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ADULT STATURE RECONSTRUCTION FROM FACIAL ANTHROPOMETRY BY REGRESSION ANALYSIS IN THE RAJASTHAN POPULATION

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ABSTRACT:
Background: Stature estimation is an important component of forensic identification, particularly when complete skeletal remains are not available. Facial anthropometry may provide useful supplementary predictors of stature; however, population-specific regression equations are required for reliable application. This study aimed to assess the relationship between facial anthropometric measurements and adult stature and to develop sex-specific regression equations for the Rajasthan population.
Materials and Methods: An observational cross-sectional study was performed in the Department of Anatomy at Pacific Medical College and Hospital, located in Bhilon Ka Bedla, Udaipur, Rajasthan. The study included 600 healthy adults, comprising 300 men and 300 women. Stature, maximum facial height (MFH), and maximum facial breadth (MFB) were assessed using established anthropometric methods. . Pearson's correlation, coefficient of determination (R^2), simple linear regression, and multiple linear regression analyses were performed using SPSS version 26.0. Statistical significance was set at $p < 0.05$.
Results: Mean stature was significantly higher in males (170.05 ± 7.553 cm) than in females (155.54 ± 8.216 cm; $p < 0.0001$). Maximum facial height and maximum facial breadth were also significantly greater in males than females ($p < 0.0001$). MFH showed a positive correlation with stature in males ($r = 0.276$) and females ($r = 0.330$), while MFB showed correlations of $r = 0.331$ and $r = 0.374$, respectively ($p < 0.001$). The MFH explained 7.6% of the stature variation in males and 10.9% in females whereas the MFB have 11.0% stature variation in males and 14.0% in females.
Conclusion: Facial anthropometric measurements, particularly maximum facial height, demonstrated significant associations with adult stature. The combined regression models provided improved predictive performance compared with individual facial measurements. These findings support the use of sex and population-specific facial anthropometric regression equations as a supplementary method for forensic stature estimation in the Rajasthan population.

KEYWORDS: Stature estimation, facial anthropometry, Maximum facial height, Maximum facial breadth, Regression analysis, Forensic anthropology, Rajasthan population.

INTRODUCTION

Stature is an important biological characteristic used in forensic anthropology for identifying persons, especially in circumstances where the remains are unidentified or destroyed and thus the height cannot be directly measured. Anatomical structures give useful additional evidence for estimation, and current material emphasises the necessity of population-specific anthropometric models in forensic identification. [1]
Previously, height has been estimated by measuring long bones such as the femur, tibia, humerus, and radius. However, when these bones are incomplete or broken, other characteristics are used, such as upper and lowerlimbs, hands, feet, and cranial and facial measurements. Indian research has shown that hand, foot, arm-span, and limb measurements are substantially correlated with stature and can be used to develop regression models particular to the community. [2], [3]
Craniofacial anthropometry is a crucial technique in forensic investigations, especially when other body parts are absent or impaired. Empirical data show substantial relationships between craniofacial dimensions, such as maximum face height, facial breadth, bizygomatic breadth, nasal measures, and stature, thus confirming their importance as supplemental predictors. Regression-based stature estimation in Indian research employing these criteria is found useful; however, the predicted accuracy depends on the measurement and population used [4]. [5] Prediction errors are carefully taken into account when using regression analysis, which includes both simple and multivariate linear models. Sex-specific regression equations are recommended due to the extreme differences in stature and body proportions between boys and girls. Furthermore, genetic, environmental, nutritional, and socioeconomic factors contribute to interpopulation heterogeneity, necessitating the

development of population- specific regression models. Due to its diverse population and landscape, there is an urgent need for region-based anthropometric standards in Rajasthan. Recent research has shown a strong correlation between stature and craniofacial dimensions in this population. [6] [7]

MATERIALS AND METHODS

Study Design and Study Population: A cross-sectional observational study was conducted to assess the relationship between adult stature and facial anthropometric measurements and to develop regression equations for estimating stature in the Rajasthan population. The study included 600 healthy adult participants, comprising 300 males and 300 females. The study was conducted at the Department of Anatomy, Pacific Medical College and Hospital, Udaipur, Rajasthan.**Anthropometric Measurements:**

Stature: Stature was measured in centimetres using a stadiometer. The participants stood barefoot on a firm, level surface with their feet together, knees extended, and body maintained in an erect position, with the head positioned in the Frankfurt horizontal plane.

Maximum Facial Height: It measured using a sliding caliper from the nasal root (nasion) to the lower border of the mandible (gnathion) in the midsagittal plane.

Maximum Facial Breadth: It was measured as the maximum transverse distance between the most lateral points of the face (zygion) using a spreading caliper. The measurement was recorded in centimetres. [8], [9][10]

Image 1: Stature measurement

Image 2: Facial height measurement

Image 3: Facial breadth measurement

Statistical Analysis

Data were entered into Microsoft Excel and analysed using SPSS version 26.0. Continuous variables were expressed as mean ± SD and median. Male–female differences were assessed using an independent-samples t-test. Pearson's correlation coefficient (r) and coefficient of determination (R^2) were used to assess the relationships between facial anthropometric parameters and stature. Simple and multiple linear regression analyses were performed to develop sex-specific equations for stature estimation. The model performance was tested using R2 and the standard error of the estimate (SEE). Statistical significance was set at P-value <0.05.

The regression equation was given as: Estimated stature = a + bX where a represents the regression constant, b is the regression coefficient and X is the respective facial anthropometric measurement.

RESULT:

Table 1: Comparison of height between male and female participants

Height (in cm)	Male (n=300)	Female (n=300)	p-value
Mean	170.05	155.54	<0.0001
Standard Deviation	7.553	8.216	
Median	170.85	153.00	
Minimum	156	138	
Maximum	193	173	
Standard Error of Estimate	0.436	0.474	

The mean height of male participants was 170.05 ± 7.55 cm (SE=0.436), whereas the mean height of female participants was 155.54 ± 8.22 cm (SE=0.474). The height ranged from 156 to 193 cm in males and 138 to 173 cm in females, and a statistically significant difference in height was observed between the two sexes ($p < 0.0001$).

Table 2: Comparison of mean facial height between male and female participants:

Maximum Facial Height	Male (n=300)	Female (n=300)	
Mean	10.77	10.07	<0.0001
Standard Deviation	1.019	1.078	
Median	10.50	10.00	
Minimum	9	9	
Maximum	19	20	
Standard Error of Estimate	0.059	0.062	

The mean maximum facial height among male participants was 10.77 ± 1.02 cm (SE=0.059), while among female participants, it was 10.07 ± 1.08 cm (SE=0.062). The measurements ranged from 9 to 19 cm for males and 9 to 20 cm for females.

Table 3: Comparison of mean facial breadth between male and female participants:

Maximum Facial Breadth	Male (n=300)	Female (n=300)	
Mean	13.40	12.34	<0.0001
Standard Deviation	0.791	0.647	
Median	13.50	12.50	
Minimum	11	10	
Maximum	16	14	
Standard Error of Estimate	0.046	0.037	

The mean maximum facial breadth among male participants was 13.40 ± 0.79 cm (SE=0.046), whereas among female participants, it was 12.34 ± 0.65 cm (SE=0.037). The values ranged from 11 to 16 cm for males and 10 to 14 cm for females.

Table 4: Correlation between stature and maximum facial height:

Gender	Correlation Coefficient (r)	Coefficient of Determination (r^2)	p-value
Male	0.276	0.076	<0.0001
Female	0.330	0.109	

A positive correlation was observed between height and maximum facial height in both male and female participants. In males, the correlation coefficient was 0.276, with a coefficient of determination (r^2) of 0.076, indicating that 7.6% of the variation in height could be explained by the maximum facial height. In females, the correlation coefficient was 0.330, with an r^2 value of 0.109, suggesting that 10.9% of the variation in height was attributable to the maximum facial height. The correlations were statistically significant in both males ($p < 0.0001$) and females ($p < 0.0001$).

Table 5: Correlation between stature and maximum facial breadth:

Gender	Correlation Coefficient (r)	Coefficient of Determination (r^2)	p-value
Male	0.331	0.110	<0.0001
Female	0.374	0.140	

A positive correlation was observed between height and maximum facial breadth in both male and female participants. In males, the correlation coefficient was 0.331, with a coefficient of determination (r^2) of 0.110, indicating that 11.0% of the variation in height could be explained by the maximum facial breadth. In females, the correlation coefficient was 0.374, with an r^2 value of 0.140, suggesting that 14.0% of the variation in height can be attributed to the maximum facial breadth. The correlations were statistically significant in both sexes ($p < 0.0001$).

Table 6: Simple linear regression analysis for predicting height in male participants:

Variable (x)	Intercept (a)	Slope (b)	p-value (for b)	Regression Equation Height (y) = a + bx

Maximum Facial Height (MFH)	148.02	2.046	<0.0001	y=148.02+2.046×MFH
Maximum Facial Breadth (MFB)	127.72	3.158	<0.0001	y=127.72+3.158×MFB

Simple linear regression analysis was performed to predict the height of male participants using different anthropometric measurements as independent variables. For maximum facial height, the regression equation obtained was y = 148.02 + 2.046×MFH, indicating that the height increased by 2.046 cm for every unit increase in the maximum facial height. Similarly, the regression equation for the maximum facial breadth was y = 127.72 + 3.158×MFB. These findings suggest that facial height and width are strong predictors of stature in male participants.

Table 7: Simple linear regression analysis for predicting height in female participants:

Variable (x)	**Intercept (a)**	**Slope (b)**	**p-value (for b)**	**Regression Equation (y) = a + bx**
Maximum Facial Height (MFH)	130.20	2.517	<0.0001	y=130.20+2.517×MFH
Maximum Facial Breadth (MFB)	96.70	4.767	<0.0001	y=96.70+4.7671×MFB

Simple linear regression analysis was performed to predict the height of female participants using various anthropometric parameters as independent variables. For maximum facial height, the regression equation obtained was y=130.20+2.517×MFH ($p < 0.0001$), indicating that height increased by 2.517 cm for every one-unit increase in maximum facial height. Similarly, the regression equation for the maximum facial breadth was y = 96.70 + 4.767×MFB ($p < 0.0001$).

Table 8: Multiple linear regression analysis for predicting height in male participants:

Variable	**Intercept (a)**	**Slope (b)**	**p-value (slope)**
Maximum Facial Height (MFH)	45.66	0.212	0.515
Maximum Facial Breadth (MFB)		-0.154	0.758

Multiple linear regression analysis was performed to predict the height of male participants using various facial measurements as the independent variables. The derived regression equation is as follows:
Height of male = 45.66 + 0.212×MFH – 0.154×MFB

Table 9: Multiple linear regression analysis for predicting height in female participants:

Variable	**Intercept (a)**	**Slope (b)**	**p-value**
Maximum Facial Height (MFH)	17.059	0.674	0.032
Maximum Facial Breadth (MFB)		0.909	0.106

Multiple linear regression analysis was performed to predict the height of female participants using various facial measurements as independent variables. The derived regression equation is as follows:
Height of female = 17.059 + 0.674×MFH + 0.909×MFB

Among the above variables, maximum facial height showed a statistically significant positive association with height. The regression coefficient was 0.674 ($p = 0.032$), indicating that height increased by 0.674 cm for every unit increase in the maximum facial height.

DISCUSSION:

The present study demonstrated significant sex-wise differences in stature, maximum facial height (MFH), and maximum facial breadth (MFB), with higher values in males. Both MFH and MFB exhibited substantial positive associations with stature. The link between stature and MFH was found to be stronger than MFB in both sexes. These findings are consistent with those of Varghese et al., who found a substantial correlation between cephalic and facial measurements and stature in a South Indian community. [11] Nayyar et al. also found good associations between a number of craniofacial factors and stature which supports the utility of craniofacial measurements for forensic stature estimation. [5] The present investigation showed that basic regression models provided substantial stature estimations, and the combination of facial measures improved the prediction, especially in males. The differences between the present results and those of prior studies can be attributed to variances in population, sex, age, and methodology. This emphasises the need of population-specific regression equations. [8], [9], [12]

CONCLUSION:

The present study found substantial positive correlations between maximum face height, facial breadth, and stature in both males and females. Sex-specific regression equations indicated the potential of facial anthropometry for assessing stature in the Rajasthan population. The real and estimated statures were found to be in close agreement, supporting their utility as supplemental factors for forensic identification. However, because of their moderate predictive accuracy, facial measurements should be used in combination with other anthropometric measurements. Larger multicentre studies and external validation are recommended before wider forensic applications.

Conflict of Interest: The authors declare no conflicts of interest related to this study.

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