Anthropometric predictors for sexual dimorphism of skulls: A Comparative study

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Abstract— *Quantitative morphometric measurements with advanced analytical methods are emerging as reliable methods for sex differentiation of skeletal remnants. Aim of present study was to determine the difference in morphometric measurements in male and female skull and to determine the independents predictors and accuracy for sex differentiation using discriminant function analysis. A comparative observational study was conducted using 44 skull of known sex including 24skulls of males and 20 skulls of females. Various morphometric parameters are measured and analyzed using univariate, multivariate and discriminant function analysis. Cranial AP length, Bi Zygomatic diameter, Nasal Height, Nasal width and Mastoid length were found to be significantly higher in male skull. Discriminant function analysis predicted correctly the sex of skull with 79.5% accuracy. Morphometric measurement of cranium can be developed as objective method of sex determination with higher accuracy and repeatability and further enhanced by advanced statistical method like discriminant function analysis.*

Keyword: Sexual Dimorphism, Morphometric Measurements, Skull.

I. INTRODUCTION

Anthropometry is a Greek word which means measurement of man: *anthropos*-man and *metron*-refers to the measurement. Anthropometry is a science which deals with the measurement of human beings, whether living or dead or of skeletal materials and constitutes a series of systematized measuring techniques of expressing quantitatively the form of the human body and skeleton.[1]

Study of human skeleton for sex determination has been a topic of interest among researchers,[2] as bones of the body are last to perish after death, next to enamel of teeth. Almost all bones of the human skeleton show some degree of sexual dimorphism. Sex of an individual can be identified accurately in 80% of cases using skull alone and in 98% cases using pelvis and skull together. The sex is best assessed from the pelvis but it is very often damaged.[3] Skull is the main reliable bone exhibiting sexually dimorphic traits, because skull is highly resistance to adverse environmental conditions over time, resulting in the greater stability of dimorphic features as compared to other skeletal bony pieces.[4] Skull requires the most frequent sexing in medico legal cases.[4]

In the skull, Mastoid region is one of the most dimorphic traits;[5,6] the temporal bone is highly resistant to physical damage; thus it is commonly found as remainder in skeletons that are very old; of this, the petrous portion has been described as important for sex determination. Moreover, in case of burning, petrous part of temporal bone is generally preserved because of its compact structure and protected position at the base of skull.[7,8]

Previous studies by non-metrical methods used morphological traits which were not reliable because these features varied with nutrition, race, geographical regions and observer variation.[9] Subsequently trend changed to Quantitative morphometric methods; however no single parameter could differentiate male and female sex with 100% accuracy because of overlap between male & female values. The recent trend is to apply advanced analytical methods to metrical data.[10]

Present study aims to determine the difference in morphometric measurements in male and female skull and to determine the independents predictors and accuracy for sex differentiation using discriminant function analysis.

II. METHODOLOGY

A comparative observational study was conducted at Department of Anatomy, SMS Medical College, Jaipur from July 2014 to April 2015. For study purpose 44 dry macerated adult Human skulls of age group above 18-25 years of known sex including 24 skulls of males and 20 skulls of females, were included in which suture between the basiocciput and basisphenoid were united. Skulls with deformity or craniofacial defects were excluded from study. Ethical clearance was taken from the institution's Ethical Committee before initiation of the study. The measurements were taken separately for either side after putting the skull in Frankfurt's Plane (Figure 1). Vernier Calipers were used for measurements of skull. Two readings were taken for each measurement and average of these readings was taken to reduce the error of measurements. All measurements were recorded to the nearest millimeter. Anthropometric parameters used for the study were Maximum cranial length, Maximum cranial breadth, Cranial index, Upper facial height, Bizygomatic diameter, Upper facial index, Nasal height, Nasal width, Nasal index and Mastoid process length.

Figure 1
Measurement of skull in Frankfurt's Plane

Cranial Index was calculated as (Maximum Cranial Breadth / Maximum Cranial Length) x 100. Upper facial index was (Upper Facial Height / Bizygomatic Breadth) x 100. Nasal index was calculated as (Upper Facial Height / Bizygomatic Breadth) x 100.

Statistical analysis: Data was collected using predesigned proforma. Morphometric measurements were expressed as Mean and standard deviation and were analyzed using unpaired 't' test. Multivariate logistic regression and Discriminant function analysis was done to identify the independent predictors. Sectioning point received by using mean values of both was used to classify the skull into either category. P value <0.05 was considered significant. Statistical software SPSS Trial Package for Windows version 20 was used for data entry, processing and statistical analysis. Descriptive statistics were used to calculate all the relevant variables.

III. RESULTS

A total of 24 male and 20 female skulls were included in study. On statistical analysis Cranial AP length, Bizygomatic diameter, Nasal Height, Nasal width and Mastoid length were found to be significantly higher in male skull as compared to female skull (Table 1).

Table 1
Comparison of various morphometric parameters in male and female skull

S.No.	Morphometric Parameters	Male (N=24)		Female (N=20)		*P Value
		Mean	SD	Mean	SD	
1	**Cranial AP Length**	18.13	0.7	17.57	0.82	**0.019**
2	**Cranial breadth**	12.93	1.22	12.61	0.55	0.285
3	**Cranial index**	71.38	6.57	71.87	3.96	0.772
4	**Upper Facial Height**	65.48	4.36	63.85	3.92	0.203
5	**Bizygomatic breadth**	12.64	0.38	12.24	0.31	**<0.001**
6	**Upper facial index**	51.84	3.7	52.18	3.39	0.754
7	**Nasal height**	49.45	2.40	47.77	2.86	**0.040**
8	**Nasal width**	24.82	1.45	23.54	1.97	**0.017**
9	**Nasal index**	50.27	3.36	49.41	4.73	0.486
10	**Mastoid length right**	34.90	2.7	32.59	2.54	**0.006**
11	**Mastoid length left**	34.13	3.10	31.21	2.78	**0.002**

P value was calculated using unpaired 't' test

Among these morphological parameters which were found significant on univariate analysis (as in table 1) were then entered in Binary logistic regression (forward wald) model, which found Bizygomatic diameter and Mastoid length left side to be independent predictors for sex determination. (Table 2)

Table 2
Multivariate logistic regression analysis of identified morphometric skull parameters

Parameters	B	S.E.	Wald	df	Sig.	Exp(B)
Bizygomatic diameter	5.212	2.150	5.877	1	.015	183.487
Mastoid length (left)	.487	.201	5.846	1	.016	1.628

On discriminant function analysis (step wise), Bizygomatic diameter and Mastoid length left side were found to predict correctly the sex of skull with 79.5% accuracy (Table 3).

Table 2
Skulls correctly sexed on discriminant function analysis (stepwise)

	Male (N=24)	Females (N=20)	Overall (N=44)
N	20	15	35
Percentage	75%	83.3%	79.5%

Un-standardized canonical discriminant functions evaluated at group means was for Male=0.670 and for female = - 0.804

IV. DISCUSSION

Today many unidentified human remains are sexed though DNA analysis, but a number of situations remain in which morphological approaches are preferred. These situations include cases of genocide or mass fatality where the cost of bio-molecular analysis might be prohibitive, cases of ancient human remains where the material may be too degraded to yield amplifiable DNA, and cases where invasive analysis is impermissible on legal or ethical grounds.

It is necessary to have local data of these parameters since this standard reflect the potentially different pattern of craniofacial growth resulting from racial, ethic, sexual and dietary differences.[11] Present study found most parameters to be higher in male as compared to female skull. Most of the past similar studies like Deshmukh & Devershi et al[12] (Maharastra), Passeyet et al[13] (Kanpur), Vidya C S et.al.[14] (Mysore), Sumati et al,[15] Farkas et al.[16] (Caucasians), reported different skull morphometric parameters to be higher in male skull on univariate analysis.

Discriminant function analysis method identifies which variables contribute to making the classification, thus it serves as an entirely objective statistical technique for sex determination giving proper weightage to each character.[17] On discriminant function analysis, these parameters predicted sex of skull with 80% accuracy in present study. Previous studies like Giles et al. and Kajanoja P also reported nearly 80% accuracy in sex determination using various morphometric skull parameters.[17,18] Holland et al. reported discriminant analysis using occipital bone measurements, correctly determined sex with around 80% accuracy.[19]

Thieme and Schull[20] and Harihara[21] in linear discriminant function analysis reported a high accuracy of 98.5% and 90% accuracy respectively using various skull morphological parameters. Wescott[22] in study of adult crania using occipital bone measurements reported approximately 73% accuracy of sex differentiation on multivariate analysis.

These differences in the overall accuracy reported in various studies could be due to the fact that these parameters are population specific and probably affected by ethnic and racial variations and this also makes it necessary to have local data of these parameters.

V. CONCLUSION

Sex determination using morphometric measurement of cranium provides objectivity with higher accuracy and repeatability and advanced statistical method like discriminant function analysis further enhances it. The parameters like nasal height, nasal width and mastoid process length can be used as predictors to determine gender. Also gender differences in cranial morphology emphasize the significance of applying these data to an individual subject in a given population. Such knowledge is not only applicable to forensic scientists but also in plastic surgery and oral surgery with craniofacial deformity. Results of this study will be of immense use in forensic medicine and anthropology and will also serve as a future framework for estimating the craniofacial dimensions of other Indian population.

CONFLICT OF INTEREST

None declared till now.

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