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Stature and Sex Estimation from Face Anthropometric Measurements in Bangladeshi Population

Md. Asadujjaman[1*], Mahbubur Rahman[2], and Md. Zafor Iqbal[3]

[1]Department of Industrial & Production Engineering, Rajshahi University of Engineering & Technology, Rajshahi, Bangladesh
[2]Procurement Department, Urmi Group, Gulshan-1, Dhaka, Bangladesh
[3]Process Engineering Department, SDS International Limited (Gildan), Nayarhat, Savar, Dhaka, Bangladesh

emails: *[*1]asadujjaman@ipe.ruet.ac.b; [2]mahbub.ruet13@gmail.com; and [3]zaforipe13@gmail.com ('*' - corresponding author)*

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ABSTRACT

This study aimed to estimate the stature from different facial dimensions in the Bangladeshi population. The study was conducted on randomly selected 290 Bangladeshi adults (152 males and 138 females) aged 18 to 60 years old with no physical disability. Stature and seven facial measurements were taken using standard measuring instruments. To estimate the stature, simple and multiple linear regression analyses were used. Binomial logistic regression and discriminant function tests were conducted to estimate the sex from facial measurements. It was seen that the mean values of all measurements were significantly higher in males than females ($p \leqslant 0.001$). All the facial measurements were statistically significant ($p \leqslant 0.001$) and positively correlated with the stature. The value of the standard error of estimation varied from ±4.381 mm to ±5.559 mm using linear regression analysis. In sex estimation, the most reliable results were obtained by the binomial logistic regression (96.38%) and the discriminant function test (95.70%) in women. In both males and females, nasal height was the most reliable estimator of sex. Multiple regression models showed better accuracy in the estimation of stature from facial dimensions. Moreover, facial measurements can be used as a useful tool to estimate the sex in the Bangladeshi population with greater reliability.

1. INTRODUCTION

The estimation of stature of unknown humans to investigate the biological profile when a body part is found is a primary challenge for forensic identification. An accurate estimation of stature helps to find an individual's identity in forensic investigation. The first mathematical model to estimate the stature from biological anthropometry was developed by Rollet (1888). Rollet (1888) investigated the correlation between human height and long bone on a sample of 50 males and 50 females. Later, Manouvrier (1892) re-examined the data of Rollet, excluding the participants who were over 60 years old. The first regression formula was developed by Pearson (1898) to estimate the height of the individuals. Pearson (1898) used the data of Rollet (1888) to estimate the stature from the long limb bone. A brief history of stature estimation in forensic anthropometry and its application in a diverse population is found in the study of Prasad (2018).

The estimation of stature is an essential process in forensic investigations, particularly for the identification of unknown individuals when only partial remains, such as bones, are available. It holds significant importance in cases involving mass disasters or accidents where bodies may be fragmented, aiding in victim identification. Additionally, stature estimation is pivotal in legal and forensic contexts, contributing to the accurate determination of an individual's identity. Anthropometric research demonstrates a consistent and predictable correlation between stature and various body measurements, making it a reliable tool in such scenarios. Over the last few decades, various anthropometric measurements have been used as tools to estimate the stature of a human being. Previously, researchers determined the human height from different body dimensions such as foot (Asadujjaman *et al.*, 2020), hand (Asadujjaman *et al.*, 2019; Asadujjaman *et al.*, 2025), fingers (Sen *et al.*, 2014), upper limb (Ahmed 2013), lower limb (Nor *et al.*, 2013), radial and ulnar (Issa *et al.*, 2016), lumbar vertebrae (Oura *et al.*, 2018), femur (Chiba *et al.*, 2018), handprint (Abbas *et al.*, 2025), footprint (Abbas *et al.*, 2025; Asadujjaman *et al.*, 2022), head and facial (Agnihotri *et al.*, 2011; Ahmed *et al.*, 2016; Pelin *et al.*, 2010; Sahni *et al.*, 2010) dimensions.

The relationship between human height and facial measurements has been studied in different studies. The correlation between stature and various facial measurements such as total face length, upper face length, lower face length, minimum frontal breadth, bigonial, biocular breadth, interocular breadth, vermilion height has been reported in previous studies (Akhter *et al.*, 2013; Sahni *et al.*, 2010). Examining a group of 400 South Indian medical students, a notable link was found between facial features and body height (Ajid *et al*., 2024). The correlation coefficient between facial measurements and stature was 0.633 for male students and 0.754 for female students, indicating a strong correlation. This motivates human factor engineers, legal and forensic researchers to estimate the stature from facial measurements. To estimate the stature, researchers developed both linear (Agnihotri *et al.*, 2011; Ahmed *et al.*, 2016; Akhter *et al.*, 2013) and multiple regression (Agnihotri *et al.*, 2011; Ahmed *et al.*, 2016; Sahni *et al.*, 2010) equations. Ahmed & Taha (2016) developed both linear and multiple regression models using 15 cephalo-facial measurements based on a sample of 120 Sudanese men and 120 Sudanese women. Sahni *et al.* (2010) have conducted a study on the Indo-Mauritian population, comprising 75 males and 75 females, to estimate the stature from cephalo-facial measurements applying multiple regression equations. Sahni *et al.* (2010) examined seven facial measurements to estimate the stature in a northwest Indian population (173 males and 127 females).

Similar to stature, sex estimation is another challenge (Issa *et al.*, 2016) in forensic identification to determine the biological profile when an unknown body part is found. Over the last few decades, anatomical and anthropometric methods have been utilized to estimate the sex of unknown individuals from body parts (Islam *et al.*, 2021; Krishan *et al.*, 2016; Ozden *et al.*, 2005). For instance, foot (Islam *et al.*, 2021; Ozden *et al.*, 2005), hand (Islam *et al.*, 2021), radial and ulnar (Issa *et al.*, 2016), and face (Zaghloul *et al.*, 2019) measurements have been used to estimate the sex. A review of sex estimation from different anthropometric measurements during forensic casework is found in the study of Krishan *et al.* (2016).

Stature and sex estimation from body parts is population specific (Asadujjaman *et al.*, 2021; Krishan *et al.*, 2016; Yeasmin *et al.*, 2022). Therefore, regression models to estimate the sex and height of the individuals will vary from one population to another. To the best of our knowledge, there is no standard at this moment to estimate the stature and sex from facial measurements in the Bangladeshi population. The present study is therefore undertaken to investigate the relationship between stature and various facial measurements in the Bangladeshi population, and to develop models to estimate the height and sex of adult Bangladeshi individuals.

2. MATERIALS AND METHODS

A. Subjects

The paper has been composed based upon a sample of 290 healthy people (male 152 and female 138) from Bangladeshi origin who are from different locations. The calculation of the minimum sample size, as outlined by the general requirements for establishing anthropometric databases in ISO 15535 (ISO 15535: 2003 General R, 2003) is presented in Eq. (1) and Eq. (2), relies on estimating the true population's 5th and 95th percentiles for a given parameter with 95% confidence and a specified level of relative accuracy.

$$n \geq \left(\frac{3.006 \times CV}{a} \right)^2 \tag{1}$$

$$CV = \frac{100 \times SD}{\bar{x}} \tag{2}$$

Where, n is the sample size, a is the percentage of relative accuracy desired, CV is the coefficient of variation–the ratio of the standard deviation (SD) to the population mean ($\bar{x}$). Assuming a relative accuracy of 5% and using the largest coefficient of variation data from a similar study (CV = 16.987, calculated from SD = 9.36 and Mean = 1.59, among the population compared in this study) for stature estimation using morphological facial height in a Gujarati adults, the minimum sample size was found to be 104. The authors, therefore, included facial data from 290 individuals in this study. The age ranges of the sample were between 18 and 60 years. The age of the sample has been noted accurately, which has been verified from their national identity card. The demographic data was checked while the measurements were taken. Data was collected from several different regions of Bangladesh. The sample included in this observation was fit physically, and the injured person was excluded from this observation. The ethical approval was granted from the Research and Extension section of the Rajshahi University of Engineering & Technology, Bangladesh. Formal consent and permission were taken from the participants of this study.

B. Methods

The stature was measured by using a standard steel measuring tape. To measure the stature, the individual stands against a wall, and the height is marked and measured. Seven anthropometric measurements (frontal diameter, bigonial diameter, nasal height, nasal breadth, upper facial height, total facial height, physiognomic height) were measured by using digital slide calipers.

The parameters of facial measurements are shown in Figure 1, and the details are described as follows.

- **Frontal Diameter:** The maximum breadth of the lower jaw between the two gonion points on the angles of the mandible (Adel *et al.*, 2019).

- **Nasal Breadth:** The distance between the two most lateral points on the wings of the nostrils (Ahmed & Taha, 2016).
- **Bigonial Diameter:** The distance between the two gonia. The gonion is the anthropometric point at the most inferior, posterior, and lateral points on the angle of the mandible (Agnihotri *et al.*, 2011).
- **Nasal Height:** Distance between the lower border of the nasal aperture and the nasion (Agnihotri *et al.*, 2011; Ahmed & Taha, 2016). The middle point of the junction of the frontal and the two nasal bones is called the nasion.
- **Upper Facial Height:** Upper facial height is commonly measured as the linear distance between the midline osteological landmarks nasion, at the top of the nose and prosthion (Ahmed & Taha, 2016).
- **Total Facial Height:** Distance between the nasion and menton. The most inferior point on the chin in the lateral view of a cephalogram is called as menton (Ahmed & Taha, 2016).
- **Physiognomic Height:** Distance between the frontal hairline and the menton (Ahmed & Taha, 2016).

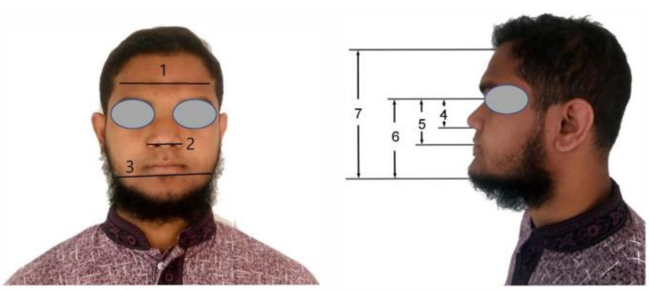

Figure 1: Facial anthropometric measurements. 1: frontal diameter, 2: nasal breadth, 3: bigonial diameter, 4: nasal height, 5: upper facial height, 6: total facial height, and 7: physiognomic height

The same type of measurement was repeated by the same tools and the same investigator to avoid inter-observer error. Each measurement was taken twice, and the average value was taken to compromise error. If the measuring value was more than 1.00 mm, then the measurement was taken again. While taking measures, the subjects stood still in a relaxed position. While measuring, the subject was standing as straight as possible.

C. Mathematical and Statistical analysis

Normal descriptive statistics such as mean, maximum and minimum value, and standard deviation (SD) were determined. The correlation between stature and face measurement was determined by using the analysis of Pearson correlation. To calculate the equation for the estimation of stature from face measurements, linear regression and multiple regression analysis were used. An independent two-tailed t-test was performed to analyze sexual morphology. The well-known discriminant function test (Shah *et al.*, 2016) and binomial logistic regression analysis (Shah *et al.*, 2016) were done to estimate the sex. In the discriminant function test, a sectioning point or cut-off point (Adamu *et al.*, 2016) was used to estimate the sex of the individuals. The cut-off point for each parameter is the average of the mean values in men and women. Therefore, the cut-off point was calculated using Eq. (3).

$$\text{Cut-off point} = \frac{\mu_m+\mu_f}{2} \quad (3)$$

Where, μ_m is the mean male value and μ_f is the mean female value. When the value of the parameter for an individual matches the cut-off point exactly, the individual is considered as indeterminate due to the equal probability of belonging to either group. The accuracy of stature and sex estimation was compared with different populations. IBM SPSS Statistics (Version 25) and Microsoft Excel 2016 were used for the statistical analysis of the data.

3. RESULTS

The mean age of male and female was 38.14±12.25 and 39.95±12.34 years, respectively. Table 1 presents the descriptive statistics (mean, maximum dimension, minimum dimension, and standard deviation) of stature and different facial dimensions. All the dimensions were higher in males than females. All the facial measurements showed statistically significant ($p \leq 0.001$) for sex determination.

Table 1

Descriptive statistics of face dimensions (stature in cm; other measurements in mm)

Parameters	Male (*n* = 152)				Female (*n* = 138)				*t*-test	
	Mean	Max	Min	SD	Mean	Max	Min	SD	*t*-value	*p*-value
Stature	165.634	181.100	152.500	5.541	152.054	163.000	137.500	4.444	22.885	≤ 0.001
Frontal diameter	110.405	140.125	96.675	5.601	108.051	118.845	97.835	4.412	3.949	≤ 0.001
Bigonial diameter	117.036	142.730	106.025	6.063	113.937	124.555	103.345	4.261	5.942	≤ 0.001
Nasal breadth	38.291	46.060	32.970	2.435	35.173	42.405	31.200	1.906	12.058	≤ 0.001
Nasal height	49.304	58.015	41.510	3.485	40.872	47.440	34.885	2.570	23.255	≤ 0.001
Upper facial height	71.296	81.315	62.000	3.977	62.561	72.820	52.505	3.810	19.065	≤ 0.001
Total facial height	114.641	129.935	101.685	5.484	104.348	116.715	91.860	5.544	15.880	≤ 0.001
Physiognomic height	173.467	190.225	152.140	8.173	166.303	190.045	151.785	6.913	8.017	≤ 0.001

Table 2 shows the linear regression equations for different age groups to estimate the stature from different facial measurements. All the coefficients of correlation (*R*) were found statistically significant ($p \leq 0.001$) and positively correlated with all the measurements in all age groups. The values of *R* were below +0.5 for all facial measurements. The standard error of estimation (SEE) was ranged from ±5.394 to ±5.599 mm in men and ±4.381 to ±4.448 mm in women.

The multiple regression equations were developed combining all the parameters. Table 3 shows multiple regression equations for different age groups. Regression coefficients of facial measurements were statistically significant with stature ($p<0.05$) for age groups except the age group 31-40 in males. In multiple regression, the values of *R* ranged between +0.29 and +0.70. The values of SEE were varied from ±3.95 to ±5.41 mm in males and ±3.15 to ±5.33 mm in females.

Table 4 shows the cut-off points of different parameters to estimate the sex from facial measurements. A measurement value above the cut-off point for any given parameter indicates a male, whereas a female is indicated by the measurement value below the cut-off point.

Table 2

Simple linear regression analysis to estimate the stature from face measurements in both sexes (all ages)

Age Range	Male					Female				
	Equation	*R*	R^2	*SEE*	*p*-Value	Equation	*R*	R^2	*SEE*	*p*-Value
18-30	S = 151.20+1.472*FD	0.189	0.036	5.282	≤ 0.001	S = 144.41+.087*FD	0.069	0.004	5.382	≤ 0.001
	S = 152.76+1.269*BD	0.155	0.024	5.315	≤ 0.001	S = 139.70+1.235*BD	0.101	0.010	5.368	≤ 0.001
	S = 130.34+9.920*NB	0.462	0.214	4.769	≤ 0.001	S = 125.13+8.368*NB	0.234	0.055	5.244	≤ 0.001
	S = 179.16-2.305*NH	0.163	0.026	5.307	≤ 0.001	S = 156.21-0.559*NH	0.031	0.001	5.393	≤ 0.001
	S = 185.69-2.543*UFH	0.177	0.031	5.295	≤ 0.001	S = 170.72-2.725*UFH	0.257	0.066	5.213	≤ 0.001
	S = 172.12-0.382*TFH	0.034	0.001	5.377	≤ 0.001	S = 168.97-1.459*TFH	0.177	0.031	5.309	≤ 0.001
	S = 207.86-2.328*PH	0.345	0.119	5.049	≤ 0.001	S = 173.65-1.175*PH	0.219	0.048	5.264	≤ 0.001
31-40	S = 151.99+1.367*FD	0.122	0.015	5.460	≤ 0.001	S = 132.42+1.872*FD	0.203	0.041	3.722	≤ 0.001
	S = 147.35+1.69*BD	0.168	0.028	5.423	≤ 0.001	S = 136.48+1.419*BD	0.149	0.022	3.759	≤ 0.001
	S = 161.28+1.459*NB	0.075	0.005	5.486	≤ 0.001	S = 148.12+1.311*NB	0.067	0.004	3.793	≤ 0.001
	S = 172.95-1.201*NH	0.088	0.007	5.480	≤ 0.001	S = 139.71+3.188*NH	0.224	0.05	3.705	≤ 0.001
	S = 140.65+3.691*UFH	0.278	0.077	5.285	≤ 0.001	S = 130.55+3.851*UFH	0.289	0.083	3.639	≤ 0.001
	S = 121.802+3.901*TFH	0.409	0.168	5.018	≤ 0.001	S = 122.712.921*TFH	0.399	0.159	3.485	≤ 0.001
	S = 125.28+2.384*PH	0.357	0.127	5.138	≤ 0.001	S = 115.00+2.277*PH	0.328	0.107	3.591	≤ 0.001
41-50	S = 137.585+2.457*FD	0.208	0.043	5.271	≤ 0.001	S = 118.27+2.930*FD	0.320	0.103	3.753	≤ 0.001
	S = 135.04+2.532*BD	0.268	0.072	5.192	≤ 0.001	S = 111.15+3.416*BD	0.317	0.100	3.758	≤ 0.001
	S = 139.71+6.619*NB	0.235	0.055	5.239	≤ 0.001	S = 173.05-6.548*NB	0.357	0.128	3.700	≤ 0.001
	S = 162.50+0.439*NH	0.022	0.001	5.389	≤ 0.001	S = 174.94-6.116*NH	0.319	0.101	3.755	≤ 0.001
	S = 146.64+2.542*UFH	0.175	0.030	5.306	≤ 0.001	S = 196.35-7.528*UFH	0.551	0.303	3.306	≤ 0.001
	S = 145.37+1.692*TFH	0.158	0.025	5.322	≤ 0.001	S = 163.27-1.299*TFH	0.124	0.015	3.932	≤ 0.001
	S = 160.49+0.244*PH	0.035	0.001	5.387	≤ 0.001	S = 154.33-0.273*PH	0.040	0.001	3.959	≤ 0.001
51-60	S = 154.41+0.709*FD	0.079	0.006	4.330	≤ 0.001	S = 175.45-2.266*FD	0.284	0.080	3.505	≤ 0.001
	S = 143.54+1.604*BD	0.245	0.006	4.211	≤ 0.001	S = 169.57-1.62*BD	0.200	0.040	3.582	≤ 0.001
	S = 129.84+8.429*NB	0.372	0.138	0.107	≤ 0.001	S = 183.55-9.12*NB	0.486	0.237	3.193	≤ 0.001
	S = 154.30+1.564*NH	0.121	0.014	4.312	≤ 0.001	S = 163.92-3.065*NH	0.220	0.048	3.566	≤ 0.001
	S = 143.20+2.589*UFH	0.250	0.062	4.206	≤ 0.001	S = 159.08-1.187*UFH	0.097	0.009	3.639	≤ 0.001
	S = 131.11+2.673*TFH	0.386	0.149	4.006	≤ 0.001	S = 161.70-0.956*TFH	0.131	0.017	3.625	≤ 0.001
	S = 134.20+1.574*PH	0.279	0.077	4.171	≤ 0.001	S = 197.05-2.754*PH	0.414	0.172	3.327	≤ 0.001

Age Range	Male					Female				
	Equation	*R*	R^2	*SEE*	*p*-Value	Equation	*R*	R^2	*SEE*	*p*-Value
18-60	S = 159.278+2.393*FD	0.241	0.058	5.394	≤ 0.001	S = 137.143+1.379*FD	0.137	0.018	4.418	≤ 0.001
	S = 140.183+2.175*BD	0.237	0.056	5.400	≤ 0.001	S = 133.253+1.65*BD	0.158	0.025	4.403	≤ 0.001
	S = 142.886+5.941*NB	0.259	0.067	5.368	≤ 0.001	S = 165.362-3.783*NB	0.162	0.026	4.400	≤ 0.001
	S = 170.729-1.033*NH	0.064	0.004	5.547	≤ 0.001	S = 157.710-1.384*NH	0.080	0.006	4.445	≤ 0.001
	S = 161.828+0.533*UFH	0.038	0.001	5.555	≤ 0.001	S = 165.713-2.183*UFH	0.187	0.035	4.381	≤ 0.001
	S = 146.877+1.636*TFH	0.161	0.026	5.486	≤ 0.001	S = 158.141-0.583*TFH	0.072	0.005	4.448	≤ 0.001
	S = 165.471+0.009*PH	0.001	0.000*	5.559	≤ 0.001	S = 160.659-0.517*PH	0.080	0.006	4.445	≤ 0.001

S = stature; FD = Frontal diameter; BD = Bigonial diameter; NB = Nasal breadth; UFH = Upper facial height; TFH = Total facial height; PH = Physiognomic height

Table 3

Multiple linear regression analysis to estimate the stature in both sexes

Sex	Age range	Equation	*R*	R^2	*SSE*	*p* -value
Male (*n*=152)	18-30	S=180.742+5.483*FD+2.630*BD-5.103*NB+0.921*NH-3.411*UFH +3.476*TFH-3.897*PH	0.65	0.43	4.41	≤ 0.001*
	31-40	S=39.792-0.455*FD+4.294*BD+2.231*NB-2.893*NH+3.555*UFH +2.830*TFH+1.678*PH	0.62	0.38	4.73	0.287 ***
	41-50	S=116.855-1.145*FD+2.281*BD+8.152*NB-2.129*NH+2.906*UFH-0.755*TFH-0.282*PH	0.38	0.15	5.41	0.002 **
	51-60	S=79.834-1.559*FD+2.569*BD+9.340*NB-2.003*NH+2.808*UFH-0.0056*TFH+1.312*PH	0.59	0.35	3.95	0.035***
	18-60	S=114.012+1.535*FD+0.608*BD+5.056*NB-1.611*NH+0.534*UFH +2.173*TFH-0.724*PH	0.39	0.15	5.22	≤ 0.001*
Female (*n*=138)	18-30	S=112.139+2.289FD-0.672*BD+8.255*NB+4.333*NH8.215*UFH +4.416*TFH-0.813*PH	0.44	0.20	5.33	0.009 **
	31-40	S=70.304+2.110*FD-0.344*BD+1.864*NB+2.614*NH-0.470*UFH +2.011*TFH+1.708*PH	0.52	0.27	3.58	0.034 ***
	41-50	S=146.459+0.691*FD+3.241*BD-1.619*NB-1.964*NH8.548*UFH +3.107*TFH-0.384*PH	0.70	0.49	3.15	≤ 0.001*
	51-60	S=197.536-2.425*FD-0.143*BD-13.748*NB+3.532*NH+3.716*UFH-0.336*TFH-0.313*PH	0.62	0.39	3.18	≤ 0.001*
	18-60	S=152.661+0.419*FD+1.251*BD-2.749*NB+1.333*NH-3.193*UFH +1.189TFH-0.458*PH	0.29	0.08	4.37	≤ 0.001*

**Significant at the 0.001 level; **Significant at the 0.05 level; ***Not significant at the 0.05 level; S = stature; FD = Frontal diameter; BD = Bigonial diameter; NB = Nasal breadth; UFH = Upper facial height; TFH = Total facial height; PH = Physiognomic height

Table 4

Estimation of cut-off points to differentiate sex from face measurements (mm)

Sex	Frontal diameter	Bigonial diameter	Nasal breadth	Nasal height	Upper facial height	Total facial height	Physiognomic height
Male	110.405	116.965	38.282	49.303	71.288	114.592	173.538
Female	108.051	113.938	35.173	40.872	62.561	104.348	166.303
Cut off Point	109.228	115.451	36.728	45.087	66.925	109.47	169.92

Table 5 presents the accuracy of sex estimation from facial measurements using the discriminant function test. In discriminant function test we use the sectioning point or cut-off point presented in Eq. (3). When a facial parameter (frontal diameter, nasal breadth, bigonial diameter, nasal height, upper facial height, total facial height, and physiognomic height) value is below the cut-off point, it is considered as a female. Similarly, when a facial parameter value is above the cut-off point, it is considered as a male. The correct and incorrect classifications are determined by comparing predicted sex with actual sex. For instance, if 135 male sample (e.g., nasal height) is above the cut-off point value among 152 male sample, then the estimation is 88.2% accurate.

Table 6 presents the accuracy of sex estimation from facial measurements using the binomial logistic regression. The binomial logistic regression models the probability of the outcome using the logistic function. The equation estimates the log-odds of the dependent variable as a linear combination of the predictors. The core idea is to find the best-fitting S-shaped curve to separate the two classes (male and female). It estimates the coefficients of a linear equation involving the predictor variables and then applies the sigmoid function to this linear combination to get the probability. This is then converted into a probability between 0 and 1. A cutoff (usually 0.5) is used to classify the outcome. If the predicted probability is above the threshold, the individual is classified as male; otherwise, as female. For instance, if the model predicts a probability of 0.7 for an individual facial parameter being male, it would be classified as male because 0.7 > 0.5.

Table 5

Percentage of correctly sex estimation from facial measurements using the discriminant function test

Parameters	Male			Female			Overall		
	Correct	Incorrect	Accuracy	Correct	Incorrect	Accuracy	Correct	Incorrect	Accuracy
Frontal diameter	80	72	52.63%	79	59	57.25%	159	131	54.83%
Bigonial diameter	85	67	55.92%	82	56	59.42%	167	123	57.59%
Nasal breadth	108	44	71.05%	117	21	84.78%	225	65	77.59%
Nasal height	135	17	88.82%	126	12	91.30%	261	29	90.00%
Upper facial height	132	20	86.84%	119	19	86.23%	251	39	86.55%
Total Facial height	124	28	81.58%	110	28	79.71%	234	56	80.69%
Physiognomic height	97	55	63.82%	105	33	76.09%	202	88	69.66%
All variables	145	7	95.40%	132	6	95.70%	277	13	95.52%

Table 6

Percentage for correctly sex estimation from facial measurements using the binomial logistic regression

Parameters	Male			Female			Overall		
	Correct	Incorrect	Accuracy	Correct	Incorrect	Accuracy	Correct	Incorrect	Accuracy
Frontal diameter	93	59	61.18%	70	68	50.72%	163	127	56.21%
Bigonial diameter	95	57	62.50%	75	63	54.35%	170	120	58.62%
Nasal breadth	112	40	73.68%	112	26	81.16%	224	66	77.24%
Nasal height	142	10	93.42%	125	13	90.58%	267	23	92.07%
Upper facial height	135	17	88.82%	117	21	84.78%	252	38	86.90%
Total Facial height	124	28	81.58%	109	29	78.99%	233	57	80.34%
Physiognomic height	107	45	70.39%	99	39	71.74%	206	84	71.03%
All parameters	146	6	96.05%	133	5	96.38%	279	11	96.21%

It was seen that the percentage of correctly sex estimation varied from 52.63% to 95.40% in men and 57.255% to 95.70% in women by using discriminant analysis. On the other hand, these values varied from 61.18% to 96.05% in men and 50.72% to 96.38% in women by using the binomial logistic regression. Considering both sexes and by using the discriminant function test, the accuracies to estimate the sex from frontal diameter, bigonial diameter, nasal breadth, nasal height, upper facial height, total facial height, and physiognomic height were 54.83%, 57.59%, 77.59%, 90.00%, 86.55%, 80.69%, and 69.66% respectively. Using binomial logistic regression, these values were 56.21%, 58.62%, 77.24%, 92.07%, 86.90%, 80.34%, and 71.03%, respectively. The combination of all parameters showed the best accuracy in both discriminant function tests (95.52%) and binomial logistic regression analysis (96.21%).

4. DISCUSSIONS

Long bones are the most accurate predictor of stature (Pelin *et al.*, 2013). However, long bones are not always available to estimate the stature in various forensic investigations. Therefore, researchers attempt to estimate the stature from different body dimensions. The study of stature estimation from facial measurements in different populations is not limited. The result of this study was consistent with the previous studies in various populations. In our study, all the facial measurements were larger in males than females. Similar findings were also reported by past research (González-Colmenares *et al.*, 2016; Krishan, 2008; Zaghloul *et al.*, 2019). However, in the study of Agnihotri *et al.* (2011) on the Indo-Mauritian population, the cephalo-facial measurements were significantly higher in men than women except the nasal height ($p>0.05$). In this study, all the facial measurements were statistically significant for sex determination at the level of 0.001. In the Northwest Indian population (Sahni *et al.*, 2016), facial measurements were statistically significant at the 0.01 level. In the study of the Gujarati population of India (Shah *et al.*, 2016), facial measurements were statistically significant at the 0.05 level.

In this study, the values of SEE were between ±5.394 and ±5.599 mm in males and between ±4.381 and ±4.448 mm in females. The SEE values observed in this study are consistent with findings from earlier research across various populations. For instance, Sahni *et al.* (2016) created equations using the total facial height, upper facial height, height of the lower face, minimum frontal breadth, bigonial breadth and reported an SEE of ±3.588 to ±3.610 cm for males and ±2.880 to ±2.914 cm for females in Northwest Indians. In the North Indian male population, Krishan (2008) examined bigonial diameter and morphological facial length and recorded the values of SEE between ±5.131 cm and ±5.820 cm. Gonza´lez-Colmenares *et al.* (2016) also considered ten different cephalo-facial measurements in Colombian population where the stature prediction ranged from ±0.63 to ±4.11 cm in men and ±0.77 to ±4.31 cm in women.

In our study, based on different age groups and all samples, the values of *R* in this study were +0.001 to +0.462 in males and +0.04 to +0.486 in females. A lower value of *R* between stature and face dimensions was also reported in previous literature. In a study on the Sudanese population (Sahni *et al.*, 2016), the values of *R* between stature and nine facial measurements ranged between +0.177 to +0.370 in males and +0.131 to +0.369 in females. In the study in a Northwest Indian population (Sahni *et al.*, 2016), the values of *R* varied from -0.030 to +0.270 in males and -0.061 to +0.195 in females. A study on 14 facial measurements in the Indo-Mauritian population showed that the values of *R* varied from -0.079 to +0.494 in men and -0.012 to +0.382 in women. In the study of male Gujjars in North India (Krishan, 2008), the value of *R* between stature and bigonial diameter was +0.462 and the value of R between stature and morphological facial length was +0.455. The above literature revealed that the correlation between stature and different facial measurements was always low, like this study. A value of *R* below 0.5 indicates that the parameter is not a good or reliable estimator (Agnihotri *et al.*, 2011). Therefore, this study finally concludes that the estimation of stature using the facial measurements was not reliable using simple linear regression models in the Bangladeshi population.

As the values of *R* are noticeably low, therefore multiple regression equations are developed (Table 3) for more reliable estimation of stature. It was seen that the values of R were above +0.5 in a few age groups. For instance, in men, the values of R were +0.65, +0.62, and +0.59 in the age groups 18-30, 31-41, and 51-60, respectively. Similarly, in women, the values of *R* were +52, +0.70, and +0.62 in the age groups 31-40, 41-50, and 51-60, respectively. Therefore, multiple regression equations were reliable to estimate the stature in those age groups.

In the estimation of sex from body measurements, researchers successfully used the discriminant function test (Poodendaen *et al.*, 2025; Shah *et al.*, 2016), and logistics regression (Boonthai *et al.*, 2025; Ochiai *et al.*, 2025; Shah *et al.*, 2016). In our study, we have used both types of methods to estimate the sex. The accuracy to estimate the sex from facial measurements was higher in females than males. The best results were obtained in females by binomial logistic regression (96.38%) and discriminant function test (95.70%). In this study, nasal height was the most reliable predictor of sex, with an accuracy of 90.00% by using the discriminant test and 92.07% by applying the binomial logistic regression analysis. This finding was quite similar to the findings of Zaghloil *et al.* (2019). In the study of Zaghloil *et al.* (2019), nasal breadth was the best predictor of sex with an accuracy of 92% in the Egyptian population. In the study of Adamu *et al.* (2016) on the Nigerian population, nasal height was also the most reliable single predictor of sex estimation with an accuracy of 76.2%. Besides, in their study using the combination of six different parameters, the percentage of accuracy increased to 91%. Another study by Shah *et al.* (2016) on the Gujarati population of India applied two different types of methods for sex determination using eight cephalon-facial measurements. In the Gujarati population, up to 92% accuracy was obtained using logistic regression in males and 80.90% in females using the discriminant function analysis. In the study of the Egyptian population (Zaghloil *et al.*, 2019), the accuracy of sex estimation using nasal length, nasal breadth, morphological facial height, and bizygomatic facial varied between 68% and 92%. This is close to the percentage accuracy obtained in the present study using different facial measurements.

Overall, in our study, considering sex estimation accuracy for both male and female, the best results were obtained by using the binomial logistic regression analysis (96.21%). On the other hand, the discriminant analysis obtained an accuracy of 95.52%. Therefore, the binomial logistic regression performed better than the discriminant analysis in terms of accuracy in sex estimation from facial measurements. Similar findings were also reported by Shah *et al.* (2016) in estimating the sex from facial measurements.

5. CONCLUSIONS

This study provides a comprehensive analysis of stature estimation and sex determination using facial measurements within the Bangladeshi population. From the present study, it was concluded that the estimation of stature using multiple regression models was reliable from facial anthropometry owing to the higher values of the correlation coefficient between the stature and the facial measurements. The sex estimation using face anthropometry is also reliable in the Bangladeshi population. Binomial logistic regression analysis proved more reliable for estimating the sex from facial dimensions than the discriminant function test. Facial measurements proved more effective, with higher accuracy rates observed in females compared to males. The findings of this study are very useful from the anatomical, medical, forensic, and human factors engineering points of view. The findings of this study provide a new standard to estimate the sex of Bangladeshi adults. Future studies should focus on refining regression models and exploring additional cephalo-facial parameters to enhance reliability across diverse populations and age groups. Similar studies in various populations are required for further comparison with different regional people. Moreover, angular measurements with linear facial measurements would be more interesting, which may generate more precision output.

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