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Determination of sex by discriminant function analysis: A cephalometric study

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ABSTRACT
The present study was conducted in Department of Anatomy, MM institute of medical sciences & research, Mullana (Ambala), on 800 Haryanvi adults comprising of 400 males and 400 females. Prior informed written consent was obtained from subjects. Inclusion and exclusion criteria for the study were predefined. Four measurements, maximum head length, maximum head breadth, morphological facial length and bigonial diameter were taken by using standard anthropometric instruments. The purpose of study was to determine the sex from these cephalometric parameters by discriminant function analysis. The results showed that all cephalometric parameters (mean) are more in male than female. Discriminant function analysis revealed that the cephalometric parameters correctly classified the sex with an accuracy of 77.5%. (76.3% males & 78.8 % females). Cross validation using "Leave one out method" prove that the model is fairly reliable with 77.3% (76% males and 78.5% females) cases correctly classified.

Keywords: *anthropometry, Haryanvi*

INTRODUCTION

The study of sexual dimorphism is important, in forensic anthropology and craniometry [1]. Sexual dimorphism is the expression of secondary sexual characteristics that are defined after puberty and during adolescent years [2,3.] Sex determination from skeletal remains is one of the most important aspects of the osteologic analysis of a given population[4].. There are several methods for determination of gender using different parameters[5]. Sex, age and racial affinity are the three most vital determinations that must be made when dealing with skeletal remains[6]. The sex is best assessed from the pelvis but the skull also offers a number of very good sex indicators and is usually better preserved[6.] A single character can not be deterministic of sex; precise identification depends on a group of diagnostic traits which exhibit population specificity [7,8]. The technique for sex determination fall into two broad categories: metric and observational [9]. Discriminant function analysis is an entirely objective statistical technique for sex determination [10]. As the best discriminators for race are not necessarily the best for sex, so skulls of unknown provenance are best tested first for race and than for sex, using different variables for each purpose[11]. Several studies have shown variability in osteometric dimensions between population and it is well established that in determination of sex from various skeletal parts, standards specific to the population under study should be used. Moreover, most of the studies for sex determination have not been used the latest statistical techniques like multivariate analysis by which percentage of accuracy (sensitivity) in identification of sex increases [12].

MATERIAL AND METHODS

The present study was conducted on 800 adult Haryanvi Banias (400 of either sex). Prior informed consent both in English & Vernacular were obtained from subjects in writing. The subjects of age group

18 years and above were included in the study .The subjects were apparently healthy and without any craniofacial deformity.

A series of six somatometric landmarks and four anthropometric measurements were taken on 800 Haryanvi Banias. The methodology for cepahlo-facial measurements was adopted from Krishan and Kumar [13].

SOMATOMETRIC MEASUREMENTS

Maximum head length:– It measures straight distance between glabella & opisthocranion.

Maximum head breadth:- It is the maximum biparietal diameter & is the distance between the most lateral points on the parietal bones.

Bigonial diameter:- It is the maximum breadth of the lower jaw between two gonion points on the angles of mandible.

Morphological facial length:- It is straight distance from the nasal root (nasion) to the lowest point on the lower border of the mandible in the mid sagittal plane (gnathion)

OBSERVATION & RESULTS

The data obtained was tabulated and statistically analyzed by Discriminant function analysis for which Statistical package for social sciences (SPSS) was used. From descriptive table 1, males have higher means than females. The comparison of standard deviation suggests that males exhibit more variability than females in all measurements except morphological facial length. Table-2 shows the result of discriminant function analysis

Table 1: observations and values

Parameters	Sex	Mean	S.D	Range	
				Min	Max.
Maximum head length	M	18.75	1.386	16	22.2
	F	17.75	0.847	13.6	20.2
Maximum head breadth	M	13.11	1.098	10.6	16
	F	12.95	0.832	10	14.7
Morphological facial length	M	11.07	0.698	8.5	13.1
	F	10.21	0.940	8.5	12.6
Bigonial diameter	M	11.45	1.104	9.3	14.2
	F	10.33	0.753	8.4	12.4

Table 2: Discriminant function score table

Variable	Unstandardized Coefficient	Standardized Coefficient	Wilks Lamda	Structure Matrix	Constant	Centroids	Section Point
Independent(Direct)							
MHL	.564	.546		.820		Male	.722+(-
MHB	.003	.003		.711		.722	.722)/2 = 0
MFL	.212	.179	.657*	.299	-20.541	Female	
BGD	.725	.686		.269		-- .722	77.5%
STEP WISE							
BGD	.726	.687		.820		M- .722	722+(-
MHL	.565	.547	.657*	.711	--20510	F = -- .722	.722)/2 = 0
MFL	.211	.178		.297			77.5%

*Significant ($p<0.05$)

Note: Only BGD, MHL and MFL are selected by stepwise approach

Discriminant function equation - The following discriminant function formula was used to calculate discriminate score (Z)

Z = bo +b1x1+ b2x2-------

Where bo is constant; b1, b2--- are unstandardised correlation coefficient and x1, x2---- are the measures of significant parameters.

If Z is more than sectioning point the subject is classified as male.

If Z is less than sectioning point the subject is classified as female.

The discriminant function equation for the determination of sex from all variables

Direct Analysis

Z = --20.541 (constant) + (.564 x MHL) + .(003 x MHB) + (.212x MFL)+ (.725 x BGD)

Stepwise Analysis

Z = --20.510 (constant) + (.565 x MHL) + (.211 x MFL) + (.726 x BGD)

Based on the table BGD is the best single predictor of sex and MHL is the next one and then MFL

The cutoff point for discrimination between gender is (.722 -- .722) / 2 = 0, value>0 Male and < 0 Female

The discriminant function analysis has been performed on all cephalo-facial variables which correctly classified 77.5 % of the cases (76.3 % males and 78.8 % females). Cross validation using "Leave one out method" prove that the model is fairly reliable with 77.3% (76% males and 78.5% females) cases correctly classified.

Table 3: Classification Results of all variables

	Sex	Predicted Group Membership		Total
		Male (%)	Female (%)	
Original count	M	305 (76.3 %)	95(23.8%)	400
	F	85 (21.3 %)	315(78.8%)	400
Cross-validated count	M	304(76 %)	96(24.0%)	400
	F	86(21.5%)	314(78.5%)	400

77.5% of original grouped cases correctly classified.
77.3% of cross-validated grouped cases correctly classified.

Table 4: Comparison of discriminant analysis showing % accuracy in sex determination

Authors	Population	No of Cephalometric parameters	%age
Hsiao et al (1996)	Taiwanese population	18	100%
Franklin et al,(2005)	South Africans	8	77 to 80%
Patil & Mody(2005)	Central Indian Population	10	99%
Hasio et al, 2010	Taiwanese children	22	95%
Naikmasur et al, 2010	South Indians	11	81%
	Immigrant Tibetans	11	88.2%
Umar et al, 2011	Yoruba of Nigeria	8	91.1 %
Binnal & Yashoda Devi (2012)	Population of Karnatka, TN, AP, Kerla (India)	9	86%
Present study	Haryanvi Banias	4	77.5%

DISCUSSION

This study shows that the cephalometric measurements of maximum head length, maximum head breadth, morphological facial length and bigonial diameter could be used for sex determination. The derived discriminant function equation in the present study was 77.5% accurate in differentiating the male and female subjects which was less than the previous studies but close to the Franklin et al (2005) study. The variation in findings of different studies may be due to the use of various cephalometric parameters in determination of sex.

CONCLUSION

From present study it was concluded that these cephalometric parameters are sexually dimorphic and therefore can also be used for determination of sex with accuracy of 77.5% when cephalofacial remains are brought for forensic examination. The most reliable variable to determine sex, using step wise discriminant function analysis was bigonial diameter and then maximum head length and morphological facial length. Since the derived discriminate function equation are known to be population and sex specific, there is a need for similar equations to be derived for other endogamous groups. .

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