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DETERMINATION OF SEX USING ORBITAL MEASUREMENTS

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ABSTRACT

The orbit is an essential anatomical landmark of skull and orbital measurements are one of the craniofacial parameters that could be used in sex identification in terms of anthropological studies. The aim of this study is to analyze data regarding the orbital aperture measurements in terms of sexual dimorphism. A total of 200 crania (100 of either sex) were included in the study. Orbital breadth (left and right), orbital height (left and right), orbital index (left and right), interorbital breadth and biorbital breadth were taken on each cranium. Sexual dimorphism was analysed by using discriminant function analysis. Using univariate analysis, highest accuracy of sex classification was achieved from biorbital breadth (76.0%) and the least accuracy was achieved from orbital height of right side (53.0%). Five multivariate functions were also formulated by combining multiple measurements in a single function. Highest accuracy was achieved up to 79.0%. Data obtained from this study showed that orbital measurements could be used in sex determination of crania. Further, it can be concluded from this study that the univariate and multivariate functions can also be applied when fragmentary remains are found.

Keywords: Cranium, sex determination, sexual dimorphism, morphometric analysis, foramen magnum, discriminant function analysis.

INTRODUCTION

Sexual dimorphism has been an important pursuit in forensic anthropological research for many years. In forensic anthropology, sex estimation is extremely important in finding the identity of decedents. General differences in size, robusticity and specific morphological traits in the skull and post-cranium indicate the sex of skeletal remains. Accuracy rates for sex estimation vary according to which skeletal elements are used. Data from earlier studies indicate that 90% to 100% accuracy in assessing sex can be achieved when using the entire skeleton. However with only pelvis, accuracy drops to 90% to 95% and with only skull, an accuracy of 80% to 90% has been reported (Stewart, 1979; Krogman and Iscan, 1986). The skull is the

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second best part of the skeleton to be used for determining sex (Bass, 1971). General features and specific traits have been researched and the classification criteria have been established, based on visual and metric measurements. Visual methods, if reliable, are difficult to apply when complete skeleton is not found and hence the use of metrical methods is preferred.

Different craniometric parameters have been employed to accurately and reliably determine the sex of a person in forensic medicine. Orbital measurements are one of the craniofacial parameters that could be used in sexual estimation in terms of anthropological studies (Weaver *et al*., 2010; Rossi *et al*., 2012).

Dayal *et al*. (2008) studied fourteen measurements on 120 skulls for the assessment of the Black South Africans. They also measured orbital breadth and orbital height. Accuracy levels achieved were 65.80% and 53.30%, respectively. Saini *et al*. (2011) explored the dimorphic characteristics of the craniofacial region to establish the standards for the skulls. Out of nine measurements, orbital breadth and orbital height were also measured. Accuracy levels achieved were 62.5% and 48.20%, respectively. Swami *et al*. (2012) worked on 5 metric variants of orbital area for sex estimation. Measurements were orbital height, orbital breadth, orbital index, inter-orbital breadth and bi-orbital breadth. By statistical analysis, orbital index and orbital breadth were found to be the best discriminants and were able to classify 61.7% of the skulls correctly. Rossi *et al*. (2012) evaluated the dimensions of the orbital aperture in Brazilian subjects to verify its relationship to gender. Orbital breadth, orbital height and inter orbital breadth were measured. Results revealed the significant difference for orbital breadth and inter-orbital breadth between sexes. The study reported that if the breadth of orbital aperture is < 3.5 cm the skull is likely to be female and if it is < 3.5 cm it is likely to be a male. If the inter-orbital distance is < 2.4 cm the skull is likely to be a female and if it is > 2.5 cm, it is likely to be a male.

Jeremiah *et al*. (2013) worked on the cranial and orbital indices for Black Kenyan population. Results revealed that mean value for orbital index was 82.57 and 83.48 for the males and females, respectively. Kaya *et al*. (2014) analyzed data regarding the computerised scans of orbital aperture measurements in Turkish population for sex estimation. Accuracies for single and multiple variable discriminant functions ranged from 59.8% to 75.0%.

An examination of past literature revealed that there are not sufficient numbers of studies about sex estimation based on orbital measurements. The aim of this study is to obtain and analyze data regarding the orbital measurements of the crania for sex estimation.

MATERIAL AND METHODS

A total of 200 dry adult crania (100 males and 100 females) were included in the study. Only the skulls with no apparent deformity were measured. Juvenile skulls were also excluded from the study. Initial examination of all the crania was done following the non-metric observations to categorize them into male and female category (Rogers, 2005). Data were collected from Department of Anthropology, Delhi University, Delhi; University college of Medical Sciences, Delhi; Lady Harding Medical College, Delhi, Holy Family Hospital, Delhi and Department of Forensic Medicine and Anatomy, All India Institute of Medical Science (AIIMS), Delhi.

Following six direct and two indirect measurements pertaining to orbital area were taken on each cranium in accordance with the standard measurement techniques recommended by Martin and Saller (1959) and Singh and Bhasin (1968):

1) Orbital Breadth (left)
2) Orbital Height (left)
3) Orbital Index (left)
4) Orbital Breadth (right)
5) Orbital Height (right)
6) Orbital Index (right)
7) Inter orbital breadth
8) Biorbital breadth

Orbital Breadth: It measures the straight distance between maxillofrontale and ectoconchion (mf-ect) (left and right both).

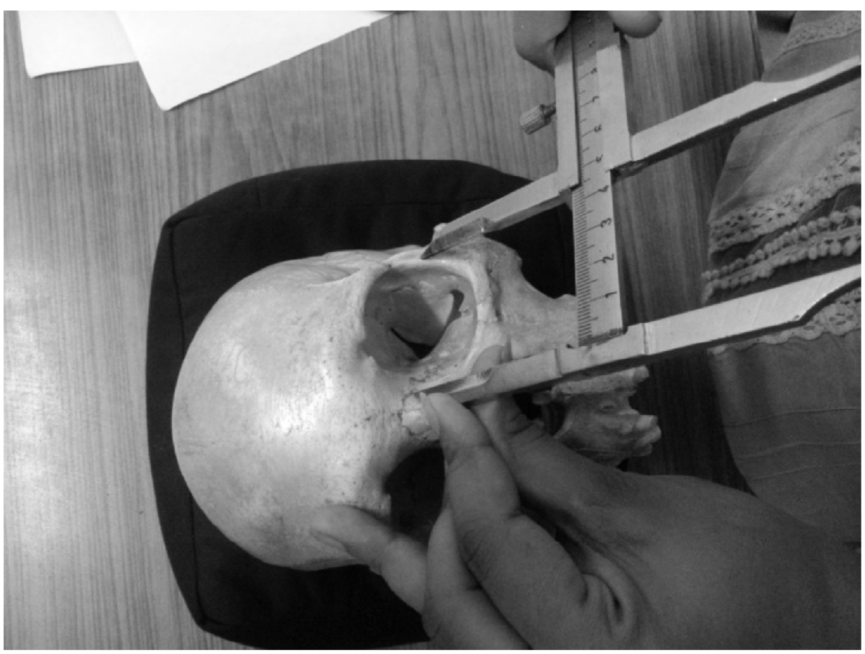

Figure 1: Frontal view of the skull showing orbital breadth

Orbital Height: It measures the straight distance between the upper and lower margins of the orbital cavity, taken at right angle to the orbital breadth (left and right side both).

Figure 2: Frontal view of the skull showing orbital height

Orbital Index: Orbital Height / Orbital Breadth ´ 100

Inter-orbital Breadth: It measures the straight distance between two maxillofrontale landmarks (mf-mf).

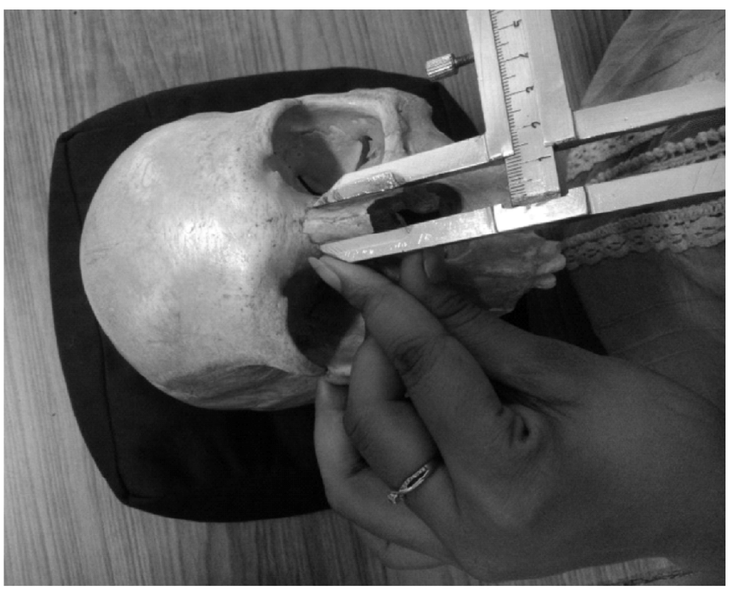

Figure 3: Frontal view of the skull showing inter-orbital breadth

Bi-orbital Breadth: It measures the straight distance between two ectoconchion (ect-ect) points.

Figure 4: Frontal view of the skull showing bi-orbital breadth

Landmarks

Ectoconchion (ect) – It is the point where a line running parallel to the upper orbital border cuts the lateral orbital margin.

Maxillofrontale (mf) – It is the point where the anterior lacrimal crest meets the frontomaxillary suture.

The data were analysed using the SPSS 16.0 program. Descriptive statistics, including mean, standard deviation, standard error and dispersion were obtained for each of the measurements. To assess the significance of sex and side differences, t-test was applied. Univariate and multivariate discriminant function analyses were performed to formulate univariate and multivariate discriminant function equations for sex determination. A 'leave one out classification' procedure was applied to demonstrate the accuracy rate of the original sample and the one created by cross-validation.

RESULTS

Data have been analysed statistically for descriptive statistics, t-test, and discriminant function analysis by using the standard programme of SPSS-16 from the Delhi University library. Univariate and multivariate discriminant functions were formulated for determining the accuracy percentages of all the measurements and functions.

Table 1 represents the mean, standard deviation, standard error of mean and dispersion for all the direct and indirect measurements of male and female crania. It is observed from the table that male crania exhibit greater mean values for all the measurements except for orbital index of both sides which indicates that male crania are larger in size than female crania. Further it is noticed that the range values are higher in the orbital indices than other measurements.

Table 2 presents the results of t-test in order to access the sex differences in different cranial measurements. It is observed from the table that sex differences are significant ($p<0.05$) in all the measurements except orbital height of both sides. The highest t- value is found in orbital breadth of left side and the least t-value, in the orbital height of left side.

Table 3 presents the results of t-test in order to access the significance of side differences in different measurements taken on male and female crania. It can be observed from the table that only orbital breadth and orbital index of female crania show significant side differences ($p<0.05$).

Table 4 presents the raw-coefficients, centroids, sectioning points, original accuracy percentages and cross-validated accuracy percentages of all the measurements of male and female crania. The raw coefficient is used to calculate discriminant scores for all the measurements. The discriminant score is obtained by multiplying each measurement by its raw coefficient and then adding the constant, as explained in the following example:

Univariate discriminant equation for orbital breadth (left)-

D = (orbital breadth (left) ´ 5.627) + (-22.960)

Whereas, sectioning point is the mean of male and female centroids.

Sectioning point= ½ × Male centroid + Female centroid

The value of sectioning point obtained for all the univariate discriminant function equations is zero. If the discriminant function score is smaller than the sectioning point or if the value is in negative then it is considered to a female, while a value greater than the sectioning point or if the value is in positive then it would indicate a male. A cross-validation using leave-one-out method was also employed to check how well the subjects are allocated to the groups.

Wilk's lambda test was also applied in order to assess the level of significant contribution of all the measurements in univariate discriminant functions. The closer wilk's lambda value is to 0, the more the variable contributes to the discriminant function.

It can be observed from the table that the highest significant contribution and accuracy is achieved from bi-orbital breadth (Wilk's lambda= 0.756; original accuracy= 76.0%; cross-validated= 76.0%) and the least accuracy is achieved from orbital height of right side (wilk's lambda= 0.988; original accuracy= 53.0%; cross-validated= 53.0%).

Table-5 presents the raw-coefficients, centroids, sectioning point, original accuracy percentages and cross-validated accuracy percentages of all the functions formulated for the sex determination. The discriminant score is obtained by multiplying each measurement by its raw coefficient, summing them and then adding the constant, as explained in the following example:

From function1, the discriminant score is calculated as –

D= (Orbital breadth (left) ´ 2.356) + (Orbital height (left) ´ -9.119) + (Orbital index (left) 0.420) + (-13.495).

Whereas, Sectioning point= ½ ´ Male centroid + Female centroid.

The value of sectioning point obtained for all the multivariate discriminant function equations is zero. If the discriminant function score is smaller than the sectioning point or if the value is in negative then it is considered to be of female, while a value greater than the sectioning point or if the value is positive then it would indicate a male.

Five multivariate functions were formulated by using direct approach. It is observed from the table that the highest significant contribution and accuracy is achieved from function 2 (Wilk's lambda= 0.711; original accuracy= 79.0%; cross-validated= 77.0%) and the least accuracy is achieved from function 3 (wilk's lambda= 0.791; original accuracy= 66.5.0%; cross-validated= 66.5.0%).

DISCUSSION

The craniofacial anthropometric studies are very valuable for anthropometry, medicine, dentistry and forensic facial reconstruction experts (Baral *et al.*, 2010; Mahdi *et al*., 2012). However, diversity in size and shape of cranial skeleton arises through ontogenic, environmental, genetic influences as well as masticatory function (Kemkes and Gobel, 2006). On the basis of these factors, studies about intra- and inter-population variations have long been an interest and have been conducted on the age, sex and racial groups.

Several authors have worked on various parameters for the purpose of sex identification, using human cranial remains. The analysis of different parts of the crania is important in the determination of the sex from fragmentary remains. Some population specific studies have also been done on sex estimation through orbital measurements. Results of these studies are found comparable with the present study which has been discussed.

Dayal *et al*. (2008) studied fourteen measurements on 120 skulls for the assessment of sex of the Black South Africans. Orbital breadth and orbital height were measured. Accuracy achieved were 65.80% and 53.30% respectively. Saini *et al*. (2011) also studied orbital breadth and orbital height for sex determination of crania. Accuracies achieved then were 62.5% and 48.20%, respectively. On the other hand, accuracy achieved in the present study from orbital breadth and orbital height is 70.0% and 57.0% from the left side and 67.5% and 53.0% from the right side, respectively.

Swami *et al*. (2012) worked on 5 metric variants of orbital area for sex estimation. Measurements were orbital height, orbital breadth, orbital index, interorbital breadth and biorbital breadth which were also taken in the present study. By statistical analysis, orbital index and orbital breadth were found to be the best discriminants and were able to classify 61.7% of the skulls correctly. In case of present study, highest accuracy of 76.0% was achieved from the bi-orbital breadth from the univariate analysis and 79.0% from the function 2 with multivariate discriminant function analysis.

Rossi *et al*. (2012) evaluated the dimensions of the orbital aperture in Brazilian subjects to verify its relationship to gender. Orbital breadth, orbital height and inter orbital breadth were measured. Results revealed significant difference for orbital breadth and inter-orbital breadth. If the breadth of orbital aperture is < 3.5 cm the skull is likely to be female; if it is >3.5 cm it is likely to be a male. If the introrbital distance is < 2.4 cm the skull is likely to be a female, if it is > 2.5 cm, it is likely to be a male. In the present study also, all the three measurements were taken. Out of them, orbital height was found to be insignificant in present study as well. Univariate and multivariate functions were formulated to find the accuracy level of sex determination. Highest accuracy was achieved up to 76.0% from univariate analysis, i.e. by biorbital breadth, and 79.0% from multivariate analysis, i.e. by function 2.

Jeremiah *et al*. (2013) worked on the cranial and orbital indices for a Black Kenyan population. Results revealed that mean value for orbital index was 82.57 and 83.48 for the male and female, respectively. In present study also, orbital index was calculated to find out its relevance in correct sex determination. Results revealed that mean value of orbital index was 79.44 and 82.40 for left side and 78.60 and 80.99 for right side of male and female, respectively. It is found from both studies that value of orbital index is higher for females than males. Accuracy of correct sex classification achieved from orbital index is 62.5% from left side and 60.5% from right side, which was not calculated in the study by Jeremiah *et al*. (2013).

Kaya *et al*. (2014) analyzed data regarding the computerised scans of orbital aperture measurements in Turkish population for sex estimation. Sexual dimorphism in terms of orbital breadth and orbital height was analyzed using discriminant function analysis which is also common to the present study. From univariate analysis, highest accuracy (67.9%) was achieved from orbital breadth of left side. In present study also, orbital breadth of left side achieved the highest accuracy (70.0%). From multivariate analysis, accuracy up to 75.0% was achieved in Kaya *et al*. (2014) study and up to 79.0% in present study.

By comparing the results of present study to the other studies done on breadth and height of orbital measurements, it has been found that orbital breadth achieved the highest accuracy for correct sex determination (Dayal *et al*., 2008; Saini *et al*., 2011; Kaya *et al*., 2014 and present study). It is also evident from the results that females displayed larger mean values for orbital index than males (Jeremiah *et al*., 2013 and present study). In the present study, bi-orbital breadth achieved the highest accuracy of correct sex determination from the univariate analysis of all the measurements.

These measurements were further used to form different multivariate discriminant functions and the accuracy of up to 79.0% was achieved which is of practical importance.

CONCLUSION

The present results revealed that out of 8 orbital measurements and 5 multivariate functions, accuracy of correct sex classification was achieved up to 79.0%. From univariate analysis, bi-orbital breadth was found to be the best reliable parameter and achieved the highest accuracy of 76.0%. These measurements were further used in formulating 5 multivariate functions and the accuracy up to 79.0% was achieved by function 2 (left orbital breadth, left orbital height, left orbital index, left inter-orbital breadth). Orbital height was not found to be a very good variable for sex determination. However, it was seen that these orbital measurements could be used for the sex determination of crania. Also, the univariate and multivariate discriminant function equations formulated in the present study could be used in finding the sex of the fragmentary remains.

Table 1: Descriptive statistics for all the different measurements of male and female crania

	Measurements	*Sex*	*Mean*	*S.E(X) ±*	*S.D ±*	*Range*	*Min.*	*Max.*
1.	Orbital Breadth (left)	M	4.18	0.01	0.17	0.80	3.90	4.70
		F	3.98	0.01	0.18	0.90	3.50	4.40
2.	Orbital Height (left)	M	3.31	0.02	0.20	1.30	2.80	4.10
		F	3.27	0.01	0.17	1.20	2.50	3.70
3.	Orbital Index (left)	M	79.44	0.46	4.62	25.83	66.67	92.50
		F	82.40	0.46	4.67	25.43	69.44	94.87
4.	Orbital Breadth (right)	M	4.22	0.01	0.18	0.90	3.80	4.70
		F	4.04	0.01	0.17	1.00	3.50	4.50
5.	Orbital Height (right)	M	3.31	0.02	0.20	1.10	2.80	3.90
		F	3.27	0.01	0.19	1.20	2.50	3.70
6.	Orbital Index (right)	M	78.60	0.45	4.53	23.81	66.67	90.48
		F	80.99	0.48	4.85	23.06	69.44	92.50
7.	Inter orbital Breadth	M	1.91	0.02	0.21	1.20	1.40	2.60
		F	1.78	0.02	0.23	1.20	1.30	2.50
8.	Biorbital Breadth	M	9.63	0.03	0.36	2.00	9.00	11.00
		F	9.20	0.03	0.36	1.90	8.40	10.30

Table 2: Sex differences in different measurements of male and female crania

	Measurements	*t- values*
1.	Orbital Breadth (left)	8.11*
2.	Orbital Height (left)	1.63
3.	Orbital Index (left)	4.50*
4.	Orbital Breadth (right)	7.31*
5.	Orbital Height (right)	1.70
6.	Orbital Index (right)	3.59*
7.	Inter Orbital Breadth	4.20*
8.	Biorbital Breadth	8.56*

*significant at $p > 0.05$ level

Table 3: Side differences in left and right measurements of male and female crania

	Measurements	*t- values*	
		Male	*Female*
1.	Orbital Breadth	1.77	2.58*
2.	Orbital Height	0.07	0.15
3.	Orbital Index	1.28	2.09*

*significant at p > 0.05 level

Table 4: Univariate discriminant functions and accuracy percentages of all the cranial measurements

S. No.	*Measurements*	*Raw coefficient*	*Centroid*	*Sectioning point*	*Wilk's lambda*	*Accuracy %* O	C.V
1.	Orbital Breadth (left)	5.627	M= 0.565	0	0.756	70.0%	70.0%
	Constant	-22.960	F= -0.565				
2.	Orbital Height (left)	5.195	M= 0.112	0	0.986	57.0%	57.0%
	Constant	-17.131	F= -0.112				
3.	Orbital Index (left)	0.215	M= -0.319	0	0.907	62.5%	62.5%
	Constant	-17.387	F= 0.319				
4.	Orbital Breadth (right)	5.505	M= 0.498	0	0.800	67.5%	67.5%
	Constant	-22.760	F= -0.498				
5.	Orbital Height (right)	5.020	M= 0.118	0	0.988	53.0%	53.0%
	Constant	-16.545	F= -0.118				
6.	Orbital Index (right)	0.213	M= -0.253	0	0.939	60.5%	60.5%
	Constant	-16.973	F= 0.253				
7.	Inter Orbital Breadth	4.410	M= 0.289	0	0.922	64.5%	64.5%
	Constant	-8.165	F= -0.289				
8.	Biorbital Breadth	2.749	M= 0.599	0	0.734	76.0%	76.0%
	Constant	-25.885	F= -0.599				

O-Original accuracy percentage; C-Cross-validated accuracy percentage; M- Male; F- Female

Table 5: Multivariate discriminant functions and accuracy percentages of different functions

S. No.	*Functions*	*Raw coefficient*	*Centroid*	*Sectioning point*	*Wilk's lambda*	*Accuracy %* O	C.V
1.	**F1**						
	Orbital Breadth (left)	2.356	M= -0.582	0	0.745	72.5%	72.5%
	Orbital Height (left)	-9.119					
	Orbital Index (left)	0.420	F= 0.582				
	Constant	-13.495					
2.	**F2**						
	Orbital Breadth (left)	4.830					
	Orbital Height (left)	-11.359	M= -0.635	0	0.711	79.0%	77.0%
	Orbital Index (left)	0.512					
	Inter Orbital Breadth	-1.769	F= 0.635				
	Constant	0.711					
3.	**F3**						
	Orbital Breadth (right)	4.405	M= -0.511	0	0.791	66.5%	66.5%
	Orbital Height (right)	-11.890					
	Orbital Index (right)	0.529	F= 0.511				
	Constant	0.791					
4.	**F4**						
	Orbital Breadth (right)	4.889	M= -0.581	0	0.746	72.5%	71.0%
	Orbital Height (right)	-11.527					
	Orbital Index (right)	0.516					
	Inter Orbital Breadth	-2.097	F= 0.581				
	Constant	-19.541					
5.	**F5**						
	Inter Orbital Breadth	-0.700	M= 0.604	0	0.731	76.0%	75.5%
	Biorbital breadth	2.982	F= -0.604				
	Constant	-26.786					

O-Original accuracy percentage; C-Cross-validated accuracy percentage; M- Male; F- Female

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