Original Article

Correlation and estimation of stature from cephalofacial measurements: A study on Western Uttar Pradesh population

Munish Reddy,
Vandana Reddy[1],
Vijay Wadhwan[1],
Arvind Venkatesh[2]

Departments of Orthodontics and Dentofacial Orthopedics and [1]Oral Pathology and Microbiology, Subharti Dental College, Meerut, Uttar Pradesh, [2]Consultant Oral and Maxillofacial Pathologist, Smile Square Multispeciality Dental Center, Karur, Tamil Nadu, India

Address for correspondence:
Dr. Vandana Reddy, Department of Oral Pathology and Microbiology, Subharti Dental College and Hospital, Meerut, Uttar Pradesh, India. E-mail: drvandanareddy@rediffmail.com

Abstract

Background: Identification of an individual from fragmented remains is still a very challenging task for forensic experts in spite of the many studies which have been carried out till date, across the globe. Stature, one of the criteria of personal identification, has a definite and proportional biological relationship with every part of the human body which includes the cephalofacial (CF) region. At instances, where only CF remains are available, it becomes difficult for the forensic scientist to identify the deceased since there is a paucity of studies pertaining to the estimation of stature from CF dimensions. Results from such a study can be used as database for forensic investigations and other anthropometric studies. **Aim:** To estimate stature of an individual using data derived from CF measurements. **Materials and Methods:** The study was conducted on 540 representative candidates (270 males and 270 females) in the age group of 20–25 years. Stature (S) and CF measurements (maximum head length [MHL], maximum head breadth [MHB], horizontal circumference of head [HHC], bigonial diameter [BGD], and morphological facial length [MFL]) of each candidate were recorded and tabulated. The statistical analysis was performed using SPSS Statistics v. 19.0 (IBM, Armonk, NY, USA) for the CF dimensions obtained. Comparisons were made between the CF measurements recorded with respect to the gender using statistical mean, standard deviation, range, and Pearson's correlation coefficient, and linear regression equation of height to the parameters recorded was derived. **Results:** Findings suggest that all the CF measurements are significantly correlated with stature ($P < 0.01$). MHL, MHB, and HHC show higher correlation coefficients (r value) when compared to MFL and BGD. The CF measurements arranged in descending order based on their r value is HHC > MHL > MHB > MFL > BGD. In general, head measurements show lower values of standard error of estimate (SEE) compared to facial measurements. Among both sexes, HHC shows the least and BGD shows the highest SEE value when compared to all the other CF measurements. **Conclusion:** It can be concluded that the recommended anthropometric measurements provided serve as a template and confirm that there

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are geographical and sexual dimorphism in anthropometric parameters; therefore, these should be considered in forensic or criminal investigations.

Key words: Anthropometry, cephalofacial measurements, stature

Introduction

Anthropology provides valuable support with regard to human identification, especially when conventional methods cannot be applied, usually due to advanced decomposition, carbonization, or fragmentation of the body.[1] Stature is one of the most important parameters in the identification of an individual, living or dead.[2] Estimation of stature from incomplete skeletal and decomposing bodies as in physical anthropology and forensic science has become useful in recent times due to mass disasters such as plane crash, mass suicide, tsunamis, forest fires, and earthquakes.[3]

Stature is the height of a person in the upright posture and has a definite and proportional biological relationship with each and every part of the human body, i.e., head, face, trunk, and extremities.[4] When intact bodies are to be examined, stature estimation does not pose any problem. However, when dismembered human body parts are the materials to work with, it is of an even greater challenge for the forensic pathologists.[2] For such estimation, regression analysis is the best method as far as the accuracy or reliability of the estimate is concerned.[5]

There are many studies in the literature concerning the estimation of stature from anthropometry of long bones.[6,7] However, no in-depth and detailed studies are available in literature as far as the stature estimation from cephalofacial (CF) anthropometry is concerned.[8] The earlier studies were conducted on male population exclusively and thus lack to show any gender difference.[9,10]

It has been proposed that each race requires its own finding for stature estimation because of ethnic, dietary, and climatic variations. Hence, results of studies done in one population cannot be applicable to other populations' entirely.[11] Therefore, there is a need for systematic study from this region. Considering this fact, the present study was undertaken to evaluate the correlation between CF dimensions and stature and also calculate regression equations for the reconstruction of stature from these dimensions among the people of Meerut, a metropolitan city located in Uttar Pradesh state, India, with the statistical aid of regression analysis of the variables obtained.

Materials and Methods

The present study involved a prospective, cross-sectional survey conducted at Meerut, Uttar Pradesh, India.

The study was approved by the University Ethical Committee, and an informed consent was obtained from all the volunteers who participated in the study.

The study participants were selected by simple random sampling from a population of representative study participants (mixed Meerut population) in the age group of 20–25 years and satisfying the inclusion and exclusion criteria.

Inclusion criteria

- Participants from Meerut, at least for three generations
- No history or clinical evidence of orthodontic and orthognathic treatment
- No history of trauma and surgery of the skull
- No history or clinical features suggestive of endocrine disturbances, developmental disorders, facial asymmetry, and history of prolonged illness.

Exclusion criteria

- Students not falling within the stipulated age limit
- Students belonging from different ethnicity or geographic area.

Anthropometric studies with a small sample size are subject to major errors. The bigger the sample size, the smaller the error. The sample size is statistically significant when it is large enough to accurately represent the population.[12]

Effective sample size for the present study was calculated based on the following formula:

Sample size = $[z^2\, p\, (1 - p)/e^2]/1 + [z^2\, p\, (1 - p)/e^2 N]$,

Where N is the population size, p is the degree of variability which was considered as 0.5 (50%), e is the level of precision expressed as decimals (0.05 for ± 5%); z-value for 90% confidence level considered is 1.64.[13]

The effective sample size calculation protocol followed is tabulated in Table 1.

Based on the calculations, a total of 540 volunteers (270 males and 270 females) satisfying the various inclusion and exclusion criteria were selected among the students of various constituent colleges of a particular university in Meerut.

From the selected study participants, the following data were obtained:
- Stature of the subject (S)
- CF measurements–the measurements made included maximum head length (MHL), maximum head breadth (MHB), horizontal circumference of head (HHC), bigonial diameter (BGD), and morphological facial length (MFL).

The detailed methodology for obtaining the above-said data is tabulated in Table 2. Moreover, diurnal variations in stature have been documented, and substantial diurnal variation in stature is known to affect height data in forensic examination. It is proposed to measure height of an individual at one defined time in a day in humans, to avoid variations in stature estimation.[12] All the measurements were made in the morning between 10 am and 12 pm.

Utmost care was taken while measuring the participants for stature and CF measurements. All instruments were regularly checked for accuracy and precision. To avoid interobserver error, all the participants were measured by a single investigator.

Statistical analyses were performed using SPSS Statistics v. 19.0 (IBM, Armonk, NY, USA) for the CF dimensions obtained.

Comparisons were made between the CF measurements recorded with respect to the gender using statistical mean, standard deviation, range [Table 3], and Pearson's correlation coefficient [Tables 4 and 5]. Male and female data were analyzed separately for linear regression of height to the parameters (MHL, MHB, HHC, BGD, and MFL) recorded.

Linear regression equation was derived as Stature (S) = $a + bx$, where a is the regression coefficient of dependable variable (stature); b is the regression coefficient of independent variable (MHL/MHB/HHC/BGD/MFL); x = any CF measurement (MHL/MHC/HHC/BGD/MFL) [Tables 6 and 7].

Results

The descriptive statistics for all the CF measurements recorded in the sample are shown in Table 3. All the CF measurements showed significant correlation with stature ($P < 0.001$) [Tables 4 and 5].

Separate regression equations have been obtained for stature determination from each CF measurement individually for males [Table 6] and females [Table 7]. Tables 6 and 7 also show the standard error of estimate calculated separately for each regression formula of stature estimation.

Discussion

Stature estimation has been considered as one of the parameters of forensic anthropology which will assist in establishing the biological profile of a person.[14] Studies

Table 1: Sample size determination

Sample size selection protocol followed for the present study	Meerut metropolitan corporation population	Effective sample size required (confidence level – 90%; CI±5%)	Sample size of the present study
Total population	1,309,023		
Population (men)	689,567	269	270
Population (women)	619,456	269	270

CI: Confidence interval

Table 2: Anthropometric measurements

Measured feature	Armamentarium used	Methodology
S [Figure 1a]	Anthropometer	Participant made to stand on a horizontal platform with Heels together and to the ground Stretching upward to full extent Back as straight as possible Head adjusted to Frankfurt's horizontal plane Horizontal arm of anthropometer made in contact with the participant's head
MHL [Figure 1b]	Spreading caliper	Straight distance between glabella and opisthocranion (mm)
MHB [Figure 1c]	Spreading caliper	Maximum biparietal diameter (mm) Distance between the most lateral points of the parietal bones
HHC [Figure 1d]	Measuring tape	Maximum circumference of the head (mm) Measured from just above the glabella area to opisthocranion
BGD [Figure 1e]	Spreading caliper	Maximum breadth of the lower jaw between two gonion (mm)
MFL [Figure 1f]	Vernier caliper	Straight distance from the nasion to gnathion (mm)

S: Stature, MHL: Maximum head length, MHB: Maximum head breadth, HHC: Horizontal head circumference, BGD: Bigonial diameter, MFL: Morphological facial length

Table 3: Descriptive statistics of variables of cephalofacial measurements and stature

Parameters (mm)	Sex	Mean	SD
MHL	Male	196	9.296697
	Female	189.2667	6.44168
MHB	Male	146.4	11.77447
	Female	134.0667	12.04041
HHC	Male	567.3333	17.09915
	Female	545.6667	17.81519
MFL	Male	119.6	11.28083
	Female	112.5	8.483598
BGD	Male	122.6667	11.81807
	Female	118.0714	8.305477
S	Male	1699	5.717142
	Female	1581.667	6.081784

S: Stature, MHL: Maximum head length, MHB: Maximum head breadth, HHC: Horizontal head circumference, BGD: Bigonial diameter, MFL: Morphological facial length, SD: Standard deviation

Table 4: Pearson's correlation coefficient between stature and cephalofacial measurements in males

Measurements	Correlation coefficient (*r*)	SE
MHL	0.715	0.064
MHB	0.612	0.058
HHC	0.729	0.060
MFL	0.498	0.091
BGD	0.462	0.052

MHL: Maximum head length, MHB: Maximum head breadth, HHC: Horizontal head circumference, BGD: Bigonial diameter, MFL: Morphological facial length, SE: Standard error

Table 5: Pearson's correlation coefficient between stature and cephalofacial measurements in females

Measurements	Correlation coefficient (*r*)	SE
MHL	0.701	0.060
MHB	0.606	0.057
HHC	0.718	0.059
MFL	0.474	0.080
BGD	0.442	0.047

MHL: Maximum head length, MHB: Maximum head breadth, HHC: Horizontal head circumference, BGD: Bigonial diameter, MFL: Morphological facial length, SE: Standard error

Table 6: Regression equation for estimation of stature from cephalofacial measurements in males

Regression equation	±SEE
S=87.946 + 4.916 (MHL)	±4.412
S=96.052 + 5.123 (MHB)	±4.897
S=63.918 + 2.841 (HHC)	±3.986
S=128.712 + 4.122 (MFL)	±5.337
S=107.817 + 6.125 (BGD)	±5.342

S: Stature, MHL: Maximum head length, MHB: Maximum head breadth, HHC: Horizontal head circumference, BGD: Bigonial diameter, MFL: Morphological facial length, SEE: Standard error of estimate

concerning the estimation of stature from head and face dimensions are not so common. This technique is based on a principle that bones or human body parts correlate positively with the stature. Whenever someone wants to estimate stature from a given bone or human body part, there must be a known relationship of that bone or human body part with the stature.[15]

Figure 1: Stature and cephalofacial measurements. (a) S, (b) MHL, (c) MHB, (d) HHC, (e) BGD, (f) MFL

This is not only because of the sex differences, but also because of ethnic, dietary, and climatic variations among individuals. Sometimes, obesity makes percutaneous measurements difficult and may increase the margin of error. However, if different measurements from different body parts are compared, we can conclusively determine the stature of an individual from unknown human remains.[9,16]

Considering this fact, an attempt had been made in the present study to estimate stature from CF measurements.

The findings in the present study indicate that all CF measurements are positively and significantly correlated with stature. The formulae of stature estimation showed high degree of reliability which may be because the growth of skull (CF) is mainly genetically determined through local epigenetic factors such as growth of brain.[17]

Comparative statistical analysis among both genders revealed that out of all variables, horizontal head circumference emerged as the major predictor of stature among both males and females. The study indicates that the CF measurements were significantly higher in males as compared to females. The results of the present study when compared with similar available studies on specific population of India varied slightly.

The results of the present study from the CF parameters vary slightly from that of the studies conducted by Krishan and Kumar in 2007[9] and Krishan in 2008[10] and widely from the study conducted by Kumar and Gopichand in 2013[18] [Table 8] for estimating stature using similar CF anthropometric parameters. Although all these studies were conducted in neighboring regions of the present study population, few minor changes are evident on comparison. Although the present study was conducted among a mixed population belonging to the same geographical area, as compared to previous studies[9,10] which were conducted among people belonging to a particular community, the results are similar with certain minor differences.

Since studies by Krishan and Kumar[9] and Krishan[10] were conducted only among men, the data obtained from only male participants of the present study could be taken for comparison. Means of all the cephalic dimensions (MHL, MHB, and HHC) of the present study were slightly higher, whereas that of the facial dimensions (MFL and BGD) were higher as compared with the previous studies. BGD had the least correlation coefficient (*r*) value in the present study on contrary to the previous studies where MFL has the least *r* value among the considered CF parameters.

The results of the study conducted by Kumar and Gopichand[18] vary drastically from that of all the previous and the present studies.

Although adequate sample size has been considered during the present study for the representative population [Table 1], the participants fall under a particular age group of 20–25 years. Hence, when generalizing the regression equation derived from the study participants to the entire population, certain factors such as age-related decline in stature need prime concern.

Dequeker *et al*. found a decrease in standing height of 2.2 cm per decade in a cross-sectional study of 128 women aged 20–90 years in French population.[19] Chumlea *et al*. observed a decline in height with age of 0.5 cm per year, and this rate of decline was approximately constant across ages.[20] van leer *et al*. showed that an age-related decline in stature of 3 cm is seen in individuals after 35 years of age.[21]

Thinning of intervertebral discs, loss of vertebral body height, stooping posture, decreased tone in muscles, and osteoporosis are considered as the major reasons of age-related decline in stature.[22]

Although the present regression equation may be applied in stature estimation taking into account the mean age-related stature loss, in future, studies should be conducted among people of different age groups and arrive at age specific-regression equations for stature calculation.

The population-, gender-, and age-specific regression models proposed will be of immense practical use in medicolegal, anthropological, and archaeological studies, where the total height of a participant can be calculated if the cranial dimensions are known.

Table 7: Regression equation for estimation of stature from cephalofacial measurements in females

Regression equation	±SEE
S=84.016 + 4.145 (MHL)	±4.497
S=92.146 + 4.986 (MHB)	±4.581
S=61.142 + 3.164 (HHC)	±3.647
S=121.064 + 3.981 (MFL)	±4.987
S=102.164 + 5.142 (BGD)	±5.016

S: Stature, MHL: Maximum head length, MHB: Maximum head breadth, HHC: Horizontal head circumference, BGD: Bigonial diameter, MFL: Morphological facial length, SEE: Standard error of estimate

Conclusion

From the present study, it can be concluded that the recommended anthropometric data provided serve as a template for the locality from which this study was carried out and confirm that there are geographical and sexual dimorphism in anthropometric parameters and therefore should be considered in forensic or criminal investigations. A more extensive research on similar lines in different populations will help in establishing stature in the field of forensic science.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given his consent for his images and other clinical information

Table 8: Comparison of various studies conducted incorporating similar cephalofacial anthropometric parameters

Author	Population	Sex	MHL	MHB	HHC	MFL	BGD
Krishan and Kumar[9]	Kolis of Himachal Pradesh	Male	0.732	0.625	0.773	0.345	0.449
		Female	-	-	-	-	-
Krishan K (2008)[10]	Gujjars of Chandigarh	Male	0.775	0.682	0.781	0.455	0.462
		Female	-	-	-	-	-
Kumar M and Gopichand P (2013)[18]	Banias of Haryana	Male	0.174	0.321	0.122	0.177	0.164
		Female	0.190	0.008	0.181	0.150	0.119
Present study	Meerut city	Male	0.715	0.612	0.729	0.498	0.462
		Female	0.701	0.606	0.718	0.474	0.442

MHL: Maximum head length, MHB: Maximum head breadth, HHC: Horizontal head circumference, BGD: Bigonial diameter, MFL: Morphological facial length to be reported in the journal. The patient understand that name and initials will not be published and due efforts will be made to conceal identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

References

1. Tinoco RL, Martins EC, Daruge E Jr., Daruge E, Prado FB, Caria PH, *et al.* Dental anomalies and their value in human identification: A case report. J Forensic Odontostomatol 2010;28:39-43.
2. Buchner A. The identification of human remains. Int Dent J 1985;35:307-11.
3. Fessler DM, Haley KJ, Lal RD. Sexual dimorphism in foot length proportionate to stature. Ann Hum Biol 2005;32:44-59.
4. Krishan K. Estimation of stature from footprint and foot outline dimensions in Gujjars of North India. Forensic Sci Int 2008;175:93-101.
5. Iscan MY. Forensic anthropology of sex and body size. Forensic Sci Int 2005;147:107-12.
6. Jasuja OP, Singh G. Estimation of stature from hand and phalange length. J Indian Acad Forensic Med 2004;26:100-6.
7. Holland TD. Estimation of adult stature from fragmentary tibias. J Forensic Sci 1992;37:1223-9.
8. Kalia S, Shetty SK, Patil K, Mahima VG. Stature estimation using odontometry and skull anthropometry. Indian J Dent Res 2008;19:150-4.
9. Krishan K, Kumar R. Determination of stature from cephalo-facial dimensions in a North Indian population. Leg Med (Tokyo) 2007;9:128-33.
10. Krishan K. Estimation of stature from cephalo-facial anthropometry in North Indian population. Forensic Sci Int 2008;181:52.e1-6.
11. Siddiqui MA, Shah MA. Estimation of stature from long bones of Punjabis. Indian J Med Res 1944;32:104-8.
12. Krishan K, Kanchan T, Menezes RG. Stature estimation in forensic examinations: A few technical considerations. Indian J Dent Res 2012;23:692-3.
13. Rosner B. Fundamentals of Biostatistics. 7th ed. Boston: Brooks/Cole; 2011.
14. Krishan K, Sharma A. Estimation of stature from dimensions of hands and feet in a North Indian population. J Forensic Leg Med 2007;14:327-32.
15. Simmons T, Jantz RL, Bass WM. Stature estimation from fragmentary femora: A revision of the Steele method. J Forensic Sci 1990;35:628-36.
16. Agnihotri AK, Sooden-Lalloo AK. Estimation of stature from fragmented human remains. Anthropology 2013;1:10000e105, 1-2.
17. Williams PL, Bannister LH, Berry MM, Collins P, Dyson M, Dussek JE, *et al*. Gray's Anatomy. 38th ed. London, England: ELBS/Churchill Livingstone; 1995. p. 607-10.
18. Kumar M, Gopichand P. Estimation of stature from cephalo-facial anthropometry in 800 Haryanvi adults. Int J Plant Anim Environ Sci 2013;3:42-6.
19. Dequeker JV, Baeyens JP, Claessens J. The significance of stature as a clinical measurement of ageing. J Am Geriatr Soc 1969;17:169-79.
20. Chumlea WC, Garry PJ, Hunt WC, Rhyne RL. Distributions of serial changes in stature and weight in a healthy elderly population. Hum Biol 1988;60:917-25.
21. van Leer EM, van Noord PA, Seidell JC. Components of adult height and height loss. Secular trend and effects of aging in women in the DOM project. Ann Epidemiol 1992;2:611-5.
22. Pini R, Tonon E, Cavallini MC, Bencini F, Di Bari M, Masotti G, *et al.* Accuracy of equations for predicting stature from knee height, and assessment of statural loss in an older Italian population. J Gerontol A Biol Sci Med Sci 2001;56:B3-7.