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Original communication

Assessment of craniometric traits in South Indian dry skulls for sex determination

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ABSTRACT

The skeleton plays an important role in sex determination in forensic anthropology. The skull bone is considered as the second best after the pelvic bone in sex determination due to its better retention of morphological features. Different populations have varying skeletal characteristics, making population specific analysis for sex determination essential. Hence the objective of this investigation is to obtain the accuracy of sex determination using cranial parameters of adult skulls to the highest percentage in South Indian population and to provide a baseline data for sex determination in South India. Seventy adult preserved human skulls were taken and based on the morphological traits were classified into 43 male skulls and 27 female skulls. A total of 26 craniometric parameters were studied. The data were analyzed by using the SPSS discriminant function. The analysis of stepwise, multivariate, and univariate discriminant function gave an accuracy of 77.1%, 85.7%, and 72.9% respectively. Multivariate direct discriminant function analysis classified skull bones into male and female with highest levels of accuracy. Using stepwise discriminant function analysis, the most dimorphic variable to determine sex of the skull, was biauricular breadth followed by weight. Subjecting the best dimorphic variables to univariate discriminant analysis, high levels of accuracy of sexual dimorphism was obtained. Percentage classification of high accuracies were obtained in this study indicating high level of sexual dimorphism in the crania, setting specific discriminant equations for the gender determination in South Indian people.

1. Introduction

The skeleton plays an important role in sex determination in the field of forensic anthropology. Though, entire skeleton is essential for accurate results, it is rarely available completely and in good condition. Therefore, it is important to apply appropriate methods for gender determination from skeletal remnants.[1,2]

The pelvis, femur, tibia, humerus, radius, mandible and cranium are useful in sex determination.[3] Among these, pelvic traits which are highly dimorphic are referred as the best gender indicator. But the skull due to its better preservation is believed to be the second among the best, after the pelvis in gender determination in archaeological contexts as it can ascertain individual sex with high accuracy.[1–3]

The better stability of the dimorphic features of skull in comparison to other bony remnants is due to its durability to changing environmental conditions. The various methods used for sex determination are classified into molecular and morphological methods.[4] Robusticityand differences in the size are the most significant factors contributing to the dimorphic features of the skull.[5]

Adult skull is preferred to sub-adult skull in sex determination due to the hormonal control on the growth and development of bones. The gender differences in skull occur due to the variability in the bone development and its forces. Bone development in females is earlier than in males and there is a drastic modification in the appearance of female skull at the time of puberty. Thus the morphological differences among the genders manifest more evidently in the adult skeletons.[6,7]

The functional expression of modeling of the face and skull, which starts acquiring the characteristic phenotypical features, is considered as sexual dimorphism. Over expressed bone elevations

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in this process in the form of tubercles, ridges, processes etc., characterize male skulls and differentiate them from females.[7]

The morphological features which indicate the sexual dimorphism help in accurate classification in more than 95% of the cases, when skeletal remnants are available in good condition. A set of 14 indicators were introduced by Krogman in 1955 followed by introduction of additional four characteristics by Krogman and Iscan in 1986,such as the shape and size of the nasal aperture, size of the nasal bone, the length of the zygomatic arch and chin shape which allowed morphological gender estimation of the human skull.[4] Sex determination based on only morphological features as done in traditional studies are variable because the features depend on various environmental conditions and individual perceptions.[8]

The scientific measurement of the dimensions of the face and skull bases is considered as craniometry, which provides information related to the race, gender and body type.[3,9] Subsequently there has been a change in trend from morphological methods to morphometric analysis and statistical comparison like univariate analysis and the use of indices. These methods also never allow 100% accurate sex determination due to overlap between male and female values in many parameters.[8]

To overcome this, advanced analytical methods, such as multivariate linear discriminant functional analysis of metrical data are used recently.[8] Discriminant function analysis is an objective statistical technique selecting least number of traits and maximum discriminatory effectiveness.[10]

Different populations have varying skeletal characteristics, making population specific analysis for sex determination essential.[11] In the present century of intermixing population, the population specific standards are of significant practical relevance.

With all these implications, the objective of our study was to analyze the accuracy of craniometric parameters for sexual dimorphism in adult preserved skulls to the highest possible percentage in South Indian population by stepwise, multivariate and univariate function analysis and to develop discriminant equations.

2. Materials and methods

This retrospective study was done in 70 adult preserved human skulls of one of the major medical colleges conforming to the inclusion and exclusion criteria from October 2012 to May 2014, after obtaining the Institute ethics committee clearance. The study included well preserved fully ossified adult skulls without any craniofacial injury. Skulls having obliterated anatomical landmarks, distorted morphological features and with obvious bone pathology were excluded from the study. Those skulls which could not be accurately sexed based on morphological features were also excluded. Mandible was excluded from this study. This was a limiting factor as majority of skulls didn't have the corresponding mandibles.

Electronic weighing machine, sliding vernier caliper, spreading caliper, non-stretchable measuring tape, measuring scale, thread, chalk and marker were used for measuring the parameters.

2.1. Methods

The sex of the adult preserved skull was initially determined by standard morphological traits.[12] Based on the morphological traits 70 skulls of unknown sex were classified into 43 male skulls and 27 female skulls. A total of 26 craniometric parameters were included in the study as adapted from Moore- Jansen et al.,[13] Buikstra and Ubelaker[13] and Deshmuk AG and Devershi DB.[8]

The parameters studied were weight, maximum cranial circumference, maximum cranial length (glabella-opisthocranion), maximum cranial breadth (euryon-euryon), bizygomatic breadth (zygion-zygion), basion-bregma height (basion-bregma), cranial base length (basion-nasion), basion-prosthion length (basion-prosthion), maxillo-alveolar length (prosthion-alveolon), maxillo-alveolar breadth (ectomolare-ectomolare), biauricular breadth (auriculare-auriculare), upper facial height (nasion-prosthion), upper facial breadth (frontomalare temporale-frontomalare temporale), minimum frontal breadth (frontotemporale-frontotemporale), nasal height (nasion-nasospinale), nasal breadth (alare-alare), orbital height (distance between superior and inferior orbital margins taken perpendicular to orbital breadth), orbital breadth (dacryon-ectoconchion), biorbital breadth (ectoconchion-ectoconchion), interorbital breadth (dacryon-dacryon), frontal chord (nasion-bregma), parietal chord (bregma-lambda), occipital chord (lambda-opisthion), foramen magnum length (basion-opisthion), foramen magnum breadth (distance between lateral margins of foramen magnum at the points of greatest lateral curvature) and mastoid length (vertical projection of mastoid process below and perpendicular to eye-ear plane).[8,13]

All the measurements were taken to the nearest millimeter and were converted to centimeter and weight was measured in grams. Left side of each skull was chosen. If left side could not be used, right side was used. After cleaning the preserved skulls, each skull was serially numbered to minimize operator bias.

2.2. Statistical analysis

The data was tabulated in Microsoft excel worksheet and the statistical analysis was done using the statistical package for social sciences software IBM SPSS 20.0 (Chicago, IL, USA) for Windows. The general descriptive statistics was done for all the craniometric measurements providing mean and standard deviation (S.D) separately for both male and female skulls. Student's t test was performed to check if any significant differences exist ($p \leq 0.05$) among genders.

Direct discriminant function analysis was done by stepwise, multivariate and univariate methods and sectioning points were calculated. Multivariate analysis is done separately for all the 26 parameters and the 6 parameters with p value of 0.000 at descriptive statistical analysis, stepwise analysis was done to determine the best dimorphic variables and univariate analysis was done to figure out the contribution of each variable. The classification results of the above were cross-validated using “leave one out classification” method.

Discriminant functional scores of male (Zm) and female (Zf) skulls were obtained by applying the mean data of male and female skulls respectively using the discriminant functional score $(Z) = b0 + b1X1 + b2\,X2 + \text{- - - - - - - - -} + b26\,X26$ (b0 - constant, b1 − b26 are coefficients, X1 − X26 are variable of parameters). Sectioning point (Z0) was obtained using the average mean value of male and female skull variables. This program has its sectioning point at zero. When the values of two group centroids are different, the sectioning point is obtained by taking the average of the two means. If the score is higher than the sectioning point, the individual is considered male; lesser than that, the individual is considered as female.[11]

3. Results

3.1. Descriptive statistics

Out of the 70 skulls, 43 (61.4%) were male and 27 (38.6%) were female. The mean value reveals statistical significant difference ($p \leq 0.05$, Independent sample student's t test) across gender for most of the craniometric parameters as shown in Table 1. Male