

The following measurements were taken on each sternum following Bass [37]:

M = Length of manubrium measured from the jugular notch to the manubriosternal joint.

B = Length of mesosternum measured from manubriosternal joint to xiphisternal joint.

MB = Combined length of the manubrium and mesosternum measured from the jugular notch to the xiphisternal joint.

S1 = Breadth of the mesosternum measured between the notches for the third costal cartilage on both sides (width at 1st Sternebra).

S3 = Breadth at the mesosternum measured between the notches for the fifth costal cartilage on both sides (width at 3rd Sternebra).

Landmarks on the sternum and measurements included in the study are described in Fig. 1.

The following sternal indices were computed from the different measurements of sternum:

Manubrio-corpus Index = $(M/B) \times 100$

Ratio of the length of mesosternum and manubrium = B/M

Sternubrial-width Index = $(S1/S3) \times 100$

2.2. Statistical analysis

The data was analyzed using SPSS (Statistical Package for Social Sciences, version 11.0) computer software (SPSS, Inc., Chicago, IL, USA). Descriptive statistics (Range, Mean, Standard Deviation) were obtained for the linear measurements of the sternum and the derived indices. Independent sample *t*-tests was performed to find if significant sex differences existed in the measurements and the indices. Univariate and multivariate discriminant function (direct, multiple variable, and step-wise) and logistic regression (direct and multiple variable) analysis were performed to derive models for estimation of sex from the different measurements of the sternum. Statistical significance was defined as $\alpha = 0.05$.

2.2.1. Discriminant function analysis

A direct analysis of each variable, and multiple variables that included a combination of length measurements (M and B), width measurements (S1 and S3) as well as for all variables together (M, B, S1, S3 and MB, S1, S3) was undertaken. A stepwise procedure was performed and stepwise discriminant functions were derived after incorporating all the sternal dimensions to select the combination of variables that best discriminates the male and female sternum. Discriminant function (P) is built using the discriminant equation: $P = a1 \times x1 + a2 \times x2 + \ldots\ldots + an \times xn + b$ ('$a1$' through 'an' are the discriminant coefficients, '$x1$' through 'xn' are the discriminating variables, and 'b' is the constant). A sectioning point in discriminant function analysis is computed using the average of male and female discriminant scores (group centroids). Value of discriminant function (P) derived is compared to the sectioning point derived from the discriminant function analysis that was taken as the cut-off point for sex estimation in discriminant function analysis. A value higher than the sectioning point (discriminant) was deemed to be male and a value below it to be female. Original as well as cross-validated accuracy rates were derived for the discriminant functions.

2.2.2. Logistic Regression analysis

Logistic regression models are derived as; $y = \beta 1 \times x1 + \beta 2 \times x2 + \ldots\ldots + \beta n \times xn + b$ ('$\beta 1$' through 'βn' are the β coefficients for each variable, '$x1$' through 'xn' denote the different variables, and 'b' is the constant). Sectioning point in logistic regression analysis is taken as 0.5. Resultant value of function (y) is used in classification of sex; all scores greater than 0.5 are classified as male, and scores below 0.5 as females. Logistic regression models were derived for each variable, and multiple variables that included a combination of length measurements (M and B), width measurements (S1 and S3) and combination of other variables as used in discriminant function analysis for effective comparisons of accuracy rates between the two statistical methods.

In the present research, sex biases were calculated as the difference between correctly classified male and female percentages for both discriminant function and logistic regression analysis in the total sample (Sex bias = % males correctly classified − % females correctly classified). A positive value of sex bias indicates that more females are misclassified and vice versa.