Egyptian Journal of Forensic Sciences (2016) 6, 114–119

HOSTED BY

ELSEVIER

Contents lists available at ScienceDirect

Egyptian Journal of Forensic Sciences

journal homepage: http://www.journals.elsevier.com/egyptian-journal-of-forensic-sciences

ORIGINAL ARTICLE

Determination of sex using cephalo-facial dimensions by discriminant function and logistic regression equations

Twisha Shah [a], M.N. Patel [b], S. Nath [c], Shobhana K. Menon [a,*]

[a] Department of Forensic Science, Gujarat University, Ahmedabad 380009, Gujarat, India
[b] Department of Statistics, Gujarat University, Ahmedabad 380009, Gujarat, India
[c] Department of Anthropology, University of Delhi, Delhi 110007, India

Received 9 January 2015; revised 4 March 2015; accepted 12 March 2015
Available online 29 April 2015

KEYWORDS

Sexual dimorphism;
Cephalofacial dimensions;
Discriminant function;
Logistic regression;
Gujarati

Abstract: The aim is to bring together the new anthropological techniques and knowledge about populations that are least known. The present study was performed on 901 healthy Gujarati volunteers (676 males, 225 females) within the age group of 21–50 years with the aim to examine whether any correlation exists between cephalofacial measures naming maximum head length, maximum head breadth, bizygomatic breadth, bigonial diameter, morphological facial length, physiognomic facial length, biocular breadth and total cephalofacial height and sex determination. Also, discriminant function and logistic regression methods were verified to check the best accuracy level for sex determination. Mean values of cephalofacial dimensions were higher in males than in females. Best reliable results were obtained by using logistic regression equations in males (92%) and discriminant function in females (80.9%). Our study conclusively establishes the existence of a definite statistically significant sexual dimorphism in Gujarati population using cephalo-facial dimensions.

1. Introduction

Anthropometry is an essential tool of biological anthropology which involves a series of standardized measuring techniques that express quantitatively the dimensions of the human body. Somatometry is one of the disciplines of anthropometry which deals with the measurement of the living body and cadaver including the head and face. Krogman[1] in his monumental publication (later on revised with Iscan et al.[2]) "The Human Skeleton in Forensic Medicine" points out that the use of anthropometry may arise under several sets of circumstances i.e. natural, intentional and accidental (war dead cases, air crash, road and train accidents, earth quake, flood, fire; deliberate mutilation,

* Corresponding author. Tel.: +91 079 26300435.
E-mail addresses: twishafs2011@gmail.com (T. Shah), snath31@rediffmail.com (S. Nath), shobhanamenon07@gmail.com (S.K. Menon).
Peer review under responsibility of The International Association of Law and Forensic Sciences (IALFS).

http://dx.doi.org/10.1016/j.ejfs.2015.03.004

disfigurement, pounding, gouging etc. of the dead body). Determination of sex is of fundamental importance both for personal identification in forensic science as well as for population data studies. Sex is generally inferred from facial morphology which is highly reliable. Many researchers have made use of somatometry widely in the estimation of sex from different body segments like the skull, long bones, pelvis, clavicle, phalanges, ribs etc. The most popular statistical model in sex determination is the recently developed discriminant function analysis which encouraged many forensic scientists to assess their anthropometric data accordingly.[3] The present study aimed to examine sexual dimorphism and to produce a practical discriminant function or logistic regression for determining the sex in Gujarati group of people. Logistic regression was always performed along with the discriminant function. A total of eight standard cephalofacial measurements were taken from 676 males and 225 females of known sex and race of Gujarati people. To date, there are no metric cephalofacial criteria for Gujarati people. Therefore, the purpose of this study is to establish population specific standards for sex determination from the cephalofacial dimensions. The ultimate aim of determining sex in forensic science is to help the law enforcement agencies in achieving 'personal identity' in the medicolegal cases like mutilated and decomposed body parts. In many cases cephalofacial dimensions are the only means of evidence for forensic examination. Such studies are also useful in forensic medicine, plastic and oral surgeries, clinical and research purpose and facial reconstruction.

2. Material and methods

The present study was carried out in the Ahmedabad district of Gujarat. A total number of 901 subjects of Gujarati origin were included in the study. The subjects were within the age limit of 21–50 years. Subjects were purely of Gujarati ethnic origin and were selected at random from different parts of Ahmedabad. Gujarat is situated on the west coast of India. Gujarati subjects were born, bred and live in the Ahmedabad district of Gujarat state. Gujarat is home to the Gujarati-speaking people of India. It has a population in excess of 50 million. Ahmedabad is the largest city in Gujarat. The subjects included in the study were healthy individuals free from any deformity. Anthropometric measurements like maximum head length, maximum head breadth, bizygomatic breadth, bigonial diameter, morphological facial length, physiognomic facial length, total cephalofacial height and biocular breadth were taken independently on each individual. Besides the above measurements, name, sex, caste, native and occupation of each subject were also recorded. All the measurements were taken in a bright room. All measurements were taken using standard anthropometric procedure with the subject sitting in a chair in a relaxed condition and head in the anatomical position. Cephalofacial dimensions are taken by spreading a calliper in centimeters according to the landmarks, techniques and procedures recommended by authors Singh and Bhasin (see Fig. 1).

Measurements	Abbreviate	Definitions
Maximum head length (g–op)	MHL	It measures the straight distance between glabella (g) and opisthocranion (op)
Maximum head Breadth (eu–eu)	MHB	It measures the straight distance between the two eurya (eu)
Bizygomatic breadth (zy–zy)	BZB	Direct distance between the two most lateral points on the zygomatic arches (zy–zy)
Bigonial breadth (go–go)	BGB	It measures the straight distance between the two gonia (go), rounded posteroinferior corner of the mandible between ramus and the body
Biocular breadth (ec–ec)	BOB	It measures the straight distance between the two external canthi (ectocanthion) i.e., outer corners of the eye
Total head height (v–gn)	THH	It measures the projective distance between vertex (v) and gnathion (gn)
Physiognomic facial height (tr–gn)	PFH	It measures the straight distance between trichion (tr) and gnathion (gn)
Morphological facial height (n–gn)	MFH	It measures the straight distance between nasion (n) and gnathion (gn)

Data were subjected to statistical analysis of mean, minimum, maximum and standard deviation of mean. These were subjected to SPSS discriminant function analysis and logistic regression.

3. Results

The types of data to be analyzed were 901 Gujarati whose cephalofacial measurements were taken directly. The samples were examined, separately and pooled. Table 1 displays the mean, minimum and maximum values with their respective standard deviation of eight cephalofacial parameters of the Gujarati.

Eight measurements derived from the data were used to produce a series of discriminant functions and logistic regression for sex determination.

Sex was also determined using discriminant function and logistic regression in the pooled sample of 901 Gujarati to check the accuracy (Table 4).

Further, the collected data were checked for their accuracy and reliability with the established equations of discriminant function and logistic regression. Table 5 illustrates the accuracy level of males and females when the values of cephalofacial measurements were placed in the formulated equations.

4. Discussions

Sex determination is very important for identification in forensic medicine, medico legal cases and forensic anthropologists.

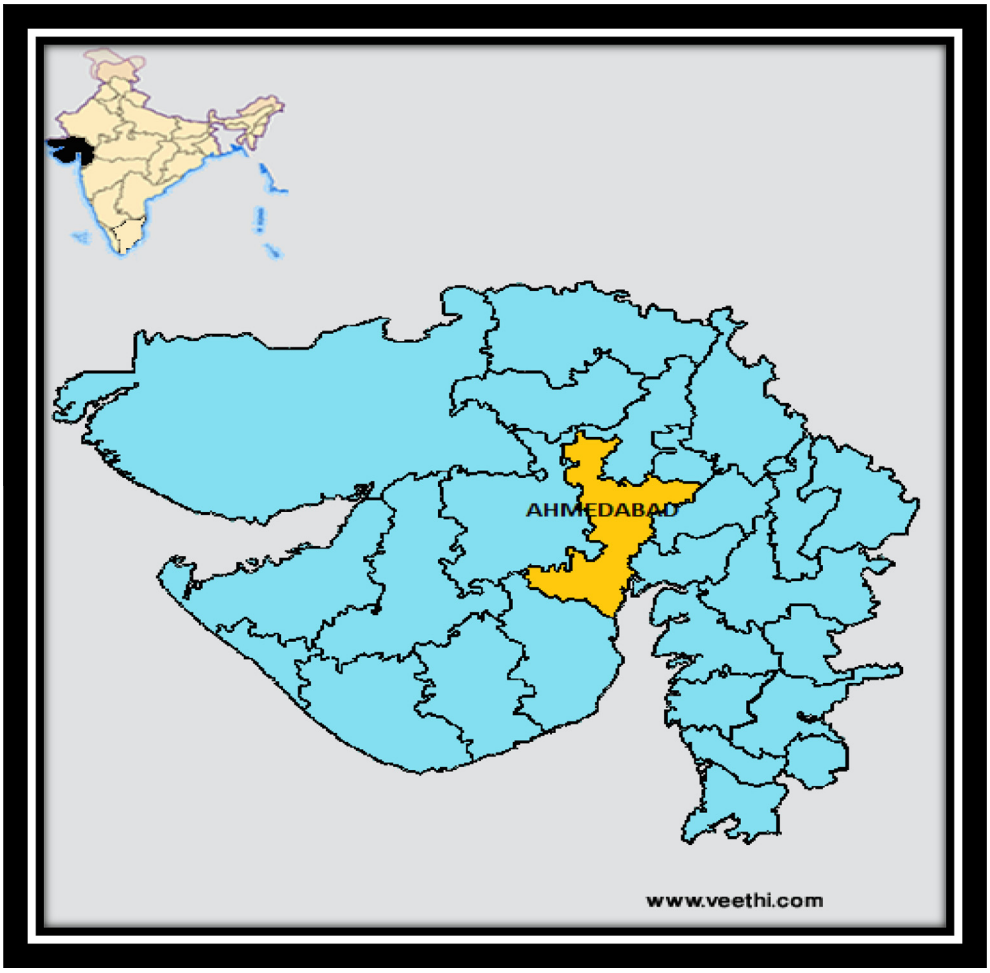

Figure 1 Map of India showing Ahmedabad.[18]

Sex determination is reliable in cases where an intact body is available. The same is difficult when only part of the body is found. It is often difficult for forensic anthropologists when only facial photographs or head or facial remains are brought for examinations because the standards available and the accessibility in this direction are very less. Hence facial measurements are useful in the absence of other evidence for sex estimation.

As the mean values of all the eight cephalo-facial measurements were greater in males than females. Two techniques, logistic regression and discriminant function analysis, were performed to check for the best reliable results. It can be clearly seen from Tables 2 and 3 that all the facial measurements show significance for sex determination at p-value < 0.05. Comparing the accuracy level for both the techniques we conclude logistic regression offers best results compared to discriminant function. Now for a given value of these variables a discriminant score is obtained. If the value is less than the score it is classified as male and if it is greater than the score it is classified as female. In logistic regression if the value is negative it is classified as male and if it is positive it is recorded as female. With multivariant, logistic analysis gives the best result with an accuracy of mean 81.9% compared to discriminant with an accuracy of mean 79.9%. Biocular breadth gives best reliable results in males with 99.9% accuracy using logistic regression and in females, physiognomic facial height gives accuracy of 67.1% using discriminant function. Hence, using multivariate discriminant function gives precise results for females with 80.9% and logistic regression gives 92% defined results in males. This metrical approach is more purposeful and less reliant on the observer's skills.

Iscan et al.[4] estimated sex using seven anthropometric parameters of tibia including tibial length, diameters and circumferences of Japanese skeleton and found accuracy range from 80% to 89% by using multiple combinations of measurements to develop formulae. The accuracy was observed to be high in males (96%) than in females (79%). Another study by Falsetti[5] was to determine sex and observe different accuracy rates in different samples using dimensions of metacarpal. Trancho et al.[6] used discriminant function analysis to determine sex on 132 Spanish adults from femur and achieved 84–97% accuracy when each variable was considered independently and 99% accuracy using combinations. Smith[7] includes length and width of foot for determination of sex and achieved 87% accuracy by using combination models for correct assignment of sex. Asala[8] successfully determined sex from femur using discriminant analysis. According to Mall et al.,[9] radius is the best bone for sex determination with an accuracy of 94.93% other than humerus and ulna. 80–82% accuracy was obtained using discriminant analysis from the measurements of scapula and clavicle by Frutos.[10]

Table 1 Descriptive of Gujarati (n = 901).

		N	Minimum	Maximum	Mean	S.D.	S.E. Mean
Maximum Head Length (g–op)	Both	901	13.6	21.4	17.34	1.72	0.05
	Male	676	14.0	21.4	17.79	1.52	0.05
	Female	225	13.6	18.8	16.01	1.6	0.1
Maximum Head Breadth (eu–eu)	Both	901	9.6	19.0	13.39	1.63	0.05
	Male	676	10.1	19.6	13.72	1.52	0.05
	Female	225	9.6	18.6	12.38	1.54	0.1
Bizygomatic Breadth (zy–zy)	Both	901	9.0	16.8	12.65	1.68	0.05
	Male	676	9.8	16.8	13.07	1.54	0.05
	Female	225	9.0	14.5	11.4	1.46	0.09
Bigonial Breadth (go–go)	Both	901	5.9	14.6	9.99	1.66	0.05
	Male	676	6.2	14.6	10.38	1.54	0.05
	Female	225	5.9	11.5	8.79	1.42	0.09
Physiognomic Facial height (tr–gn)	Both	901	12.0	21.5	15.99	1.72	0.05
	Male	676	12.0	20.1	16.4	1.55	0.05
	Female	225	12.2	21.5	14.76	1.62	0.1
Total head height (v–gn)	Both	901	10.2	25.3	21.39	1.77	0.05
	Male	676	12.5	25.3	21.85	1.48	0.05
	Female	225	10.2	23.5	20.01	1.88	0.12
Morphological Facial height (n–gn)	Both	901	6.1	12.6	9.52	1.5	0.05
	Male	676	6.3	12.6	9.85	1.36	0.05
	Female	225	6.1	12.0	8.54	1.46	0.09
Biocular Breadth (ec–ec)	Both	901	6.4	12.7	9.36	1.59	0.05
	Male	676	6.7	12.7	9.65	1.5	0.05
	Female	225	6.4	11.3	8.5	1.54	0.1

Table 2 Logistic regression of Gujarati (n = 901).

Sr. No.	Test Func	Sig.	Equations[a]	Accuracy (%)
1	g–op	0.00	10.229–0.670(g–op)*	82.2
2	eu–eu	0.00	6.183–0.558(eu–eu)*	77.8
3	zy–zy	0.00	6.993–0.662(zy–zy)*	82.69
4	go–go	0.00	5.394–0.678(go–go)*	77
5	tr–gn	0.00	8.769–0.634(tr–gn)*	78.8
6	v–gn	0.00	14.351–0.739(v–gn)*	81.5
7	n–gn	0.00	4.592–0.619(n–gn)*	79.8
8	ec1–ec2	0.00	3.169–0.470(ec1–ec2)*	76.4

[a] If sex is positive we can predict male and if negative we predict female.
* p-value < 0.05.

Rissech et al.[11] and Patriquin et al.[15] studied four variables of ischium and nine measurements of pelvis to determine sex. Frutos[12] studied on six anthropometric dimensions of 118 humeri from Guatemalan forensic sample. Kemkes-Grottenthaler[13] achieved almost 84% accuracy in sex determination from patella. Patil and Mody[14] studied ten cephalofacial measurements of 150 Central Indian populations using radiographic cephalograms and determined sex by discriminant function analysis and attained 99% reliability.

Two hundred and eighty femora from Central India were studied by Purkait[16] and concluded with accuracy rate ranging from 85% to 63%. Slaus and Tomicic[17] showed that tibia can be sexed with 92.2% accuracy from six medieval archeological sites in Croatia.

Till today discriminant function and logistic regression for determination of sex have not been derived specifically for Gujarati subjects. As differences exist in various races with regard to sex determination the results may be true for one population but may not be necessarily true for another and therefore, discriminant function was applied to establish specific standards of assessment. The present work showed the accuracy for estimating sex by cephalofacial dimensions using

Table 3 Discriminant function of Gujarati (n = 901).

Sr. No.	Test Func	Wilks' Lambda	Sig.	Equations	Score[a]	Accuracy (%)
1	g–op	0.801	0.00	−11.235 + 0.648(g–op)*	−0.288	65.6
2	eu–eu	0.874	0.00	−8.769 + 0.655(eu–eu)*	−0.22	63.7
3	zy–zy	0.816	0.00	−8.311 + 0.657(zy–zy)*	−0.279	65.1
4	go–go	0.828	0.00	−6.591 + 0.660(go–go)*	−0.263	67.6
5	tr–gn	0.832	0.00	−10.151 + 0.635(tr–gn)*	−0.259	68.4
6	v–gn	0.799	0.00	−13.439 + 0.628(v–gn)*	−0.289	69.7
7	n–gn	0.858	0.00	−6.835 + 0.718(n–gn)*	−0.235	64.8
8	ec1–ec2	0.903	0.00	−6.188 + 0.660(ec1–ec2)*	−0.19	63.6

[a] Male ⩽ score ⩽ female.
* p-value < 0.05.

Table 4 Discriminant function and logistic regression for sex determination using pooled data of Gujarati (n = 901).

Sr. No.	Group	Test Func	Sig.	Equations	Score	Accuracy (%)
1	Discriminant function analysis	Pooled data	0.00	−16.291 + 0.573(g–op)* − 0.167(eu–eu)* + 1.006(zy–zy)* + 0.027(go–go)* + 0.222(tr–gn)* + 0.270(v–gn)* − 0.181(n–gn)* − 1.281(ec1–ec2)*	−0.418[a]	79.9
2	Logistic regression	Pooled data	0.00	25.758 − 0.891(g–op)* + 0.240(eu–eu) − 1.843(zy–zy)* + 0.11(go–go) − 0.414(tr–gn)* − 0.493(v–gn)* + 0.368(n–gn) + 2.304(ec1–ec2)*	0[b]	81.9

[a] Male ⩽ score ⩽ female.
[b] If sex is positive we can predict male and if negative we predict female.
* p-value < 0.05.

Table 5 Accuracy of male and female by using discriminant function and logistic regression.

Variables	Logistic regression		Discriminant function	
	Male (%)	Female (%)	Male (%)	Female (%)
Maximum head length (g–op)	95.40	42.70	66.70	62.20
Maximum head breadth (eu–eu)	96.20	22.70	64.10	62.70
Bizygomatic breadth (zy–zy)	95.10	44.90	65.80	63.10
Bigonial breadth (go–go)	93.60	27.10	68.80	64
Physiognomic facial height (tr–gn)	93.90	32.90	68.80	67.10#
Total head height (v–gn)	95	40.90	71.30	64.90
Morphological facial height (n–gn)	96.30	30.20	65.70	62.20
Biocular breadth (ec–ec)	99.90#	5.80	64.30	61.30
Pooled data	92#	51.60#	79.60#	80.90#

Shows great percent of accuracy among other variables.

univariate analysis and multivariate analysis through both discriminant function as well as logistic regression equations of Gujarati population. Since the measurements in the study were taken on living subjects identity of unknown skeletal remains is uncertain.

5. Conclusion

From the present study it was concluded that the mean values of males were higher than those of females. The equations derived can be used for determination of sex in Gujarati population with the highest average accuracy of 92% male using logistic regression and 80.9% female using discriminant function. The greater reliability for univariate was achieved with logistic regression equation. The new functions for the pooled Gujarati sample provide fairly low sex discrimination accuracy compared to those obtained by employing logistic regression. Numerous studies have clearly demonstrated that facial characteristics vary by population.

Funding

One of the authors, Twisha Shah, gratefully acknowledges UGC (University Grants Commission), India for financial assistance.

Conflict of interest

None declared.

Informed consent

Informed consent was obtained from all subjects.

Ethical approval

Necessary ethical approval was obtained from the institute ethics committee.

References

1. Krogman WM. *The human skeleton in forensic medicine*. Springfield, Illinois, U.S.A.: Charles C. Thomas Pub Ltd.; 1962.
2. Krogman WM, Iscan YM. *The human skeleton in forensic medicine*. Springfield, Illinois, U.S.A.: Charles C. Thomas Pub Ltd.; 1986, 2nd ed.
3. Iscan MY. Forensic anthropology of sex and body size (Editorial). *Forensic Sci Int* 2005;**147**:107–12.
4. Iscan MY, Yoshino M, Kato S. Sex determination from the tibia: standards for contemporary Japan. *J Forensic Sci* 1994;**39**(3):785–92.
5. Falsetti AB. Sex assessment from metacarpals of human hand. *J Forensic Sci* 1995;**40**(5):774–6.
6. Trancho GJ, Robledo B, Lopez-Bueis I, Sanchez JA. Sexual determination of the femur using discriminant functions. Analysis of a Spanish population of known sex and age. *J Forensic Sci* 1997;**42**(2):181–5.
7. Smith SL. Attribution of foot bones to sex and population groups. *J Forensic Sci* 1997;**42**(2):186–95.
8. Asala SA. Sex determination from the head of the femur of South African whites and blacks. *Forensic Sci Int* 2001;**117**(1–2):15–22.
9. Mall G, Hubig M, Buttner A, Kuznik J, Penning R, Graw M. Sex determination and estimation of stature from the long bones of the arm. *J Forensic Sci* 2001;**117**:23–30.
10. Frutos LR. Determination of sex from the clavicle and scapula in a Guatemalan contemporary rural indigenous population. *Am J Forensic Med Pathol* 2002;**23**(3):284–8.

11. Rissech C, Garcia M, Malgosa. Sex and age diagnosis by ischium morphometric analysis. *Forensic Sci Int* 2003;**135**(3):188–96.
12. Frutos LR. Metric determination of sex from the humerus in a Guatemalan forensic sample. *Forensic Sci Int* 2005;**147**(2–3): 153–7.
13. Kemkes-Grottenthaler A. Sex determination by discriminant analysis: an evaluation of the reliability of patella measurements. *Forensic Sci Int* 2005;**147**(2–3):129–33.
14. Patil KR, Mody RN. Determination of sex by discriminant function analysis and stature by regression analysis: a lateral cephalometric study. *Forensic Sci Int* 2005;**147**(2–3):175–80.
15. Patriquin ML, Steyn M, Loth SR. Metric analysis of sex differences in South African black and white pelves. *Forensic Sci Int* 2005;**147**(2–3):119–27.
16. Purkait R. Triangle identified at the proximal end of femur: a new sex determinant. *Forensic Sci Int* 2005;**147**(2–3):135–9.
17. Slaus M, Tomicic Z. Discriminant function sexing of fragmentary and complete tibiae from medieval Croatian sites. *Forensic Sci Int* 2005;**147**(2–3):147–52.
18. http://www.veethi.com/places/gujarat-ahmedabad-district-277.htm.