Sexual dimorphism of the craniofacial region in a South Indian population

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INTRODUCTION To the best of our knowledge, the sexually dimorphic characteristics of the craniofacial region among the South Indian population are not available in the current literature. We aimed to determine these characteristics using discriminant function analysis.

METHODS A total of 80 recent skulls (40 male, 40 female) from the Department of Anatomy, Yenepoya Medical College, Yenepoya University, Karnataka, India, were analysed. Ten craniofacial parameters were measured and subjected to univariate and multivariate statistical analyses using the Statistical Package for the Social Sciences version 13.0.

RESULTS Statistical analyses revealed that the differences in the bizygomatic, orbital and biorbital breadths of males and females were significant (p < 0.05). Direct method gave an accuracy of 68.8% for sex determination. In stepwise analysis, bizygomatic breadth and upper facial height were selected, giving a 65.0% accuracy for sex prediction.

CONCLUSION Craniofacial parameters are sexually dimorphic. The present study established several features of craniofacial morphometry that can be used for sex determination among the South Indian population. The findings of the present study serve as a foundation for future studies that aim to compare craniofacial parameters among various ethnic groups in South India.

INTRODUCTION

Biological sex determination is a basic assessment in the evaluation of human remains. Further evaluation of the skeletal profile includes the identification of age at death, race, stature and ancestry. It is a challenge for forensic scientists and anthropologists to establish the biological profile of skeletal remains. Skeletal components are widely used in sex distinction because the skeleton is made up of hard tissues that can withstand extreme conditions and sex differences in the skeletal components exist due to differing growth spurts, growth patterns, strength of muscular attachments to the bone,[1] and the presence of bony ridges and processes[2] between the two sexes. Osteological variations between the sexes are population-specific.[3] The phenotypic differences between the sexes are influenced by genetic and environmental factors. Changes in socioeconomic status, nutrition and physical activities also contribute to sexual dimorphism.[1]

Studies on sexing skeletons using osteometric measurements have been reported.[4,5] The metrical method has been widely employed in the determination of sex. It involves subjecting the measurements of a set of parameters to various analyses. Discriminant function analysis, however, is a statistical method that explores the differences between groups by determining which combination of variables can best predict sex. In this method, the measurements of the different parameters are taken as independent variables, whereas sex is set as a dependent variable. Moreover, this method uses discriminant function equations that are population specific, thus making it the best method for sex determination.

The pelvis is considered to be the best skeletal structure for sexing, followed by parts of the skull such as the cranium,[6,7] mandible,[5,8] glabella,[9] mastoid process[10,11] and occipital bone.[12,13] Craniofacial anthropometry for sex identification has been widely studied in various populations. The best parameter of craniofacial anthropometry reported for sex determination is bizygomatic breadth; other parameters include nasal width, head length, head width, ramus height, depth of face, upper facial height, and inner and outer canthal distance.[4,14-17]

As South India is composed of a heterogeneous population rich in ethnic and cultural diversity, and craniofacial growth is influenced by racial, ethnic, sexual and dietary differences,[15] standard data of the local population is fundamental in the evaluation and diagnosis of craniofacial abnormalities. In other words, population-specific data is, desirable. In this regard, we conducted the present study to evaluate the degree of sexual dimorphism in a contemporary South Indian population. This data, to the best of our knowledge, is currently not available in the literature. Univariate and multivariate statistical analysis were used and discriminant functions were developed for the ten craniofacial parameters that were used in sex determination.

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METHODS

A total of 80 skulls (40 male, 40 female; age range 35–60 years) from the Department of Anatomy, Yenepoya Medical College, Yenepoya University, South India, were used. Only skulls in good condition and with recorded sex identification were included. Skulls that were damaged, incomplete or without sex identification were excluded. Ten measurements were recorded for each cranium, using digital vernier callipers (Table I, Figs. 1 & 2). Collected data were analysed using the Statistical Package for the Social Sciences version 13.0 (SPSS Inc, Chicago, IL, USA). Descriptive statistics, including mean and standard deviation (SD), were

Table I. Craniofacial parameters measured.

Craniofacial parameter	Description
Bizygomatic breadth	The straight distance between the two zygia, which are the most laterally placed points on the zygomatic bone.
Facial length	The straight distance between the basion and the prosthion.
Upper facial height	The straight distance between the nasion and the prosthion.
Orbital breadth	The straight distance between the dacryon and the ectoconchion.
Orbital height	The maximum height from the upper to lower orbital borders, perpendicular to the dacryon-ectoconchion line (orbital breadth).
Biorbital breadth	The straight distance between two ectoconchion.
Interorbital breadth	The straight distance between the two dacrya.
Nasal height	The straight distance between the nasion and the nasospinale.
Nasal bone length	The distance between the nasion and the rhinion.
Nasal breadth	The maximum width between nasal borders of piriform aperture.
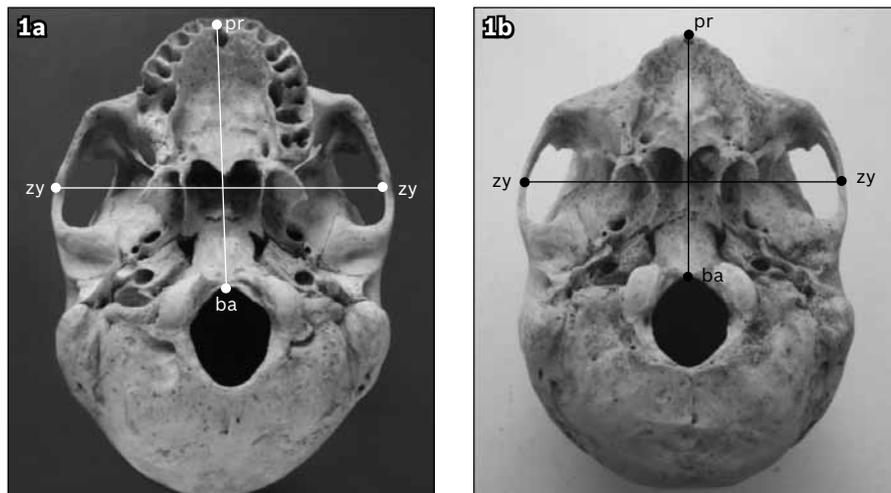
Fig. 1 Photographs of the basal view of (a) male and (b) female crania show points of craniofacial measurements. ba: basion; pr: prosthion; zy: zygion
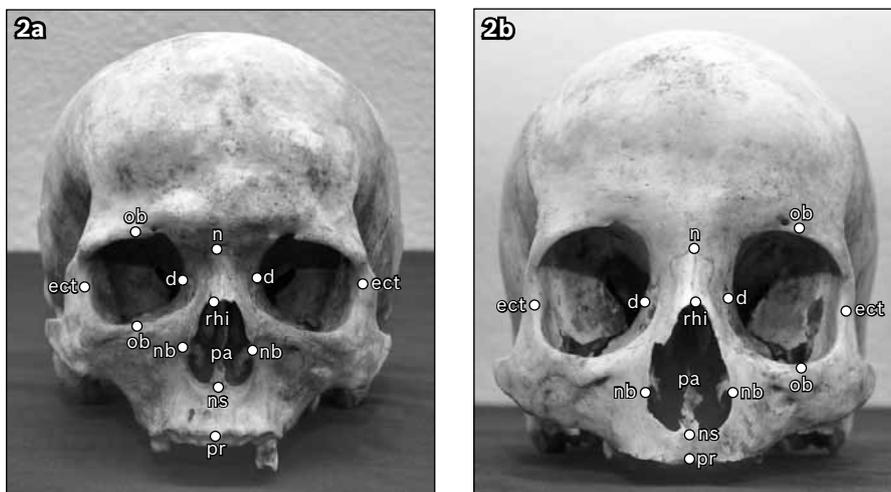
Fig. 2 Photographs of the frontal view of (a) male and (b) female crania show points of craniofacial measurements. d: dacryon; ect: ectoconchion; n: nasion; nb: nasal border; ns: nasospinale; ob: orbital border; pa: piriform aperture; pr: prosthion; rhi: rhinion

Table II. Descriptive statistics of the craniofacial parameters measured (n = 80).

Craniofacial parameter	Mean ± SD		t-value	p-value
	Male (n = 40)	Female (n = 40)		
Bizygomatic breadth	118.41 ± 5.30	113.72 ± 6.39	3.57	0.001*
Facial length	93.40 ± 5.64	92.50 ± 5.89	0.70	0.486
Upper facial height	62.26 ± 3.99	63.33 ± 5.16	1.04	0.301
Orbital breadth	40.21 ± 2.09	39.23 ± 2.08	2.09	0.040*
Orbital height	32.94 ± 1.96	33.27 ± 2.09	0.72	0.472
Biorbital breadth	96.61 ± 3.56	94.52 ± 3.94	2.49	0.015*
Interorbital breadth	24.56 ± 2.41	24.55 ± 2.34	0.02	0.985
Nasal height	47.87 ± 2.94	47.54 ± 3.03	0.50	0.618
Nasal bone length	18.75 ± 3.55	19.99 ± 2.90	1.70	0.092
Nasal breadth	24.29 ± 1.87	23.76 ± 1.80	1.32	0.192

Note: All measurements are in mm. *Difference between male and female is statistically significant.

obtained for each measurement. Stepwise, univariate and multivariate direct discriminant function analyses were performed to calculate specific discriminant function formulae for all parameters. A p-value of < 0.05 was considered statistically significant.

RESULTS

Descriptive statistics (i.e. mean ± SD, t-value and p-value) obtained for the ten craniofacial measurements are shown in Table II. All parameters were found to be larger in males, except for upper facial height, orbital height and nasal bone length. The p-values indicated that bizygomatic, orbital and biorbital breadths contributed significantly to sexual dimorphism (p < 0.05).

Table III shows the results of the multivariate analysis using all craniofacial parameters. Direct method indicated that the accuracy of sex determination using all parameters is 68.8%. Bizygomatic breadth had the highest structure matrix in relation to the discriminant function score. The formula derived is: y = (0.129 × BZB) + (−0.023 × FL) + (− 0.089 × UFH) + (−0.109 × OB) + (−0.137 × OH) + (0.146 × BOB) + (−0.140 × IOB) + (0.087 × NH) + (−0.115 × NBL) + (0.115 × NB) + (−13.58), where BZB: bizygomatic breadth; FL: facial length; UFH: upper facial height; OB: orbital breadth; OH: orbital height; BOB: biorbital breadth; IOB: interorbital breadth; NH: nasal height; and NB: nasal breadth.

Using stepwise discriminant function analysis, only two variables – bizygomatic breadth and upper facial height – were selected as the best discriminants between the sexes (Table III), with a Wilks' lambda value of 0.802. Discriminant function was subsequently developed and a sectioning point calculated. Multivariate and cross-validation classification using the 'leave-one-out' classification method was conducted for all equations. Using stepwise discriminant score, an average accuracy of 65.0% was obtained (Table III). The formula derived is: y = (0.178 × BZB) + (−0.135 × UFH) + (−12.15).

The resulting average accuracy of sex prediction ranged from 58.8% to 68.8%. In males, the single best parameter was the bizygomatic breadth (62.5%), while the most significant dimensions in females were the bizygomatic breadth (75.0%) and upper facial height (72.5%). Other than that observed in the direct method, there was almost no difference between the original and cross-validated percentage average accuracies (Table IV).

DISCUSSION

Human anthropometry is influenced by factors such as geographical location, race, sex, age, dietary habits and occupation.[15] Anthropometric studies can be used as an important tool for understanding biological variability. Craniofacial anthropometry plays a significant role in sex prediction, evolutionary biology, forensic investigation,[18] craniofacial surgery and syndromology.[19] The baseline values of local populations are fundamental in the evaluation and diagnosis of craniofacial abnormalities. It is important to have the standard data of indigenous ethnic groups in the evaluation of congenital malformations and facial defects.[15]

In the present study, except for upper facial height, orbital height and nasal bone length, all other parameters used showed larger values in males than in females. This finding is in agreement with other studies on craniofacial parameters.[4,5] The difference in the craniofacial parameters may be due to the differential growth rates of males and females; females reach skeletal maturity at an earlier age and fusion of the facial sutures is delayed in males. These genetic processes are controlled by hormones, resulting in dimorphic characteristics.[1] The present study shows that bizygomatic breadth and upper facial height are good discriminants of sex, with bizygomatic breadth being the best discriminant. Our finding concurs with other studies that found bizygomatic breadth to be the best parameter for sex determination in different populations.[4,14-17] Males have broader bizygomatic breadth than females, possibly due to hypertrophy of the masseter and temporalis muscles in males,[4,20] which causes greater convexity, and hence, increased breadth of the zygomatic arches.

Table III. Discriminant function analysis for craniofacial parameters.

Craniofacial parameter	Unstandardised coefficients	Standardised coefficients	Wilk's lambda	Structure matrix	Constant	Centroid	Average accuracy
Direct method			0.745		−13.582	M = 0.578	68.80%
						F = −0.578	
BZB	0.129	0.757		0.691			
FL	−0.023	−0.133		0.136			
UFH	−0.089	−0.410		−0.202			
OB	−0.109	−0.227		0.404			
OH	−0.137	−0.278		−0.140			
BOB	0.146	0.548		0.482			
IOB	−0.140	−0.332		0.004			
NH	0.087	0.259		0.097			
NBL	−0.115	−0.374		−0.330			
NB	0.115	0.211		0.255			
Stepwise method			0.802			M = 0.490	65.0%
						F = −0.490	
BZB	0.178	1.046		0.813	−12.146		
UFH	−0.135	−0.626		−0.237			

BOB: biorbital breadth ; BZB: bizygomatic breadth; F: female; FL: facial length; IOB: interorbital breadth; M: male; NB: nasal breadth; NBL: nasal bone length; NH: nasal height; OB: orbital breadth; OH: orbital height; UFH: upper facial height

Table IV. Validity of functions on independent samples.

Method	Original accuracy	Cross validation (IS)
Direct	68.8	62.5
Stepwise	65.0	63.8
Bizygomatic breadth	68.8	67.5
Upper facial height	58.8	60.0

Data is expressed as percentage. IS: independent sample

Using the cranial measurements of white South Africans, an overall accuracy of 85.7%[16] for sex prediction was reported, whereas cranial measurements of 8 black South Africans yielded an average accuracy of 77%–80%.[21] In the same population, Dayal et al used 14 cranial and 6 mandibular measurements and reported a discrimination accuracy of 80%–85%.[17] Saini et al developed discriminant function equations for ten craniofacial parameters and reported success rates of 61.8%–85.5% in a North Indian population.[4] Our study, which was conducted on a South Indian population, resulted in an accuracy of 58.8%–68.8% for sex prediction, comparable to that of the study conducted on North Indians.[4] Bizygomatic breadth provided the highest accuracy for sex determination in both the North and South Indian studies, in agreement with the reports of other researches in different populations.[4,14-17] Following bizygomatic breadth, Saini et al found orbital breadth to be the second best discriminant in North Indians;[4] in our study on South Indians, however, upper facial height was found to be the second best discriminant of sex. These differences in anthropometric traits between North and South Indians may be due to their different origins. The Indian population is derived from four primary ethnic groups: Caucasoid, Mongoloid, Australoid and Negrito.[22] North Indians, referred to as Aryans, belong to the Caucasian race, whereas South Indians, the original inhabitants of the country, called Dravidians, are classified as members of the Proto-Australoid or Australoid race. Differences in the morphological characteristics of these two races have been reported.[22]

In the present study, sex determination using craniofacial morphometry parameters was established for the South Indian population. Our findings could be of clinical importance, interest to forensic anthropologists and value in genetic studies. The craniofacial parameters derived for sexual dimorphism serves as a framework for future studies comparing the craniofacial anatomy of indigenous racial groups.

ACKNOWLEDGEMENTS

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