J Life Science, 9(1): 28-32 (2017)
DOI: 10.31901/24566306.2017/09.01.04

Sexual Dimorphism in Craniometric Characteristics of Occipital Bone in Adult Human Skulls from West Bengal, India

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KEYWORDS Asterion. Inion. Opisthocranion. Sex Difference

ABSTRACT In human evolution, changes in the anatomical features of skull were related to bipedalism and increase in brain volume. Three important landmarks on occipital bone are asterion (ast), inion (i) and opisthocranion (op). Objectives: To observe sexual dimorphism of craniometric characteristics (CC) and to estimate sex using a linear dimension (i-op length) and the area of triangle (bilateral) formed by the three landmarks. Methods: A sample included 24 skulls of adult humans (12 males). The CC included linear measurements between i-op, i-ast, and op-ast, an index (i-op length / i-ast length x 100), area and perimeter of the triangle involving three landmarks. Results: Higher mean values of CC in male skulls were observed than in female skulls with significant sex difference ($p < 0.001$). Discriminant function analysis models using the variables (i-op length and area of triangle) correctly estimated sex (>83 %) of unknown adult individuals.

INTRODUCTION

In human evolution, musculoskeletal characteristics of the occipital region of skull are attributed to upright locomotion and expansion of brain volume. Among the species of *Australopithecus* and early *Homo*, remarkable variations were observed in the bony morphology of nuchal region of occiput (Kimbel et al. 2004). Bony prominences were also observed in the back of the skull of *Homo erectus and Homo neanderthalensis* with remarkable sex difference *(*Tattersall 2006). In modern human skull, inion (the external occipital protuberance of the skull where two superior nuchal lines meet in the mid-sagittal plane) is more prominent in males than in females. Head circumference is also higher in males than in females involving the landmark opisthocranion (op), the posteriormost point in the midsagittal plane of the occiput (Zheng 2011).

Few reports on sexual dimorphism of craniometric characteristics of adult human skulls involving landmarks on occiput (inion, asterion and opisthocranion) are available including a recent study representing Nigerian adult population (Orish et al. 2014). In that study, sex determination using inion-opisthocranion-asterion triangle on skull was done (Orish et al. 2014). Another study reported remarkable morphological variation associated with sex and ancestry in the condylar region of occipital bone (Wescott and Moore-Jansen 2001).

The present study was based on craniometric characteristics of occipital bone of adult human skulls, using the three landmarks: asterion (ast) ionion (i) and opisthocranion (op). The study has importance in bioarchaeological research and forensic investigation involving skull, particularly the occipital bone. The objectives of the present study were:

1. To observe sex differences of linear measurements, index, perimeter and area of triangle as craniometric characteristics involving three landmarks (ast, i and op) in adult human skulls.
2. To estimate the ability of the variables (i-op length and bilateral measures of the area of triangle) to discriminate sex (male and female).

METHODOLOGY

The present study was done during August and September 2012, in two laboratories of An-

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thropology Department under Vidyasagar University in West Bengal, India (see acknowledgements). The human skeletons were available for osteometry practical class as a part of the University curricula. Information on the skeletons (authorized suppliers, approximate age and sex) were available in the laboratory. Ethical clearance was not obtained from the authorities since the study was done using the skulls as laboratory specimens (without individual identity). Based on standard criteria (Stranding 2008), the author identified 24 skulls (12 male and 12 female) of adult individuals, fully ossified and free from any damage and deformity. Population background of the sample was unknown. However, it might be presumed that the skeletons were procured by the authorized laboratory specimen suppliers from local populations in West Bengal. The craniometric measurements were done placing the skull on a standard craniophore in the norma occipitalis facing the observer. Landmarks asterion (ast), inion (i) and opisthocranion (op) on the occipital bone of skull for the present study were identified (Orish et al. 2014). Linear measurements (mm) between inion and opisthocranion (i-op length), inion and asterion (i-ast length) (bilateral), opisthocranion and asterion (op-ast) (bilateral) were recorded using a standard digital sliding caliper with a precision of 0.01 mm (Mitutoyo). An index (Inion-opisthocranion-asterion index) involving three landmarks was calculated (i-op length / i-ast length x 100). Perimeter (mm) and area of triangle (mm^2) were also calculated using the three landmarks. Sexual dimorphism ratio of craniometric characteristics was calculated (mean value in male skulls divided by the mean value in female skulls). Significance of sex differences of linear measurements, index, perimeter and area of triangle was estimated using Student's t-test. Discriminant function analysis (DA) was done to understand the capacity of the variables (i-op length, bilateral measures of the area of triangle) to differentiate male and female skulls. Data analysis was done using the Statistical Package for Social Sciences (Version 13.00, Chicago IL, USA) for windows and $p< 0.05$ indicated statistical significance.

RESULTS

Mean values, standard deviation (SD) and range (minimum and maximum values) of craniometric characteristics in male (n = 12) and female (n = 12) skulls are presented in Table 1. Minimum and maximum values of craniometric characteristics were higher in male skulls than those observed in female skulls. The inion to opisthocranion length (i-op length) in male skulls was higher (34.30 ± 3.54 mm) than in female skulls (25.12 ± 5.76 mm) with significant sex difference ($t = 4.70$, $p< 0.001$). Other measurements were bilateral and mean values of craniometric characteristics (linear measurements, perimeter and area of triangle, involving the landmarks i, op and ast) were higher in male skulls in comparison with female skulls with significant sex difference ($p< 0.05$), except i-ast length (right side). Sexual dimorphism ratio was highest for area of triangle (left 1.44, right 1.45) and lowest for i-ast length (left 1.05, right 1.06) (Table 1).

The discriminant function analysis (DA) models were used to separate male and female skulls, based on craniometric characteristics: i-op length and bilateral estimates of the area of triangle (i-op-ast) (Table 2). The DA models for sex, estimated by the craniometric variables were significant ($p< 0.001$) as tested by ANOVA. There was no missing data and correct classification rate for sex was very high (>83%) in the models. Box's M (values: i-op length 2.50, area of triangle left 1.05, area of triangle right 1.32) tests did not violate the assumption ($p>0.05$); in each model, predicted groups did not differ in their covariance matrices. Association between DA models and the dependent variable (sex) as tested by canonical correlation coefficient was high (i-op length 0.71, area of triangle left 0.75, area of triangle right 0.73). Eigen value ($\geq$1.0) showed high variance in the dependent variable as explained by the function. Wilk's Lambda values were relatively low (i-op length 0.50, area of triangle left 0.44, area of triangle right 0.47) indicating high discriminatory abilities of the functions and Chi-squared test results were significant ($p< 0.001$) in three DA models (i-op length 14.95, area of triangle left 17.83, area of triangle right 16.34) (Table 2).

DISCUSSION

The present study demonstrated that craniometric measures had higher mean values in male skulls than in females with significant sex difference ($p<0.05$). The craniometric variables (inion to opisthocranion length and area of triangle) were reliable measures for sex differentiation in

Table 1: Descriptive statistics, t-test for significant sex difference of craniometric characteristics in adult human skulls (male =12, female =12)

Craniometric characteristics	*Male Mean (SD) [Min-Max]**	*Female Mean (SD) [Min-Max]*	*t (p-value)*	*Sexual dimorphism ratio*
Inion-opisthocranion length (mm)	34.30 (3.54) [30.05-39.86]	25.12 (5.76) [17.46-33.72]	4.70 (<0.001)	1.37
Inion-asterion length (left) (mm)	62.91 (2.73) [58.41-66.95]	59.69 (3.85) [55.72-65.59]	2.36 (0.03)	1.05
Inion-asterion length (right) (mm)	63.03 (2.97) [57.60-69.34]	59.42 (5.46) [53.97-68.96]	2.01 (0.06)	1.06
Opisthocranion-asterion length (left) (mm)	71.72 (3.17) [65.93-76.70]	64.99 (4.05) [58.39-72.38]	4.54 (<0.001)	1.10
Opisthocranion-asterion length (right) (mm)	71.82 (3.43) [65.18-79.60]	64.74 (5.65) [57.04-75.44]	3.71 (<0.001)	1.11
Inion-opisthocranion-asterion index (left) (%)	54.57 (5.80) [48.54-66.68]	42.27 (10.32) [28.32-59.01]	3.60 (<0.001)	1.29
Inion-opisthocranion-asterion index (right) (%)	54.47 (5.71) [47.47-65.98]	42.52 (10.33) [30.46-56.83]	3.51 (<0.001)	1.28
Perimeter of triangle (left) (mm)	168.93 (7.93) [154.92-181.79]	149.80 (10.52) [131.57-168.57]	5.03 (<0.001)	1.13
Perimeter of triangle (right) (mm)	169.14 (8.51) [153.29-188.04]	149.28 (13.73) [129.46-175.00]	4.26 (<0.001)	1.13
Area of triangle (left) (mm^2)	1079.60 (126.87) [893.09-1290.10]	749.14 (173.20) [486.44-1003.53]	5.33 (<0.001)	1.44
Area of triangle (right) (mm^2)	1081.94 (133.27) [878.69-1355.60]	747.71 (189.09) [488.88-1055.09]	5.00(<0.001)	1.45

SD: Standard deviations. * Min: Minimum value, Max: maximum value. Note: Paired t-test estimating bilateral difference of mean values of craniometric traits by sex was not significant (p>0.05)

Table 2: Discriminant function analysis for sex using craniometric characteristics of occipital bone in adult human skulls (male =12, female =12)

*Discriminant function analysis model**	*i-op length*	*Area of triangle (left)*	*Area of triangle (right)*
Cannonical discriminant function coefficient for sex			
-Unstandardized coefficients	-6.21 + 0.21 x (i-op length)	-6.02 + 0.01 x AT** (left)	-5.59 + 0.01 x AT (right)
Fisher's linear discriminant functions			
-Classification function coefficient for males	-26.41 + 1.50 x (i-op length)	-25.98 + 0.05 x AT (left)	-22.57 + 0.04 x AT (right)
-Classification function coefficient for females	-14.49 + 1.09 x (i-op length)	-12.87 + 0.03 x AT (left)	-11.14 + 0.03 + AT (right)
Correct classification rate (%)	83.33	87.5	87.5
Eigen value	1.0	1.29	1.14
Cannonical correlation coefficient	0.71	0.75	0.73
Box's M (p-value)	2.50 (0.12)	1.05 (0.32)	1.32 (0.26)
Wilk's Lambda	0.5	0.44	0.47
Chi square (p-value)	14.95 (<0.001)	17.83 (<0.001)	16.34 (<0.001)

*(male = 1, female = 0); i-op length: Inion-opisthocranion length; ** AT: Area of triangle

adult human skulls of unknown individuals. The discriminant function analysis models of the variables showed high degree correct classification of sex.

An earlier study on sex determination using inion-opisthocranion-asterion triangle on skull from Nigerian adult population reported higher mean value of i-op length in males (30.03 ± 0.50 mm) than in females (22.34 ± 2.10 mm) (Orish et al. 2014). The mean values of i-op length in male and female skulls in that report were lower than the values estimated in the present study. Sex difference of i-op length in both studies was significant ($p < 0.05$). The range of i-op length values on skulls of the present study (male: 30.05 to 39.86 mm; female: 17.46 to 33.72 mm) was different from that reported earlier from Nigeria (male: 22.21 to 46.59 mm; female: 14.10 to 32.22 mm) (Orish et al. 2014). The estimated sexual dimorphism ratio was similar in these two studies (Present study: 1.37; report from Nigeria: 1.34), showing higher mean values of i-op length in male skulls. When compared with the previous study (Orish et al. 2014), the mean value of craniometric character, i-ast length (bilateral) in the present report was lower in male skulls and almost similar or marginally higher mean value in female skulls. However, mean values of op-ast length and i-op-ast index (bilateral) were higher in the present study in both sexes. Area of triangle (bilateral) was lower in the adult skulls from Nigeria (Orish et al. 2014) in comparison with results obtained in the present study.

Musculoskeletal features of male skulls are more robust than of female skulls (Stranding 2008). It was mentioned in the introduction of the present report that occipital region of human skull has remarkable anatomical characteristics of bones and associated muscles that have evolutionary significance. In modern human skulls, significant sex differences of musculoskeletal traits are reported from different countries that are cited in the previous study (Orish et al. 2014). However, information on sex difference of i-op length was lacking except the earlier study from Nigeria (Orish et al. 2014). It might be presumed that due to lower values of i-op length in the Nigerian adult skulls (male and female), in spite of more or less similar values of i-ast length, the area of triangle was also lower (bilateral) in comparison with adult skulls from eastern India (present report). Previous studies reported higher dimensions (length and breadth) of adult human skulls from Africa (Maina et al. 2011) in comparison with information on skulls available from India (Kumar and Nagar 2013). Another recent study (Orish and Ibeachu 2016) on the same sample (Orish et al. 2014) of Nigerian adult skulls has reported higher cranial length and breadth in comparison with the cranial dimensions reported from India (Kumar and Nagar 2013). In the present sample from India, data on cranial length and breadth were not available. However, we can presume that due to higher dimensions of Nigerian skulls and thereby stronger suboccipital muscles, i-op length was lower (Orish et al. 2014) than that recorded in the present study from Eastern India.

CONCLUSION

The uniqueness of the present study was the estimation of degree of reliability of i-op length and area of triangle formed by the landmarks on occipital bone (i, op, ast) to differentiate male and female skulls. However, we must take into consideration that the sample represented a population without any information on ethnic background from eastern region of India, more particularly from the state of West Bengal. Moreover, sample size was relatively low. Therefore, it is better to state that the estimated discriminant function models in the present study are appropriate for the present sample. In summary, it can be stated that in absence of similar reports, the present study proposes an easier way to estimate sex from skulls of unknown adult individuals using craniometric characteristics (i-op length, area of triangle) on occipital bone with high reliablilty. Future research in this line with higher sample size across all age groups and representing populations with clear ethnic affinities will verify the present results.

ACKNOWLEDGEMENTS

During the period of study, the author was a Reader of Biological Anthropology at Vidyasagar University, Midnapore in West Bengal, India. The specimens were available at the Anthropology laboratories in an institution (Sitananda College, Nandigram, East Midnapore) and the postgraduate Department of Anthropology, both under Vidyasagar University. The author is thankful to the authorities of the respective institutions and other colleagues in the Anthropology Department for support.

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Paper received for publication on May 2017
Paper accepted for publication on July 2017