Original Research Article

Morphometric Assessment of Western Indian Crania by discriminant function analysis

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Abstract

Background: Craniometric measurements are used in anatomy, anthropology bioarchaeology, forensic medicine, neurosurgery, maxillofacial surgery and plastic surgery. Despite the fact that sex determination using craniometric traits is commonly used worldwide, very few studies are noted in Western Indian region which fill up the gaps existing in local forensic literature. **Objectives:** The purpose of this study is to evaluate sexual dimorphism in the cranium and to develop a population specific discriminant function equations that can be applied in sex determination from cranium during personal identification. **Material and Methods:** This study was conducted on 136 adult crania of known sex (102 male and 34 female) available in Anatomy departments of M P Shah Government Medical College, Jamnagar and other medical colleges across Gujarat. Five cranial parameters were measured and analyzed using both univariate and multivariate discriminant function analysis. **Results:** Males are statistically significantly greater than females in all dimensions with p value < 0.001. Maximum cranial length provide an accuracy rate of 83.8% on average by univariate discriminant analysis. By multivariate analysis accuracy is raised up to 88.2%. **Conclusion:** Sexual dimorphism in Western Indians is well reflected in cranial measurements. Mutivarite analysis give the highest classification accuracy and maximum cranial length is most dimorphic variable in univariate analysis. The study derived population specific discriminant equations for sex determination from crania of Western Indian population.

Key words: Sex determination, Discriminant function, Skull, Morphometry, Western India

Introduction

Identification of a deceased individual has social, economic and legal implications. Various natural and accidental circumstances may necessitate the use of anthropometry to identify the deceased person[1]. Since the skull is amongst the best preserved parts of the skeleton after death, many osteometric measurements have concentrated on cranial and mandibular measurements[2]. Craniometry is an important branch of anthropometry which measure skull bones dimensions useful for forensic experts, anthropologists, anatomists, surgical fields especially maxillofacial and plastic surgery for race, sex and age related differences and also for facial reconstructions of disputed identity. It is also useful for research purpose as studying growth trends in various races in defined geographic zone.

Various studies conducted on skulls by using morphological[3-6] and morphometrical approach. The dominance of metrical over non metrical assessment in current literature may be directly attributed to the margin of objectivity offered by this approach[7]. Some of the earlier studies following metric approach include South Africans[8-11], Americans[12], Japanese[13], Chinese[14,15], Greeks[16] and Thai population[17,18]. As a drawback however, morphometric assessment derived functions are highly population specific and sensitive to secular trends in size. Despite the fact that sex determination using craniometric traits is commonly done worldwide, very few studies are noted in Western Indian population on cranial measurements to fill up the gaps existing in local forensic literature. Present study aimed to evaluate sexual dimorphism in the cranium and to develop a population specific discriminant function equations that can be applied in sex determination from cranium during personal identification.

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Materials and methods

Material for the study consisted of 136 adult crania from individuals of known sex out of which 102 were from males and 34 from females. These bones were obtained from anatomy departments of M P Shah Government Medical College, Jamnagar and other medical colleges across Gujarat. Only those crania were chosen for study which were intact and free from any pathological or congenital anomaly. Firstly craniometric points were determined and marked by pen then distance measured between them by using spreading caliper or vernier caliper according to standard osteometric techniques described by Ales Hrdlicka[19], Sing and Bhasin[20] and Jaun Comas[21].

The following measurements were defined and recorded in millimeters.

(1) Maximum cranial length: Distance measured between glabella and opisthocranion by spreading caliper
(2) Basion nasion length: Distance measured from basion to nasion by spreading caliper
(3) Maximum cranial breadth: Maximum breadth measured above supramastoid crests between eurion by spreading caliper
(4) Maximum frontal breadth: Distance measured between coronalia by vernier caliper
(5) Basi bregmatic height: Distance measured from basion to bregma by spreading caliper

Data obtained from the study have been arranged in tabular form showing distribution according to sex of the crania. By methods of statistics, arithmetic mean and standard deviation (S.D.) were calculated for both male andfemale crania, for all the five observations. Student's t-test was applied to test the significance of difference of mean between the values observed in the male and female. Both demarking point and discriminant analysis were applied.

The principle of multivariate linear discriminant function is that measured variables are taken as independent variables whereas sex is dependent variable. After feeding the measurements of the present study and analyzing the same by computer SPSS program, coefficients and constants were obtained. For each cranium a discriminant score were obtained by multiplying each variable with its coefficient, summing them and adding in a constant. Discriminant function score was calculated by formula: Z = b0 + b1X1 + b2X2+……+bnXn. Where, Z is Discriminant function score, b0 is constant, b1 – bn are coefficients and X1 – Xn are variable of parameters.

The male – female sectioning point was determined as being halfway between the mean score for males (centroid) and the mean score (centroid) for females. A discriminant score greater than the sectioning point was classified as male and a score lower than the sectioning point was classified as female.

Results

Table: 1- Comparison of measurements of various parameters in male and female crania (All measurements are in mm.)

Diameter	Male			Female			T test	P value
	Range	Mean	S.D.	Range	Mean	S.D.		
Max cranial length	158-191	175.28	6.10	154-179	164.22	4.87	10.72	P<0.001
Basion nasion length	91-110	99.00	3.90	87-103	94.47	3.50	7.21	P<0.001
Max cranial breadth	120-154	33.23	6.45	110-137	127.39	6.15	4.73	P<0.001
Max frontal breadth	98-128	114.57	6.13	93-123	108.61	5.58	6.04	P<0.001
Basi bregmatic height	115-143	129.96	5.54	114-133	123.02	4.74	8.24	P<0.001

Table: 2- Univariate discriminant function of various parameters in male and female crania (All measurements are in mm.)

No.	Parameters	Co Efficient	Constant	Sectioning point	% identified	
F1	Maximum cranial length	0.172	-29.624	-0.475	M F Total	81.4 % 91.2 % 83.8 %
F2	Basion nasion length	0.262	-25.691	-0.2975	M F Total	74.5 % 70.6 % 73.5 %
F3	Maximum cranial breadth	0.157	-20.658	-0.228	M F Total	60.8 % 67.6 % 62.5 %
F4	Maximum frontal breadth	0.167	-18.847	-0.248	M F Total	66.7 % 73.5 % 68.4 %
F5	Basi bregmatic height	0.187	-23.946	-0.324	M F Total	73.5 % 82.4 % 75.7 %

Table: 3 - Multivariate discriminant function of various parameters in male and female crania

Parameters	Co Efficient	Constant	Equation	Sectioning point	% identified	
Function 1 1. Maximum cranial length 2. Maximum cranial breadth 3. Basibregmatic height	0.141 0.072 0.040	-38.888	-38.888 + (0.141 × L) + (0.072 × B) +(0.040 × H)	-0.563	M F Total	83.3 % 88.2 % 84.6 %
Function 2 1. Maximum cranial length 2. Basion nasion length 3. Maximum frontal breadth	0.148 0.017 0.083	-36.552	-36.552 + (0.148 × L) + (0.017 × L1) + (0.083 × B1)	-0.552	M F Total	87.3 % 91.2 % 88.2 %

Where, L - Maximum cranial length B - Maximum cranial breadth H - Basibregmatic height L^1 -Basionnasion length B1 - Maximum frontal breadth

Descriptive statistics, including means, standard deviation and P value for the cranial measurements are listed in Table 1. The differences between the sexes in all of these measurements were statistically highly significant (p<0.001). Table 2 shows sectioning points for each variable when discriminant function is applied to each of them. This classification provides a test to determine sex of unknown skull. Highest accuracy rate is achieved by using F1 (83.8%) followed by F5, F3, F4 and F2. Table 3 provides discriminant function statistics for identification of unknown individual when whole skull or skull with damaged facial skeleton available by putting values of parameters into discriminant equation; when score is greater than sectioning point the cranium is male and when score is less than sectioning point the cranium is female. Function 1 used three dimensions (maximum cranial length, maximum cranial breadth and basi bregmatic height) and 84.6% crania were correctly classified. Function 2 used three dimensions (maximum cranial length, basion nasion length and maximum frontal breadth) and accuracy rate is raised up to 88.2%.

Discussion

The present study deals with accuracy of sex determination of Western Indian crania by morphometric assessment. A statistically highly significant difference was found in both sexes for all five parameters. However because of overlapping ranges in each one, only few crania were correctly classified by demarking point analysis. When univariate and multivariate discriminant functions applied to results, it highly increases accuracy rate. It might be difficult to include large number of parameters to determine the equation when skull with damaged facial skeleton available for identification. Considering this fact present study selected three parameters to develop equations as shown in Table 3. As mentioned above present study provided efficient discriminant equations to determine sex from Western Indian crania.

Nine measurements taken on 408 American Whites and Negros crania by Giles E and Elliot O[12]. Accuracy of 82-89% was attained by discriminant functions. Hanihara K[13] studied Japanese crania with nine craniometric variables, achieved accuracy from 85.6% to 89.7%. Franklin D et al[10] studied 332 crania of known sex in South African population and found facial width, cranial length and basi bregmatic height as strongest discriminant. Accuracy of 77-80% was achieved by using eight measurements in discriminant function analysis. Steyn M and Iscan MY[9] measured 91 crania in South African Whites using 12 cranial parameters. Five functions obtained by using different parameters; 86.4% males and 80.9% females were correctly classified by using discriminant function with cranial length, basion nasion length and maximum frontal breadth. Present study achieved higher accuracy rate of 87.3% for male and 91.2% for female with the same function. Song HW et al[15] studied 60 Chinese skulls. Discriminantion rate for group of five variables resulted in accurate sex determination in 96.7% of cases, for group of fourteen variables there was 100% success rate. Kranioti EF et al[16] in Cretan population (Greeks) studied 178 crania of known sex. They used stepwise method involving five dimensions resulted in accuracy up to 88.2%. Mahakkanukrauh P et al[17] studied 200 Thai skulls. In their study discriminant equation using six cranial measurements was derived which could provide 90.6% accuracy rate, 91.1% in males and 90.0% in females. Sangvichien S et al[18] studied 101 skulls and derived multiple logistic equation for Thai population, gained overall accuracy of 88.8%; 92.1% and 82.9% among males and females respectively. Zavando MDA et al[22] identified 76.36 % of male crania and 76.9 % of female crania by applying discriminant function of maximum cranial length, maximum cranial breadth and basi bregmatic height on 226 skulls data. Present study identified 83.3% and 88.2% of male and female crania respectively by applying discriminant function using same parameters.

Shanthi et al[23] observed 85% of discrimination rate in South Indian crania by multivariate analysis. 95.5% of males and 86.2% of female crania were correctly classified using multivariate analysis in Indian study on 73 skulls data by Geetanjali SB et al[24]. Saini et al[25] studied 483 North Indian crania. In stepwise analysis accuracy reached up to 84.75% with the selection of five cranial variables. Multivariate analysis was used to formulate a series of discriminant functions on 300 crania in Indian study by Jain D et al[26] and highest accuracy rate was attained up to 84.0%. Deshmukh AG and Devarshi DB[27] observed that there was a lot of overlap in values of male and female crania by demarking point analysis supporting to our study. They also concluded that multivariate discriminant analysis is best method to determine sex of cranium with available resources. 90% of male and 82.29% of female crania were sexed correctly.

Conclusion

Sexual dimorphism in Western Indians is well reflected in cranial measurements. Mutivarite analysis give the highest classification accuracy and maximum cranial length is most dimorphic variable in univariate analysis followed by basi bregmatic height. The study derived population specific discriminant equations for sex determination from crania of Western Indian population and added data for future studies on skeletalized remains.

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