Original Article

Estimation and Determination of Stature and Gender of Adult Chhattisgarh Population using Digital Lateral Cephalograms

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ABSTRACT

Context: Digital lateral cephalograms are crucial in ascertaining stature and gender which lead to a clue for establishing identity as they are cost-effective, are easily available, and have reliable accuracy.
Aims: The present study has an objective to determine gender and stature among 1000 adult Chhattisgarh males and females in the age range of 21–50 years using 14 linear lateral cephalometric measurements. The study attempted to derive a prediction equation for stature using lateral cephalometric parameters.
Settings and Design: An observational, cross-sectional study was planned for stature and gender estimation using digital lateral cephalogram with study duration from July 2017 to August 2018.
Methods: A total of 500 male and 500 female adult subjects in the age range of 21–50 years were subjected to digital lateral cephalogram, and 14 linear measurements were recorded for all subjects. Stature was measured using a stadiometer.
Statistical Analysis: Linear regression analysis and correlation of lateral cephalometric parameters with stature were used for stature determination. Discriminant function analysis for gender prediction was used for ascertaining gender from lateral cephalometric parameters.
Results: Of total 14 linear measurements, nine measurements among males and five among females were found to be positively and significantly correlated with stature. Correct gender determination was done in 83.5% of subjects using discriminant function analysis from lateral cephalometric measurements.
Conclusions: Digital lateral cephalometric analysis can be used with fair accuracy for stature and gender prediction among adult Chhattisgarh population.

KEY WORDS: *Digital cephalogram, discriminant function analysis, gender prediction, lateral cephalometric parameters, stature estimation*

INTRODUCTION

Personal identification is the process of linking an unknown personal object or material which may be a whole body, a skeleton, a fingerprint, a biological fluid, etc., back to an individual of known identity.[1] Necessity for personal identification arises in both natural mass and artificial disasters and in cases where severely mutilated, decomposed, dismembered body parts are found to conceal identity of an individual.[2] For social, economic, and medico-legal purposes, identity establishment is essential.

Radiographs have been used for the identification of skeletal remains and the determination of gender. Various researchers have stated that the radiographs are cost-effective, easily available, and reliable in providing accuracy of 80%–100% as far as the identification is concerned.[3,4]

Lateral cephalometric projection being standardized type of radiography with wide application provides objective evidence for dental, skeletal, and soft tissue alterations.[5]

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As craniofacial bones are least prone for disintegration and highly resistant under extreme conditions, they can be used for gender determination.[6]

Gender is primarily being determined from the pelvis and secondarily from the skull and is based on its morphological and morphometric features. Of all the bones, after pelvis, the skull is the next most easily sexed portion of the skeleton.[7]

Different body parts have allometric relationship with one another, and hence, this relationship can be explored to get estimates of the stature from the bones of the skeleton. Furthermore, the long bones contribute in stature and correlate positively with stature of person and hence are used to obtain the most common stature estimates.[8-10]

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Stature estimation forms a criteria for the personal identification and assists in narrowing down the investigation process.[11]

The purpose of the study was to determine stature and gender using digital lateral cephalograms in the Chhattisgarh population.

The present study had used 14 linear cephalometric parameters to determine stature and gender. Among these 14 variables, nine variables have been used by various researchers, either independently or in groups of 2 or 3, to determine stature and gender. Five new parameters were used for the first time in this study.

The aims and objectives of this study were:

1. To measure various lateral cephalometric parameters in the adult Chhattisgarh population
2. To predict gender and stature from various lateral cephalometric parameters in Chhattisgarh population
3. To determine which parameter among those used in the study best predicts the gender and stature in the study group
4. To derive prediction equation for stature for Chhattisgarh population from the cephalometric parameters used
5. To correlate various lateral cephalometric parameters with gender and stature.

Methods

Ethics

The procedures for lateral cephalogram imaging followed were in accordance with the ethical standards of the IHEC on Human Experimentation (institutional or regional) and with the Declaration of Helsinki 1975, as revised in 2000.

Study design

The study design for the estimation of gender and stature among adults of the Chhattisgarh population was observational and cross-sectional. The study was performed from January 2017 to July 2018 in the Department of Oral Medicine and Radiology at Chhattisgarh Dental College and research Institute (CDCRI) (Chhattisgarh), India. A sample size of 1000 (500 males and 500 females) in the age range of 21–50 years was calculated for the estimation and determination of stature and gender in adult Chhattisgarh population Using G* Power software (Heinrich Heine University Dusseldorf, Germany) at 95% confidence interval and power of 80%.

Sampling technique used in this study was nonprobabilistic method using convenience sampling with the prescribed inclusion criteria.

Inclusion criteria

- Healthy, normal adults of Chhattisgarh population
- Individuals of age 21 years and above.

Exclusion criteria

- Individuals with a history of, or clinical features suggestive of, trauma or surgery of the skull, vertebral column, and long bones
- Individuals with developmental anomalies of the skull
- Individuals who have undergone orthodontic and orthognathic treatment
- Individuals with a history of or clinical features suggestive of endocrinal disturbances, hereditary, nutritional, and developmental disorders, facial asymmetry
- Cases of kyphosis, scoliosis, other vertebral column anomalies, and stature defects
- Individuals with completely edentulous upper and lower jaws.

The protocol of the study was approved by the institutional ethics committee. Those subjects who were willing to participate in the study were only included in the study after obtaining written and informed consent. Each subject was explained about the purpose and entire procedure of the study. Subjects were given freedom to leave the study at any point of time.

All the study subjects were subjected to detailed case history and thorough clinical examination and later on to lateral cephalometric radiographic examination. Using the standard procedure, digital lateral cephalograms were recorded with SIRONA orthophos XG 5 machine, with exposure time of 14.9 s, tube voltage used of 60–90 kV, and tube current used of 3–16 mA, and viewed using Using Sidexis, (Dentsply Sirona global, Italy). Cephalometric landmarks were identified and plotted, and linear measurements were traced and recorded. Three observers independently measured 14 linear measurements from digital lateral cephalograms of 1000 study subjects. All three observers were blinded about the study subject information (single blinding). Following linear measurements were recorded:

1. Basion to ANS (Ba-ANS): Linear measurement from basion (Ba) to ANS
2. Upper facial height (N-ANS): Linear distance between nasion (N) and ANS
3. Length of cranial base (Ba-N): Linear measurement from basion (Ba) to nasion (N)
4. Total face height (N-M): Linear measurement from nasion (N) to menton (M)
5. Frontal sinus height (FsHt): Linear distance between V1 and V2
6. Perpendicular distance from mastoidale to SN plane (Ma-SN): Perpendicular distance from mastoidale (Ma) to sella-nasion (SN) plane
7. Perpendicular distance from mastoidale to Frank-Furt horizontal (FH) plane (Ma-FH): Perpendicular distance from mastoidale (Ma) to FH plane
8. Mastoid height from cranial base (MaHt: Ma-B1B2): Anterior and posterior parameter of mastoid width at the level of cranial base, respectively
9. Mastoid width at the level of cranial base (MaWd: B1-B2): Mastoid width at the level of the cranial base
10. Nasion to gnathion (N-Gn): Linear measurement from nasion to gnathion
11. Sella to menton (S-M): Linear measurement from sella to menton
12. Sella to gnathion (S-Gn): Linear measurement from sella to gnathion

13. Gonion to gnathion (Go-Gn): Linear measurement from gonion to gnathion
14. Gonion to menton (Go-M): Linear measurement from gonion to menton.

Measured living stature or standing height of each subject is recorded using a wall-mounted stadiometer. The subject was asked to stand barefooted close to the wall with feet apposed, looking straightforward, with a stable head, stadiometer placed in contact with vertex marks the height of the subject on scale, and the reading was recorded.

All observations were mentioned as mean and standard deviation. All the data were checked for correctness and completeness.

Statistical analysis

Statistical analysis for stature estimation using lateral cephalometric parameters was carried out by deriving Pearson's correlation coefficient and linear regression analysis. Statistical analysis for gender prediction using lateral cephalometric variables was carried out to find the significant difference between values obtained in males and females using *t*-test, and $P < 0.05$ is considered statistically significant. For gender prediction, discriminant function analysis was carried out using these parameters.

Results

All male and female subjects were divided into 3 age groups as per Table 1.

Table 1. Gender and age group wise distribution of subjects

Table 2. Comparison of Stature and lateral cephalometric parameters among males and females.

Mean height was higher in males than the females so do the all cephalometric parameters except B1B2 which was higher in females. All parameters differs significantly sex-wise.

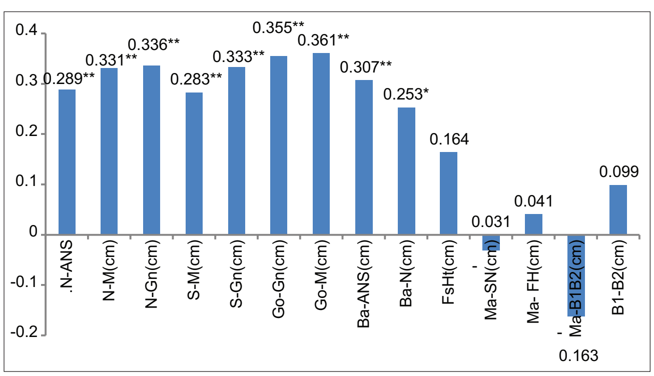

Figure 1: Pearson's correlation coefficient for lateral cephalometric parameters and MLS in males

Table 1: Gender and age group-wise distribution of subjects

Gender	Age group			Total
	21-30	31-40	41-50	
Male, count (%)	190 (19)	155 (15.5)	155 (15.5)	500 (50)
Female, count (%)	185 (18.5)	155 (15.5)	160 (16)	500 (50)
Total, count (%)	375 (37.5)	310 (31)	315 (31.5)	1000 (100)

Figure 1. shows correlation between cephalometric parameters and Height (MLS) among males subjects. Multiple linear regression equations were derived from lateral cephalometric parameters having significant r values (Pearson's Correlation coefficient).

Using the lateral Cephalometric Parameters Prediction equation for Stature was derived as given below:

Table 3. Multiple regression equation for Stature in Males.

Table 4: Multiple regression equation for stature in females using lateral cephalometric parameters. Parameters like N-M, N-Gn, S-m, S-Gn, Go-M and Ma-B1-B2 are predictors of stature in females as opposed to N-ANS, Go-Gn,Ba-ANS, Ba-N which in addition predicts stature for males stature.

Figure 2. shows correlation between cephalometric parameters and Height (MLS) among femalemales subjects. Multiple linear regression equations were derived from lateral cephalometric parameters having significant r values (Pearson's Correlation coefficient).

Table 5. Discriminant Function analysis for Gender determination using lateral Cephalometric parameters.

Table 6. Classification Results for DFA for Gender prediction

Model predicts 83 .50 % values correctly for the gender analysis.

Discussion

Mean height and lateral cephalometric measurements were significantly higher in men than in women, in this study group population, which supports previous studies that reported consistently smaller stature and cephalofacial/ cranial measurements for women than for men in different populations. These results are consistent with the findings of Patil and Mody,[12] Sahni *et al*.,[13] Agnihotri *et al*.,[14] Giurazza *et al*.,[15] Kalia *et al*.,[16] and Badam *et al*.[17]

Mahalakshmi and David[11] studied 10 linear cephalometric variables in 156 subjects comprising 76 males and 80 females in the age range of 25–55 years in the South Indian population. Mean height for male was statistically higher (167.87 ± 6.58) than for female (154.09 ± 5.76). G-Op was found to be a significant predictor of stature in males as well as in females. Ma-Ht (0.90) was found to be significantly and positively correlated with stature among males, and N-M (0.26) was found to be positively and significantly correlated with stature among females. Inverse relation (negative beta-coefficient) was observed between N-ANS, V1-V2, and Ma-FH in males, but none of these factors significantly influenced stature.

All the parameters together were able to explain 61.5% of the variation in stature in males. It was observed that MaHt, V1-V2, G-OP, Ba-N, N-M, BA-ANS, Ma-Width, and Ma-SN were major variables in the determination of sex, and their respective discriminative powers were 71.2%, 65.4%, 64.7%,

Table 2: Comparison of stature and lateral cephalometric parameters among males and females

Parameters	Males			Females		
	Minimum	Maximum	Mean±SD	Minimum	Maximum	Mean±SD
Height (cm)	135.60	194.20	171.18±8.25*	150.20	174.90	159.66±6.02
N-ANS (cm)	3.92	6.14	4.88±0.35*	3.65	6.14	4.64±0.51
N-M (cm)	9.26	12.64	11.30±0.71*	7.92	12.19	10.46±0.82
N-Gn (cm)	9.08	12.10	10.69±0.67*	8.10	11.75	9.91±0.85
S-M (cm)	7.74	13.26	11.95±0.77*	9.17	12.99	11.15±0.68
S-Gn (cm)	9.61	13.17	11.84±0.67*	8.90	12.73	11.00±0.67
Go-Gn (cm)	6.05	8.54	7.35±0.58*	5.07	7.92	6.88±0.51
Go-M (cm)	5.70	7.92	6.91±0.51*	4.90	7.56	6.45±0.47
Ba-ANS (cm)	7.65	11.84	9.81±0.59*	7.83	11.30	9.28±0.59
Ba-N (cm)	8.10	11.75	10.15±0.55*	8.46	11.84	9.63±0.56
FsHt (cm)	1.25	5.07	3.05±0.76*	1.25	4.90	2.71±0.77
Ma-SN (cm)	2.67	5.78	4.13±0.59*	2.40	7.56	4.00±0.80
Ma-FH (cm)	1.78	3.92	2.70±0.43*	1.60	3.92	2.60±0.50
Ma-B_1B_2 (cm)	0.27	1.51	0.67±0.21*	0.36	1.51	0.65±0.24
B_1B_2 (cm)	0.89	2.67	1.72±0.33*	0.98	4.18	1.74±0.46

*P<0.05 statistically significant. SD: Standard deviation

Table 3: Multiple regression equation for stature in males

Multiple regression equation	SEE	*P*
Y (Stature) = 89.961+0.063 (N-ANS) − 1.455 (N-M) + 4.712 (N-Gn) + 0.144 (S-M) − 0.281 (S-Gn) + 2.028 (Go-Gn) + 1.983 (Go-M) + 3.273 (Ba-ANS) − 1.195 (Ba-N)	7.583	<0.01

SEE: Standard error of estimate

Table 4: Multiple regression equation for stature in females

Multiple regression equation	SEE	*P*
Stature (Y) = 127.95+2.147 (N-M) + 0.036 (N-Gn) + 2.653 (S-M) − 0.858 (S-Gn) − 1.135(Go-M) − 5.997(Ma-B_1B_2)	5.475	<0.01

SEE: Standard error of estimate

Table 5: Discriminant function analysis for gender determination using lateral cephalometric parameters

Dicriminant function = −22.583−0.165 (N-ANS) + 0.239 N-M (cm) + 0.158 N-Gn (cm) + 0.031 S-M (cm) + 0.693 S-Gn (cm) − 0.443.Go-Gn (cm) + 0.637 Go-M (cm) + 0.364 Ba-ANS (cm) + 0.887 Ba-N (cm) + 0.065.FsHt (cm) − 0.174 Ma-SN (cm) − 0.769 Ma-SN (cm) + 1.156 Ma-B1B2(cm) − 0.406 B1-B2 (cm)

Table 6: Classification results for discriminant function analysis for gender prediction

From\to	Female	Male	Total	Percentage correct
Female	85/425	15/75	100/500	85.00
Male	18/90	82/410	100/500	82.00
Total	103/515	97/485	200/1000	83.50

64.1%, 64.1%, 63.5%, 62.8%, and 60.9%, respectively. N-ANS and Ma-FH were the least reliable variables to determine sex.

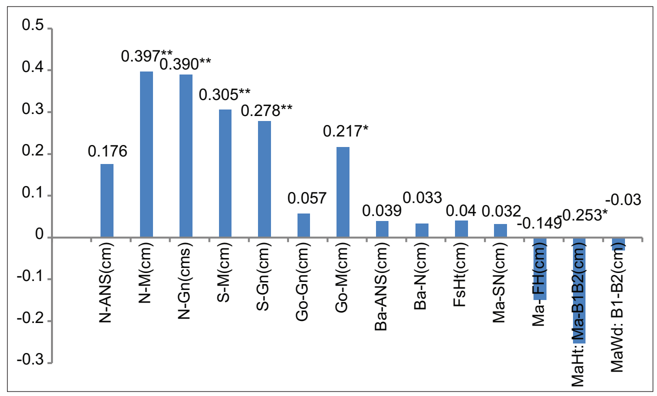

Figure 2: Pearson's correlation coefficient for lateral cephalometric parameters and MLS in females

However, in the present study, significantly higher values for mean height were noted for both males (171.18 ± 8.25) and females (159.66 ± 6.02). The present study observed the highest correlation between Go-M (0.361), Go-Gn (0.355) followed by N-Gn, S-Gn, N-M, Ba-ANS, N-ANS, S-M, Ba-N, and stature among males. For females, the highest correlation was for stature was found with N-M (0.397) and N-Gn (0.390) followed by S-M, S-Gn, and Go-M.

The findings for females in the present study were similar to that of Mahalakshmi and David's findings. Using 14 lateral cephalometric parameters, the present study has accuracy of 83.5% for gender prediction. However, discriminative power observed in the present study is the highest for Ba-N-78% followed by S-Gn - 77%, Go-M - 76%, N-M - 75%, Ba-ANS - 71.5%, N-Gn - 69.5%, S-M - 67%, N-ANS - 64.5%, Go-Gn - 63%, FsHt - 64.5%, Ma-N - 58%, Ma-FH - 57.5%, Ma-B1B2 - 53%, and B1-B2 - 46.5%, respectively.

Patil and Modi[12] evaluated 10 lateral cephalometric parameters among 150 (75 males and 75 females) Central Indian subjects for stature and gender estimation in the age group of 25–54 years using conventional radiographs. Mean height for males (164.81 ± 5.84) and females (151.88 ± 4.34) differ significantly. They concluded that maximum length of the skull (G-Op) was highly reliable in determining height of a person in both males and females. The difference between the average actual and average estimated heights for male and female was 0.15 and 0.22 cm, respectively, which was negligible which indicated reliability of regression formulae.

Patil and Mody observed 99% reliability for discriminant function for determining gender. Similarly, they concluded that Ba-N, MaHt, N-M, MaWd, Ba-ANS, Ma-FH, and G-Op were major variables in the determination of sex and their respective discriminative powers of 25.88%, 15.12%, 13.31%, 11.88%, 7.78%, 7.02%, and 6.90%. However, FsHt, Ma-SN, and N-ANS were the least reliable variables used in sex determination.

Similarly, our study observed negligible difference among mean actual stature and mean estimated stature for males (0.03 cm) and females (0.02 cm), respectively, which were smaller than those of Patil and Mody and indicated higher degree of reliability of our regression equations for stature.

The present study observed reliability of 83.5% for gender determination. As compared to Patil and Mody, we observed Ba-N, S-Gn, Go-M, N-M, Ba-ANS, and N-Gn, S-M as the major parameters for gender prediction, while all other lateral cephalogram parameters were also reliable for gender prediction. Similarly, Patil and Mody observed discriminative power for Ba-N as 25.88% for gender determination, while our study observed 78% discriminative power for Ba-N, indicating relatively greater discriminative power. The present study found that newly introduced parameters such as S-Gn (77%) and Go-M (76%) were the good predictors of gender.

González-Colmenares *et al.*[18] estimated stature for 54 males and 16 females using 10 lateral cephalometric parameters in the Columbian population in the age range of 20–45 years. They observed N-M (correlation coefficient $r = 0.47$; $P < 0.001$); G-Op ($r = 0.34$; $P < 0.01$), Ba-N ($r = 0.32$; $P < 0.020$), and Ma-SN ($r = 0.30$; $P < 0.027$) as the best parameters for stature in males. However, for the other measurements (N-ANS, FsHt, Ma-FH, MaHt, MaWd), the correlation coefficients were found to be low. Among females, the coefficient of correlation was not found to be statistically significant for stature and cranial measurements. The SEE for multivariate regression equation was in the range of 5.321–5.902 cm in males and 2.836–4.310 cm in females.

The present study observed the highest correlation with Go-M ($r = 0.361$, $P < 0.001$) for males as well as significant correlation of N-M ($r = 0.331$, $P < 0.001$) with stature as that of González-Colmenares *et al.* in males. However, in contrast to González-Colmenares *et al.*, the present study found significant predictors of stature among females such as N-M, N-Gn, S-M, S-Gn, Go-M, and MaHt. SEE of the present study for males (7.583) and females (5.475) was higher than those of González-Colmenares *et al.*

Giurazza *et al.*[15] estimated stature in 200 Caucasian males and females by measuring CT parameters such as Ba-N and FsHt. They observed high correlation coefficient for Ba-N ($r = 0.94$) for both sexes.

The present study evaluated males and females separately for stature estimation and observed significant correlation coefficient for males and Ba-N ($r = 0.253$) and no significant correlation coefficient for Ba-N and stature in females ($r = 0.033$).

The results of the present study indicate that stature and most cephalometric measurements are positively and significantly correlated in the Chhattisgarh population; furthermore, there are different parameters correlating with stature gender-wise.

The present study observed different lateral cephalometric measurements for stature estimation in males and females; a few were common parameters in both sexes, namely N-M, N-Gn, S-M, S-Gn, and Go-M.

While the present study observed the highest correlation coefficient for N-M ($r = 0.391$) among females, it was Go-M ($r = 0.361$) in males. N-Gn, S-M, and S-Gn have the next lower values of Pearson's correlation coefficient among females. The moderate values of correlation coefficients in the present study could be attributed to the homogeneous nature of the samples and population from which sample is drawn.

The present study has derived multiple regression equation for stature from the significant parameters separately for males and females. The SEE of these equations was 7.58 and 5.47, respectively, for males and females. Low SEE value favors greater reliability of these equations in females.

Due to resilient nature and ability to resist decomposition/destructional forces, the hard tissues such as teeth and bones are well preserved. Maxillofacial radiographs and study of dentition have similar role in ascertaining identity of the person either living or dead.

Lateral cephalogram apart from giving information about facial relationships, planning for orthognathic surgery, orthodontic treatment, and assessing the growth in children are also helpful aid in identification. With availability of the skull as only skeletal remains, it is possible to determine sex and estimate stature from various cephalometric dimensions for establishing identity.

Likewise, skull has well-defined, standardized, and easily localizable anatomical landmarks,[16] and the cephalometric radiographs are a good method which reproduces and determines the linear measurement from these landmarks for stature estimation.[12] Hence, making cephalometric radiographs of a skeleton should be a routine procedure for the purpose of identification.

Likewise, skull dimensions also have some definite relationship with the stature. With unavailability of long bones and only availability of the skull as skeletal remains, the relationship between stature and skull dimension would be helpful for determining stature. Gender determination has an imperative role in establishing biological profile of deceased. It narrows the possibility for the identification by 50%.[19,20]

Despite the use of morphometric and anthropometric methods, radiographs offer an accurate, simpler, perfect, emulative, and explicit method of sex determination by linear and angular measurements and also aid in reducing the interobserver bias as documented by Hsiao *et al.*[21] and Divakar *et al*.[22]

Lateral cephalogram is exemplary for the analysis of skull as it provides information of a variety of anatomical points in a single radiograph. Hence, the present study utilizes lateral cephalogram for the estimation of stature and the determination of gender.

The main goals of this study were to test the validity of stature estimation and sex determination using lateral cephalometric radiography with discriminant function analysis on the Chhattisgarh adult population and to test the validity, efficacy, and reliability of dimorphic features of the skull by digital lateral cephalometric radiographs.

The neurocranium is the earliest growing region of the skull, followed by mid-face and parts of the cranial base and finally structures relating to mastication. New parameters introduced are facial as well of mandibular in origin and growth of which continues till attainment of linear height. Similarly, earlier studies have explored craniomaxillary parameters; hence, along with facial parameters, mandibular parameters (Go-Gn and Go-M) were also explored. Cranial base and upper face have relative less growth than mandible; hence, the mandibular parameters which continue to grow show optimum correlation with stature of the individual.

The study subjects were in the age range of 21–50 years. The lower limit of the age group was set because growth of the craniofacial region is about complete by that age for normal healthy individuals. The higher limit of age was based on the W. M. Krogman's proposition which states that the craniomandibular parameters are age phenomena appearing or becoming pronounced at puberty and many are affected by the changes of senility.[23]

Skeletal growth is completed by this age in both sexes. Stature determination either below or above this age range may show high variations. In adolescents, the physical growth of the head and face has little effect on the determination of stature because the peak growth of the head and face occurs up to the 13th year of life.[12] The findings of this study suggest that cephalometric measurements can be utilized in estimating stature, only when the skull is available for forensic examination.

For stature determination, all five new parameters correlated significantly with stature, except Go-Gn in females. Thus, being good predictors, all these new parameters can be used to estimate stature in the Chhattisgarh population, except the Go-Gn in females which did not show significant correlation.

Discriminant analysis is for grouping individuals into two or more different groups, with reference to sets or measurements. Similarly, it identifies the variables responsible for making categorization.[17] This technique overcomes several problems ingrained in instinctive procedures of sexing skulls, implementing a reasonably clear, objective method of sexing material with a computable accuracy,[7] and helps as an objective statistical procedure for the determination of sex.[17]

Various studies conducted by Hsiao *et al*.,[21] Patil and Mody,[12] and Veyre-Goulet *et al*.[24] concluded that the technique used for sexing the skull by means of lateral cephalograms with discriminant function analysis appeared to be appropriate.

The results of the present study revealed that the human skull exhibits anatomic variability between genders. For gender determination, all the 14 lateral cephalometric measurements were used together in discriminant model to differentiate between males and females. The resulting equations were statistically significant and could predict gender with an accuracy of 82% in males and 85% in females using the given parameters. Hence, the accuracy of the given model comes out to be 83.5% to predict gender for the adult Chhattisgarh population.

The discrepancy in the results of various studies for stature and gender determination may be elucidated, due to the differing number of parameters and differing population.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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