

Research Article

Stature Estimation from Regression Analysis of Craniofacial Anthropometry in an Indian Population

Kamakshi Nayyar^{1*}, Pragnesh Parmar², Yadukul S³, Prashanth M⁴ and Divya R⁵

¹Senior Resident, Department of Forensic Medicine and Toxicology, AIIMS, Jammu, India

²Additional Professor and HOD, Department of Forensic Medicine and Toxicology, AIIMS, Bibinagar, Telangana, India

³Additional Professor, Department of Forensic Medicine and Toxicology, AIIMS, Bibinagar, Telangana, India

⁴Associate Professor, Department of Forensic Medicine and Toxicology, AIIMS, Bibinagar, Telangana, India

⁵Assistant Professor, Department of Forensic Medicine and Toxicology, Gandhi Medical College, Hyderabad, Telangana, India

More Information

***Address for correspondence:** Dr. Kamakshi Nayyar, Senior Resident, Department of Forensic Medicine and Toxicology, AIIMS, Jammu, India, Email: nayyarkamakshi1974@gmail.com

 <https://orcid.org/0009-0003-5674-8851>

Submitted: September 03, 2025

Approved: September 23, 2025

Published: September 24, 2025

How to cite this article: Nayyar K, Parmar P, Yadukul S, Prashanth M, Divya R. Stature Estimation from Regression Analysis of Craniofacial Anthropometry in an Indian Population. J Forensic Sci Res. 2025; 9(2): 179-183. Available from: <https://dx.doi.org/10.29328/journal.jfsr.1001099>

Copyright license: © 2025 Nayyar K, et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Keywords: Stature; Craniofacial; Identification; Regression; Forensic; Anthropometry



Abstract

Background: Stature is a key biological characteristic for identifying individuals, particularly in forensic investigations. While long bones are traditionally used for stature estimation due to their strong correlation with height, craniofacial structures offer an alternative in cases where only partial remains are available, given their durability and relative preservation.

Objectives: This study aimed to evaluate the relationship between craniofacial anthropometric parameters and stature, and to assess their usefulness for stature estimation in the Indian population.

Methods: Twelve craniofacial parameters were measured and analyzed using regression analysis, the preferred statistical method for estimating stature from skeletal dimensions. The study focused on assessing the strength of correlation between these craniofacial measurements and actual stature.

Results: All twelve craniofacial parameters demonstrated a positive correlation with stature, indicating their potential utility in forensic contexts where only craniofacial remains are present. Although long bones remain the gold standard, these findings provide support for the supplementary use of craniofacial data.

Conclusion: Craniofacial anthropometry can serve as a reliable method for estimating stature, especially in scenarios where long bones are unavailable. This study contributes valuable data to the limited literature on this topic in the Indian population and aligns with existing global research supporting the role of craniofacial structures in forensic identification.

Introduction

Personal Identification is the backbone of scientific methodology needed to determine the individuality of victims, suspects, and the accused in cases of mass disasters, airplane crashes, fire accidents, wars, and bomb explosions, and all other forensic investigations. Stature which is the total vertical length of an individual, is one significant pillar out of the four that are the basis of such procedure, others being race, age and sex, and it assumes great significance in cases where the whole body is not available or in cases of

decomposed dead bodies or cases where just skeletal remains are available [1-3]. Availability of complete long bones like the humerus, femur or tibia facilitates estimation of stature to a great precision, but, if only partial bone fragments are available, such as skull or one of the limbs, stature estimation can be done using regression equations. While several studies highlight the relationship between stature and long bone lengths—including the femur, humerus, tibia, and fibula—only a limited number have examined its correlation with craniofacial morphological features. Among the various



anthropometric parameters that can be utilized to estimate Stature, craniofacial anthropometry is one. Craniofacial anthropometry involves the measurements of the face and head with respect to various bony landmarks. This objective technique utilizes systematic measurements and proportional analyses to characterize phenotypic variation and quantify dysmorphic features [4-7]. It is a non-invasive, quantitative method of assessment of the anatomy of human faces. There are Direct and Indirect methods of craniofacial anthropometry. While Direct Anthropometry involves the manual measurements of various parameters defined with respect to various landmarks on the head and face using instruments like Vernier calipers, spreading calipers, and measuring tape, in Indirect Anthropometry, 2D photographs or 3D images of the face are taken, and measurements are done using predefined landmark points. Both methods require well-trained personnel to record measurements in order to obtain accurate results [8-13].

Although there are studies available describing the relationship between the stature and the various anthropometric measurements, Pearson, Hamman-Todd, Dupertuis and Hadden, Musgrave and Harneja, to name a few, most of them are based on the long bones [7]. Most of such standards are based on the studies conducted on American Whites and Blacks; those for the Indian population are limited.

Though India is a racially diverse country, and it is not possible to develop regression equations precise enough, this study is an attempt to develop regression equations for the estimation of stature by using craniofacial anthropometric measurements in a heterogeneous Indian population. It is an established fact that estimation of stature, assessment of age, or determination of sex based on various methods available, including skeletal maturity, dental development, sexual maturity, and anthropometric parameters, are likely to be reliable when applied to individuals from the population for which those standards are derived [3].

Material and methods

This Cross-sectional descriptive study was carried out after obtaining Institutional Ethics Committee approval (IEC No. AIIMS/BBN/IEC/JULY/2022/192 dt. 02nd August, 2022), with the aim of estimating stature from the various craniofacial variables measured using Sliding digital Vernier Callipers (MITUTOYO Corp. Digimatic Caliper precision value - 0.01 mm), Harpenden Anthropometer (HOLTAIN Limited), Spreading Vernier Calipers (HOLTAIN Limited), Medical scale for height, weight, and BMI. Any participants found to be suffering from injuries, fractures, or developmental abnormalities were excluded from the study. The stature estimation was made using 12 craniofacial parameters including maximum head length (MHL), maximum head breadth (MHB), bizygomatic breadth (BZB), bigonial breadth (BGB), biocular breadth (BOB), total head height (THH), physiognomic facial height (PFH), morphological facial height (MFH), nasal height (NH), nasal width (NW), physiognomic ear height (PEH) and physiognomic ear width (PEW). The

study was conducted over a period of 18 months from 2022 to 2024. The study group consisted of 498 subjects, including the patients coming to the OPD, Nursing Staff, Faculty, and students of AIIMS, Bibinagar, who were found suitable as per the Inclusion and Exclusion criteria. Both males and females aged 21 years and above but less than 60 years, with a BMI value of more than 18.5 but less than 24.9, Indian in origin, who were willing to participate after giving informed consent, were included in the study. Individuals with a history of any facial surgery or those having any gross Craniofacial deformity or any gross skeletal deformity, such as kyphosis, scoliosis, facial asymmetry, or any skeletal dysplasia, were excluded from the study. The sample size was calculated to be 498.

After taking due informed consent from each participant, Height (in centimeters) and all the Craniofacial parameters (in centimeters) were measured with reference to anatomical landmarks, keeping the head in Frankfurt's horizontal plane in accordance with the methods suggested by Vinita, et al. [14] and Singh and Bhasin [15]. The diurnal variations in stature have been documented, and substantial diurnal variation in stature is known to affect height data in forensic examination [16]. So, to avoid any variations, all the measurements were taken at the same time of the day, i.e., between 10 am and 12 pm. To avoid any inter-observer error, all the measurements were taken by the same person, i.e., the Principal Investigator. The data collected was analysed using IBM Statistical Package for the Social Sciences (SPSS) Statistics 29.0.2.0(20) version software program.

Results

For the purpose of the present descriptive study aimed at studying the relationship between the craniofacial morphological parameters and the stature and whether they can be used to estimate stature, data pertaining to 12 craniofacial variables of 498 subjects were obtained and statistically analyzed for this purpose; out of which the number of males and females were 230 (46.2%) and 268 (53.8%) respectively. The mean age of the study participants was 30.53 years. Participants in the age group of 21-30 years constituted 61.6% of the total study population. The participants ranged in age from 21 years to 60 years. The age-wise frequency distribution of the study sample shows that the highest number of individuals among both females and males was present in the age group of 21-30 years (Figure 1). For the total study population, the majority of the individuals were in the age group of 21-30 years ($n = 307$, % = 61.6). The study participants belonged to 23 different states, with many of them belonging to Telangana (47.2%), followed by Kerala (11.4%) and Maharashtra (6.4%). The mean value of the stature for the study population was found to be 163.984 cm, with the highest and lowest values being 196.0 cm and 148.0 cm, respectively (Table 1). For the overall study population, the correlation coefficient value was found to be highest for Nasal height (NH), followed by Total Head height (THH), with a p -value of less than 0.05 for all variables except for Physiognomic facial height (PFH) (Table 2 and Figure 2).

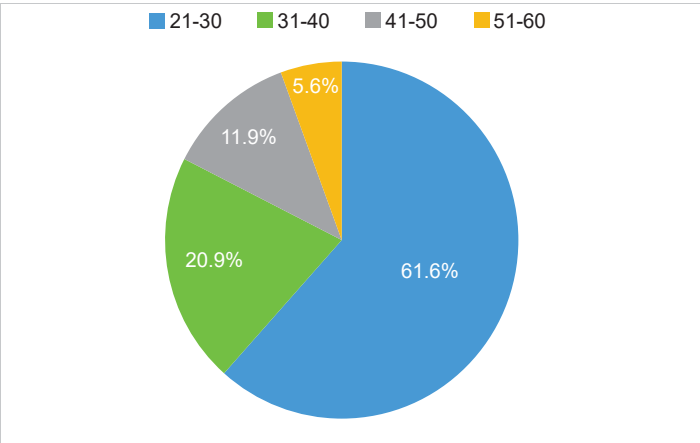


Figure 1: Percentage of participants in different age groups.

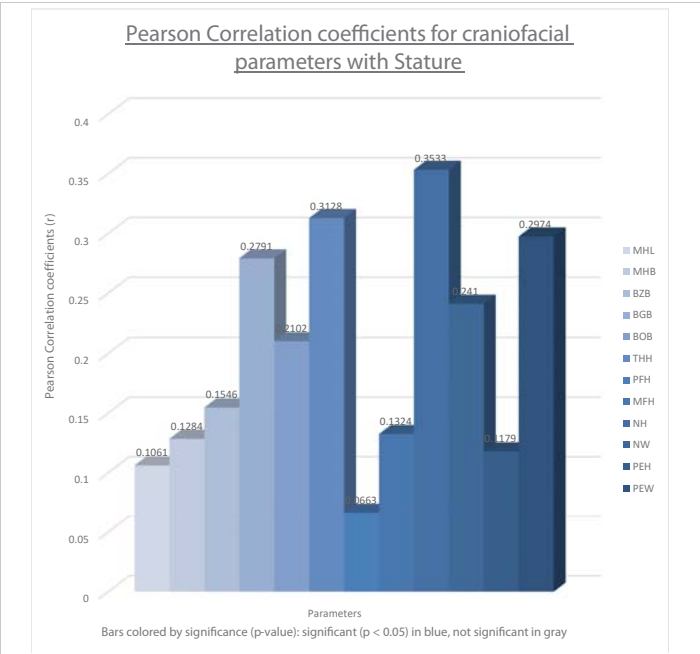


Figure 2: Bars colored by significance (p-value) depicting the Correlation coefficients between the Stature and the various craniofacial parameters.

Table 1: Descriptive statistics of the Stature of the study participants.

Measurement	Max. Value (cm)	Min. Value (cm)	Mean (cm)	Median	S.D.	Range
Stature (cm)	196.0	148.0	163.984	163.000	8.4145	48.0

Table 2: Pearson Correlation coefficients for craniofacial measurements with Stature.

Measurement (cm)	Pearson Correlation coefficients (r)	Significance (p - value) (2-tailed)
MHL	0.1061	0.018
MHB	0.1284	0.004
BZB	0.1546	0.001
BGB	0.2791	<0.0001
BOB	0.2102	<0.0001
THH	0.3128	<0.0001
PFH	0.0663	0.139
MFH	0.1324	0.003
NH	0.3533	<0.0001
NW	0.2410	<0.0001
PEH	0.1179	0.009
PEW	0.2974	<0.0001

Among males, the maximum and minimum values of the stature were found to be 196 cm and 150 cm, with a mean value of 164.8 cm. Among males, the correlation coefficient value was found to be highest for Nasal height (NH), followed by Physiognomic ear width (PEW), with a p-value of less than 0.05 for all variables except for Physiognomic ear height (PEH), Maximum head length (MHL), and Bizygomatic breadth (BZB). Among females, the correlation coefficient value was found to be highest for Bigonial breadth (BGB), followed by Total head height (THH) and Nasal height (NH), with a p-value of less than 0.05 for all variables except for Physiognomic facial height (PFH) and Morphologic facial height (MFH). Table 3 shows the logistic regression models that can be used for the calculation of stature from the various craniofacial parameters.

Discussion

Stature estimation from skeletal remains is based on the availability of tissues, and owing to the relative indestructibility of craniofacial structures, they are highly useful for the purpose of identification. Regression analysis is the statistical method of choice for estimating stature from the percutaneous bone lengths or skeletal remains [6]. Estimation of these parameters accelerates the analysis of human remains by narrowing the pool of victims to match and provides more definitive markers for final confirmation in the course of a forensic investigation [17]. In general, long bone measurements are considered more reliable than any other anthropometric parameters for stature estimation due to various reasons including - their stronger correlation with stature, lesser variability in shape and size compared to craniofacial structures, and most importantly due to more established formulas and methods for stature estimation from long bones, which have been developed and tested over time [18-22], but, in instances where the complete skeletal remains are not available, or only the craniofacial skeletal remains are available, results derived from studies such as this one can be useful for stature estimation. So, in the present study which was an attempt to estimate the strength of relationship between stature and craniofacial anthropometry, all the twelve parameters studied were found to be positively correlated

Table 3: Logistic regression equations for craniofacial measurements with Stature.

Measurement (cm)	Regression equation	Standard error of estimate (SEE) (cm)
MHL	157.11+0.429xMHL	8.37548
MHB	157.69+0.526xMHB	8.35326
BZB	154.60+0.809xBZB	8.32179
BGB	145.29+1.621xBGB	8.08841
BOB	148.23+1.263xBOB	8.23478
THH	142.72+1.149xTHH	8.00037
PFH	160.19+0.267xPFH	8.40446
MFH	156.02+0.773xMFH	8.34890
NH	140.89+5.359xNH	7.87979
NW	150.66+3.498xNW	8.17481
PEH	155.53+1.636xPEH	8.36432
PEW	142.73+6.408xPEW	8.04201



with stature upon statistical analysis, thus supporting the use of craniofacial anthropometry for stature estimation, aligning with the previously available research [6,23-26]. The p-value, which denotes the significance of the results, was less than 0.05 for all the variables except for one, i.e., physiognomic facial height (PFH), where it was 0.139. The correlation coefficients ranged from 0.1061 for maximum head length (MHL) to 0.3533 for nasal height (NH). Considering the strength of the relationship given by the numeric value of the correlation coefficient, the strength of the relationship between the stature and craniofacial parameters was found to be in the small to medium range. Notably, nasal height (NH) showed the strongest correlation with stature ($r = 0.3533$) in the total study group, followed by total head height (THH) ($r = 0.3128$), physiognomic ear width (PEW) ($r = 0.2974$), and bigonial breadth (BGB) ($r = 0.2791$). These findings suggest that these craniofacial variables can be reliable predictors of stature.

Comparing the findings with the study by Yadav, et al. [6], similarities and differences emerge. The comparison can be done only on the basis of five common variables studied in both studies, including PFH, MFH, BOB, BZB, and BGB. Both studies found significant correlations between facial measurements and stature, but the strongest predictors differed. Yadav, et al. reported physiognomic facial height (PFH) as the best regressor for females and Bigonial breadth (BGB) for males, whereas the present study found Bigonial breadth (BGB) among females and Morphologic facial height (MFH) among males to be the strongest predictors. These variations may be attributed to population-specific differences or methodological variations. However, both studies agree on the importance of considering sex-specific differences in stature estimation.

Linear regression analysis yielded regression models for stature estimation from the twelve craniofacial variables. The standard error of estimate (SEE) was lowest for nasal height (NH) at 7.88, indicating its potential as a reliable predictor. The mean stature values for males and females were 164.81 cm and 163.27 cm, respectively.

Notably, the studies by Kewal Krishan [16] and Dinakaran, et al. reported higher correlation coefficients, potentially due to the homogenous population samples. Additionally, the studies highlight the importance of considering sex-specific differences in stature estimation, as different craniofacial variables may be more predictive in males and females.

The study's findings also align with previous research that found significant correlations between cephalic and facial measurements and stature [24,26]. However, the strongest predictor variables and correlation coefficients differed between studies, highlighting the importance of population-specific and sex-specific analysis.

Overall, the findings suggest that nasal height (NH), bizygomatic breadth (BZB), and bigonial breadth (BGB) are consistently among the strongest predictors of stature. However, the studies also emphasize the need for population-specific formulas and consideration of racial, genetic, climatic, and nutritional factors when applying stature estimation models. Stature constitutes an essential characteristic in the description of an individual. Stature estimation from skeletal remains is based on the availability of tissues, and owing to the relative indestructibility of craniofacial structures, they are highly useful for the purpose of identification. Regression analysis is the statistical method of choice for estimating stature from the percutaneous bone lengths or skeletal remains [6].

Conclusion

From the present study, it can be concluded that stature can be estimated from various facial dimensions, similar to stature estimation from other parts of the human body. However, the correlation is not strong enough to use it as a primary method, but can be utilized in the absence of other better parameters, such as long bones, or when only craniofacial remains are presented for forensic examination.

Regression equations derived for the estimation of stature from craniofacial parameters can be used as a supplementary approach in cases where only craniofacial remains are available.

But these formulae, being population-specific, can only be applied to the specific population for which they have been derived.

Future research should expand sample sizes across diverse Indian subpopulations to enhance the generalizability of regression models. Also, the use of AI and advanced imaging may help improve accuracy.

Informed consent

Informed Consent was obtained from all the participants for the purpose of the above study.

Author's contribution

All the authors contributed to the collection, compilation, and analysis of the data for the study.

References

1. Kanchan T, Krishan K. Personal identification in forensic examinations. *Anthropol.* 2013;2:114. Available from: <https://www.longdom.org/open-access-pdfs/personal-identification-in-forensic-examinations-2332-0915.1000114.pdf>
2. Verma R, Krishan K, Rani D, Kumar A, Sharma V. Stature estimation in forensic examinations using regression analysis: a likelihood ratio perspective. *Forensic Sci Int Rep.* 2020;2:100069. Available from: <https://doi.org/10.1016/j.fsir.2020.100069>
3. Preedy VR, editor. *Handbook of anthropometry: physical measures of human form in health and disease.* New York: Springer Science & Business Media. 2012. Available from: <https://link.springer.com/book/10.1007/978-1-4419-1788-1>

4. Jayaratne YS, Zwahlen RA. Application of digital anthropometry for craniofacial assessment. *Craniofacial Trauma Reconstr.* 2014;7(2):101–7. Available from: <https://doi.org/10.1055/s-0034-1371540>
5. Encyclopedia of Body Image and Human Appearance. 2012. Available from: https://www.researchgate.net/publication/296094384_Encyclopedia_of_Body_Image_and_Human_Appearance
6. Yadav AB, Kale AD, Mane DR, Yadav SK, Hallikerimath S. Stature estimation from regression analysis of facial anthropometry in the Indian population. *J Oral Maxillofac Pathol.* 2019;23(2):311. Available from: https://doi.org/10.4103/jomfp.jomfp_140_19
7. Krogman WM, Iscan MY. *The human skeleton in forensic medicine.* 2nd ed. Springfield (IL): Charles C Thomas; 1986. p.310, 311, 312, 317, 323, 338, 349. Available from: <https://www.scirp.org/reference/referencespapers?referenceid=1526382>
8. Katzenberg MA, Grauer AL, editors. *Biological anthropology of the human skeleton.* 3rd ed. Hoboken (NJ): Wiley-Blackwell; 2018;43–71. Available from: <https://www.wiley.com/en-us/+Anthropology+of+the+Human+Skeleton%2C+3rd+Edition-p-9781119151630>
9. Christensen AM, Passalacqua NV, Bartelink EJ. *Forensic anthropology: current methods and practice.* 2nd ed. London: Academic Press; 2018. Available from: <https://www.sciencedirect.com/book/9780128157343/forensic-anthropology>
10. Byers SN. *Introduction to forensic anthropology.* 5th ed. New York: Routledge; 2016. Available from: <https://www.taylorfrancis.com/books/mono/10.4324/9781315642031/introduction-forensic-anthropology-steven-byers>
11. Wiersema JM. Evolution of forensic anthropological methods of identification. *Acad Forensic Pathol.* 2016;6(3):361–9. Available from: <https://doi.org/10.23907/2016.038>
12. Yoshino M. *Cranial morphometry: a practical guide.* San Diego (CA): Academic Press; Chapter 9, Stature estimation from cranial morphometry. 2015;157–70.
13. Steenberg CL. *Forensic craniofacial reconstruction.* San Diego (CA): Academic Press. Chapter 11, Estimating stature from cranial remains. 2016;245–62. [cited 2025 Jun 22]. Available from: <https://pressbooks.ccconline.org/ppscant2315introtoforensicanthropology/chapter/chapter-11-estimating-stature-in-human-skeletal-remains/>
14. Murgod V, Angadi P, Hallikerimath S, Kale A. Anthropometric study of the external ear and its applicability in sex identification: assessed in an Indian sample. *Aust J Forensic Sci.* 2013;45(4):431–44. Available from: <http://dx.doi.org/10.1080/00450618.2013.767374>
15. Singh IP, Bhasin MK. *A laboratory manual on biological anthropology.* 2nd rev ed. Delhi: Nazia Offset Press. 1989;29–44.
16. Krishan K, Kanchan T, Menezes RG. Stature estimation in forensic examinations: A few technical considerations. *Indian J Dent Res.* 2012;23(5):692–3. Available from: <https://doi.org/10.4103/0970-9290.107414>
17. Ahmed AA, Taha S. Cephalo-facial analysis to estimate stature in a Sudanese population. *Legal Med.* 2016;20:80–6. Available from: <https://doi.org/10.1016/j.legalmed.2016.04.008>
18. Wilson RJ, Herrmann NP, Bennett JL. Stature estimation from skeletal remains: a review of the literature. *J Forensic Sci.* 2011;56(3):761–71. Available from: <https://doi.org/10.1111/j.1556-4029.2010.01343.x>
19. Ross AH, Konigsberg LW. Stature estimation from cranial and long bone lengths in modern humans. *Am J Phys Anthropol.* 2015;156(2):291–301.
20. Kokati DB, Jayaprakash BR, Pinjar MJ. Stature estimation from fragments of femur in the South Indian population. *Cureus.* 2025;17(2):e78877. Available from: <https://doi.org/10.7759/cureus.78877>
21. Zhang J, Zhang Y, Liu W. Stature estimation from long bone lengths in a Chinese population. *Legal Med.* 2018;31:53–8.
22. Kumar A. Stature estimation from long bones in a North Indian population: A study of 500 individuals. *J Forensic Sci.* 2020;65(2):437–43.
23. Dinakaran J, Hariganesh P, Shamala S, Dhivya K, Saranya V, Saranya M. Stature estimation of an individual using nasal, facial, and palatal height among Tamil Nadu population. *J Pharm Bioall Sci.* 2021 Jun;13(Suppl 1):S751–6. Available from: https://doi.org/10.4103/jpbs.jpbs_595_20
24. Obaje SG, Ibegbu AO, Hamman WO, Waitieh-Kabehi AK. A regression analysis to determine personal stature from craniofacial parameters of the Idoma tribe in Nigeria. *J Exp Clin Anat.* 2017;16(2):116–20.
25. Pelin C, Zağyapan R, Yazıcı C, Kürkçüoğlu A. Body height estimation from head and face dimensions: a different method. *J Forensic Sci.* 2010;55(5):1326–30. Available from: <https://doi.org/10.1111/j.1556-4029.2010.01429.x>
26. Varghese AM, Vaswani VR, Shenoy V, Babu B, Ajid A. Estimation of stature using cephalic and facial measurements. *J Indian Acad Forensic Med.* 2022;44(1):27–30. Available from: <https://jiafm.in/index.php/jiafm/article/view/18?articlesBySameAuthorPage=7>