Journal of Population Therapeutics & Clinical Pharmacology

RESEARCH ARTICLE
DOI: 10.53555/3yg6nx81

ANTHROPOMETRIC STUDY OF THE CEPHALO-FACIAL PARAMETERS TO ESTIMATE RELATIONSHIP WITH STATURE OF AN INDIVIDUAL IN INDIAN POPULATION: A CROSS-SECTIONAL STUDY

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ABSTRACT
Estimating stature is crucial in forensic anthropology, especially while identifying people during criminal investigations, mass disasters, and cases involving unidentified human remains. The purpose of this study is to establish regression equations to evaluate stature using cephalofacial features in a heterogeneous sample of Indian MBBS students. The study included 100 participants (50 males and 50 females) aged 18 to 25 years who selected using convenience sampling. Cephalofacial measurements were recorded using calibrated anthropometric devices such as digital vernier calipers, spreading calipers, and measuring tapes. Regression analysis was then utilized to generate predictive equations for estimating stature using these variables.
The strongest association was established between stature and horizontal head circumference (r = 0.448), followed by physiognomic face length. Nasal breadth showed the least correlation (r = -0.173). For each parameter, regression equations were developed, and standard errors of estimation were determined. Horizontal head circumference was determined as the most reliable criterion for estimating stature, followed by physiognomic face length. The research shows that cephalofacial measures can be used to determine stature with high accuracy, especially when only cephalofacial remains are available. The findings highlight the significance of cephalofacial characteristics in forensic investigations, particularly when alternative sources of stature data are lacking. These findings provide significant forensic tools for estimating stature in the Indian population.

KEYWORDS: Forensic anthropology, Facial recognition, Stature, Cephalon facial dimensions, Facial dimensions, Human identification, medicolegal

INTRODUCTION

In mass disaster scenarios when only the skull is recovered, forensic experts turn to cephalofacial anthropometry to assist in human identification, including stature estimation. Since stature is a key biological profile element along with age, sex, and ancestry, being able to estimate it from skull measurements becomes critical.

Anthropometry, the scientific study of body measurements, is a valuable research technique in the field of forensics that aids in the identification of unknown human remains. Stature, derived from the Latin statura, which means "to stand," is an important aspect of a person's biological profile.

In the field of forensic anthropology, stature, age, gender, and ancestry formed the basis for human identification. In scenarios like mass disasters where badly decomposed or disfigured dead bodies are found, stature approximation becomes equally important as other clues [1, 2] .

Many studies have attempted to estimate stature using various human skeleton bones, particularly in situations of dismembered and mangled corpse parts, with varying degrees of accuracy [3, 4]. Complete skeletal recovery is often impractical in both archaeological and forensic contexts. Hence It becomes a matter of necessity to use available body parts like the head, skull or face region for forensic examination [5].

The history of facial dimension analysis has been dated long back to the period of Alexander the Great, in the Hellinistic period of around 300 BC 6. Since the anatomical landmarks of the face and cranium are constant, cephalofacial dimensions can be calculated and obtain a promising alternative for stature estimation [6] .

The in-depth knowledge of cephalofacial parameters is of critical value not only in forensics but also in cosmetic and reconstructive surgery, where aesthetic standards are often aligned with facial proportions [7, 8] .

Due to the limited literature available on the cephalofacial region, forensic scientists often face challenges in medico-legal and forensic investigations, especially when cephalofacial features are the only remains available for analysis. The application of facial reconstruction techniques is sometimes hindered by the lack of expertise, standardized reference data, or appropriate equipment. In such scenarios, the ability to estimate an individual's stature from cephalofacial measurements can significantly aid in narrowing down potential identities during forensic investigations [5].

Given the scarcity of research on estimating stature from cephalofacial dimensions and the importance of such data in forensic and medico-legal situations, the current study seeks to investigate the anthropometric relationship between cephalofacial measurements and stature. Furthermore, it establishes regression equations to predict stature based on these dimensions. The primary objective was to study a correlation between cephalofacial parameters and the stature of an individual by anthropometric analysis, and the secondary objective was to derive regression equations to assess the stature using cephalofacial parameters.

MATERIALS AND METHODS

This cross-sectional observational study was designed to investigate the relationship between several cephalofacial measurements and an individual's stature. This study design was selected due to its practicality, low cost, and effectiveness in generating baseline data for future investigations [9]. The Forensic Medicine and Toxicology Department of an Indian medical institution conducted this investigation from January 2022 to July 2023.

The study included second-year MBBS students at the institution who volunteered to participate after completing the inclusion and exclusion criteria and obtaining informed written consent. The Institutional Ethics Committee provided ethical permission (IEC/pharmacy/2022/407, dated 21/05/2022), and participants were told that their data would be kept secure, with no personal information disclosed.
The sample size was established with the primary goal of investigating the relationship between cephalofacial dimensions and stature. Using G*Power 3.1 software, the required sample size was calculated to be 40, assuming 90% statistical power and a 5% alpha error[10]. The final study population comprised of 100 participants (50 males and 50 females) aged 18 to 25 years. Participants were chosen using a convenience sample method, which is a non-probability selection methodology based on ease of access and willingness to participate [11].
Participants with head/spinal cord injuries or skeletal abnormalities were excluded. Participants with a family history of endocrine or metabolic disorders affecting height and those who did not provide consent for the study were also excluded.
Written informed consent was obtained from all the participants before initiation of the study. Prior to data collection, the cranium's anatomical landmarks were assessed to ensure their visibility and palpability. The following anatomical landmarks were used for cranial measurements:

- Zygion (zy): The most outward point on the zygomatic arch.
- Glabella (g): The most prominent point on the forehead along the midline.
- Opisthocranion (op): The farthest point on the back of the skull.

During the measurement, individuals were sitting in a relaxed position with their heads aligned with the Frankfurt horizontal plane.

Anthropometric Measurements

Standard anthropometric tools were employed to record the following measurements:

- Stature: Used a conventional anthropometer to measure the participant's vertical height from the floor to the vertex of their head while standing barefoot.
- Horizontal Head Circumference: To measure horizontal head circumference (Figure 1), use a flexible measuring tape from the glabella to the opisthocranion and back [12].
- Nasal Breadth: Measured as the linear distance between the most lateral points of the alae nasi using a spreading caliper [13]. (Figure 2)
- Morphological Facial Length (Figure 3): Measured from the nasion to the gnathion with a digital vernier caliper (Mituyoto, Japan; precision ±0.01 mm).
- Physiognomic Facial Length (Figure 4): Measured from trichion to gnathion using a digital vernier caliper (Mituyoto, Japan; precision ±0.01mm).
- Bizygomatic Breadth (Figure 5): The distance between the furthest points of the zygomatic arches, measured with a Martin's spreading caliper (Biotech Ltd., Agra, India).

All dimensions were collected in centimeters and rounded to the nearest millimeter. To limit measurement error, anatomical landmarks were identified by palpation prior to data collection. To assure measurement accuracy, these devices were calibrated and verified on a regular basis.

Statistical Analysis

The study population's demographic and measurement data were summarized using descriptive statistics. The Kolmogorov-Smirnov test was used to determine whether each variable's distribution was normal. To investigate the relationship between cephalofacial measures and stature, Karl Pearson's correlation coefficient was determined. Simple linear regression analysis was used to create gender-specific regression models for estimating stature. All statistical analyses were conducted using IBM SPSS Statistics software, Version 19.0 (IBM Corp., Armonk, NY) 14.
In the regression equations used for stature estimation

Y= C+MX

Where Y represents the estimated stature, C is the constant or intercept of the regression equation, M denotes the regression coefficient corresponding to the cephalofacial parameter (independent variable), and X is the measured value of the cephalofacial dimension. In addition, the standard error of estimate (SEE) was determined to determine the accuracy of the regression models.

RESULTS

A total of 100 participants with gender distribution in 1:1 ratio were recruited for the present study. The average stature of participants was approximately 169.86 cm, with a moderate range (141–152.5 cm). Head circumference showed relatively low variability, suggesting consistent cranial size across individuals. Facial dimensions like morphological and physiognomic lengths also demonstrated moderate variability. Males in the current study demonstrated higher values across all measured cephalo-facial parameters compared to females, including stature, head circumference, nasal breadth, facial lengths, and bizygomatic width. These differences reflect typical patterns of sexual dimorphism, where males generally exhibit greater skeletal and cranial dimensions.(Graph 1)

The head circumference had a significant relationship to height ($r = 0.531$, $p < 0.001$), followed by physiognomic and bizygomatic lengths. Morphological length exhibited a moderately significant connection ($r = 0.306$, $p = 0.008$). Nasal breadth demonstrated the smallest but most significant connection ($r = 0.178$, $p = 0.049$). Overall, vertical and circumferential facial dimensions correspond better with height than transverse ones. (Table 1).

The regression analysis identified head circumference and physiognomic face length as significant predictors of stature, with p-values of 0.000 and 0.015, respectively. This indicates that individuals with larger values in these measurements tend to be taller. Other variables like nasal breadth, morphological face length, and bizygomatic width showed no significant contribution. Overall, head circumference and physiognomic length are the most dependable measures for assessing stature. (Table 2)

The independent t-test revealed significant differences in all craniofacial parameters between males and females. Males exhibited bigger head circumference, nasal breadth, facial lengths, and bizygomatic widths than females. These differences were statistically significant (p-values < 0.01). This indicates clear sexual dimorphism, making these measurements useful in gender estimation and forensic analysis. (Table 3)

DISCUSSION

The identification of unknown human remains has long been central to forensic science, especially when decomposition or fragmentation obscures the body's integrity. In scenarios such as terrorist bombings, plane crashes, landslides, or fire disasters, only partial remains, particularly the skull or head may be recovered. In such cases, forensic anthropologists often rely on the four major biological attributes: age, sex, ancestry, and stature 5 Among these, stature estimation becomes particularly critical when dealing with a decapitated or mutilated corpse.

Cephalofacial anthropometric measurements offer a useful alternative for estimating stature and, to some extent, assisting in facial profiling, particularly in cases where skeletal remains are unavailable due to the lack of soft tissues. The current study aims to assess the association between stature and several cephalo-facial anthropometric factors, and additionally establish a regression model for estimating stature in a sample of 100 people (50 men and 50 women). The findings demonstrated that head circumference and physiognomic facial length are the most reliable predictors of stature, with statistically significant correlations and regression coefficients.

In this study, data were collected from 100 live participants aged 18 to 25 years using standardized anthropometric tools, including digital vernier calipers, spreading calipers, and measuring tapes. All instruments were regularly calibrated, and a single observer conducted the measurements to minimize inter-observer variability. This approach contrasts favorably with earlier studies based on skeletal remains, [15, 2] where post-mortem changes can compromise landmark accuracy.

The stature of participants was measured at a consistent time interval (2:00 PM–4:00 PM) to minimize the influence of diurnal variation in stature as noted by Gonzalez-Colmenares et al. (2016)16 and Wankhede et al. (2012) [17].

The mean stature observed in the current study (169.86 ± 6.50 cm) was slightly higher than that reported in some African populations, such as Nigerian students (168.45 cm). Male participants (171.17 ± 5.01 cm) were significantly taller than females (166.78 ± 5.35 cm), consistent with the expected pattern of sexual dimorphism reported by Kharyal and Nath (2008) [18].

The primary aim was to develop a combined regression model for stature estimation rather than explore sex differences in detail. Nevertheless, significant gender differences were observed in all craniofacial parameters. This approach aligns with Albanese et al. (2016) [19], who emphasized population-specific rather than gender-specific regression models. However, researchers like Krishan et al. (2008) [2] and Kyllonen et al. (2017) [20] advocate for gender-stratified models to enhance precision.

Among the five craniofacial parameters studied, Head circumference showed the strongest and most significant correlation with stature ($r = 0.531$, $p < 0.001$), in line with the findings of Krishan (2008) [2]. Physiognomic facial length had a moderate connection ($r = 0.423$, $p < 0.001$), indicating that vertical facial dimensions are more predictive of stature than transverse ones. Conversely, nasal breadth had the weakest correlation ($r = 0.178$, $p = 0.049$), mirroring results from Pelin et al. (2010) [21], who found no significant link between nasal width and stature in Turkish populations.

The regression model revealed that head circumference ($B = 1.84$, $p = 0.000$) and physiognomic facial length ($B = 1.00$, $p = 0.015$) were significant predictors of stature. Other variables, including morphological facial length and bizygomatic width, did not reach statistical significance. These findings support the strategy of using a minimal set of high-yield variables for stature estimation, as advocated by Krishan et al. (2008) [2] and Yadav et al. (2019) [4]. This contrasts with models like Agnihotri et al. (2009) [22], which incorporated as many as 14 variables but offered only marginal gains in predictive power.

The relatively low standard error of estimate (SEE) observed in this study indicates a reliable and accurate model. This is notably better than the higher SEE values reported by Patil and Mody (2005)[15], except for head length.

These results are consistent with North Indian studies by Krishan (2008)[2], which also found head dimensions to be significantly associated with stature. However, differences across populations reinforce the need for regional and population-specific regression equations, as highlighted by Sahni et al. (2009)[23]. Their comparison of univariate and multivariate models suggested that simpler models may suffice for practical applications without compromising accuracy.

In conclusion, this study confirms that cephalofacial dimensions—particularly head circumference and physiognomic facial length—are valuable predictors of stature in young adults from South India. While the current model performed well, future research incorporating larger, sex-stratified samples and additional cranial markers may further enhance model precision for forensic and anthropological use.

The study had certain drawbacks, the most noteworthy of which was the extremely small population sample of 100 participants, which can limit the findings' generalizability, particularly in terms of ethnic and geographical variety. The study was conducted within a specific age range (18-25 years), limiting its applicability to other age groups. Additionally, only five cephalofacial parameters were considered, which might not encompass all possible variables influencing stature. Future studies could include larger, more diverse samples to refine these findings

CONCLUSION

While the derived equations can be useful for calculating stature when other body parts do not exist, they should only be used in conjunction with primary data sources such as measured height when available. Among the measures tested, horizontal head circumference was the most reliable for estimating stature, followed by physiognomic face length, while nasal breadth was the least reliable. The present study underscores the anthropological significance of facial dimensions in the estimation of stature. By analyzing five key facial parameters, it is demonstrated that facial morphology holds predictive value in reconstructing biological profiles, particularly in scenarios where only craniofacial remains are available. While the strength of correlation varied across the parameters, certain facial measurements showed comparatively stronger associations with stature. The findings add to the increasing amount of research demonstrating the value of craniofacial indices in bioarcheology and forensic anthropology. Nonetheless, it is important to note that age-specific regression models remain essential, as facial and somatic dimensions are subject to ethnic, environmental, and genetic influences.

Acknowledgment
We sincerely thank all the participants and acknowledge the constant support of all the staff members in the Dept of Forensic Medicine and Toxicology, All India Institute of Medical Sciences, Nagpur.

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FIGURE LEGENDS

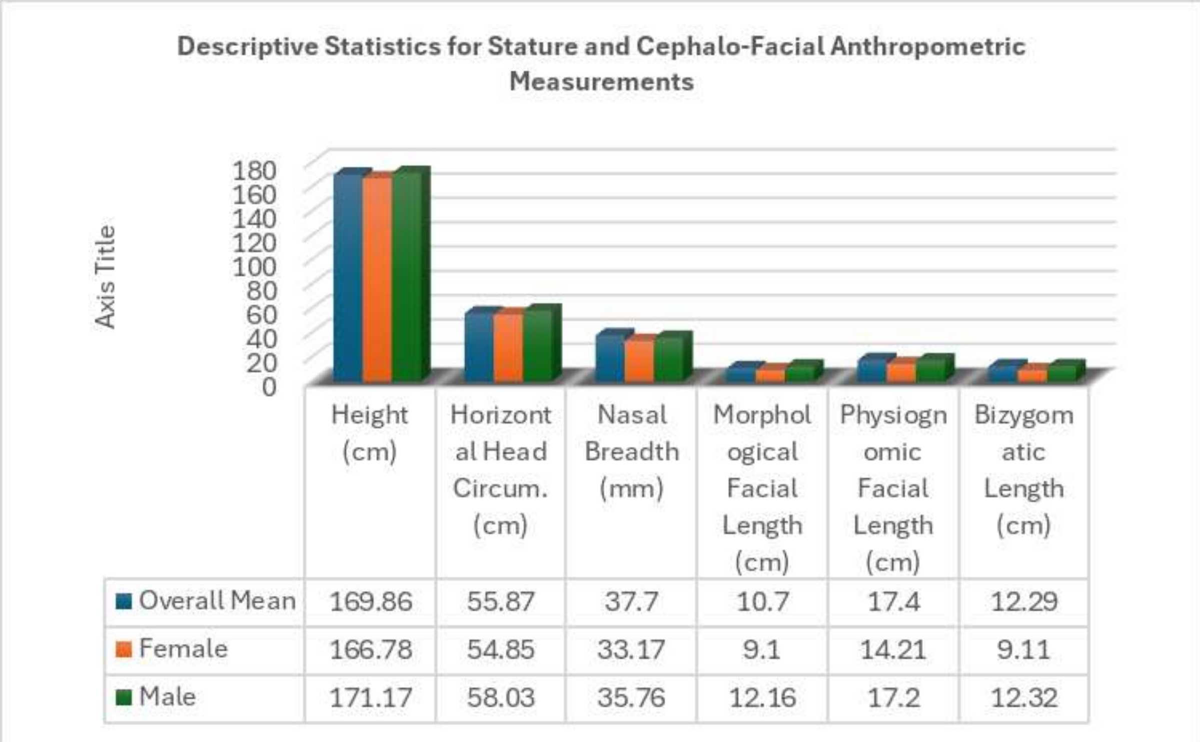
Figure 1: Horizontal head circumference- measured from glabella to glabella using a measuring tape passed through the opisthocranion.

Figure 2: Nasal breadth - measured as the distance between the two most prominent points on the lateral aspect of the ala nasi.

Figure 3: Morphological facial length- measured as the distance from the nasion to the gnathion (the lowest point on the lower border of the mandible in the midsagittal plane) .

Figure 4: Physiognomic facial length- straight distance measured from the trichion (the midpoint of the anterior hair line) to the gnathion

Figure 5: Bizygomatic breadth measured between the two most lateral points on the zygomatic arches, i.e. zygion to zygion, using a spreading caliper.



Graph 1; Descriptive Statistics for Stature and Cephalo-Facial Anthropometric Measurements (N = 100; Male = 50, Female = 50)

Table 1; Correlation Coefficients Between Stature and Cephalo-Facial Measurements

Measurement	**Correlation Coefficient (r)**	**p-value**
Head Circumference	0.531	p < 0.001
Nasal Breadth	0.178	p = 0.049
Morphological Length	0.306	p = 0.008
Physiognomic Length	0.423	p < 0.001
Bizygomatic Length	0.380	p = 0.002

Table 2; Regression Equation for Estimating Stature (cm)

Predictor	**Coefficient (Coef.)**	**p-value**
Head Circumference	1.84	0.000
Nasal Breadth	0.13	0.799
Morphological Face Length	1.26	0.080
Physiognomic Face Length	1.00	0.015
Bizygomatic Length	0.71	0.233

Table 3; Comparison of Cranial Parameters Based on Gender – independent t test

Measurement	**Female (Mean ± SD)**	**Male (Mean ± SD)**	**t-statistic**	**p-value**
Head Circumference	54.71 ± 1.65 cm	57.04 ± 1.35 cm	5.31	0.000002
Nasal Breadth	36.76 ± 2.51 mm	38.65 ± 3.02 mm	2.69	0.009
Morphological Length	10.48 ± 0.63 cm	10.92 ± 0.71 cm	2.67	0.0096
Physiognomic Length	16.86 ± 0.96 cm	17.93 ± 1.09 cm	3.96	0.0002
Bizygomatic Length	11.99 ± 0.57 cm	12.59 ± 0.77 cm	2.85	0.0059