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Gender-Specific Regression Equations for Stature Estimation Using Age, Facial Height, and Nasal Height

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Abstract

Introduction: Stature is a key identifier, but estimating it can be challenging for forensic pathologists when dealing with dismembered remains, as stature varies greatly with sex, race, and age. The present study aims to establish regression equations for estimation of stature from age, facial height and nasal height of participants

Materials & Method: The study was conducted in Medical College, Safai, Uttar Pradesh, among a total of 324 healthy subjects (18-50 years), comprising 162 males and 162 females. Those with cranio-facial defects were excluded from the study. Mean stature facial height and nasal height were obtained by direct measurement; co-relation co-efficient were obtained and regression equation formulated for estimating stature.

Result: The study showed that males exhibited a higher mean height (171.92 cm) compared to females (167.11 cm), aligning with established population trends. Furthermore, males demonstrated greater mean facial height (121.98 mm) and nasal height (61.29 mm) compared to females (117.23 mm and 56.94 mm, respectively). The study showed strong and significant correlations between stature and facial height in both males ($r = 0.585$) and females ($r = 0.537$). Moderate yet significant correlations were also found between stature and nasal height in both males ($r = 0.313$) and females ($r = 0.321$). Notably, facial height and nasal height emerged as significant predictors of stature in both sexes. Specifically, for males, every 1 mm increase in facial height corresponded to a 0.361 cm increase in stature, while every 1 mm increase in nasal height corresponded to a 0.290 cm increase. For females, every 1 mm increase in facial height corresponded to a 0.300 cm increase in stature, while every 1 mm increase in nasal height corresponded to a 0.270 cm increase.

Conclusion: Facial and Nasal height can be used as a reliable tool in estimating stature. While age has a minimal impact on stature estimation, facial and nasal measurements prove to be essential predictors.

Keywords: Facial height, Nasal height, age, stature

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Introduction:

Physical anthropology encompasses the subfield of anthropometry, which is concerned with the systematic measurement and analysis of body parts (1). During archaeological investigations or forensic examinations subsequent to mass disasters, the estimation of height is conducted utilizing rudiments or bone pieces for identification (3). The process of personal identification constitutes the determination of an individual's distinct characteristics. It may be comprehensive (absolute) or partial. Comprehensive identification necessitates an absolute emphasis on an individual's distinctive attributes. Partial identification indicates that certain aspects of a person's identity have been determined, while others remain unknown. The primary determinants of identification include age, gender, and size (4). The systematic application of anthropometry encompasses numerous scientific domains, including: Paleo-anthropology and human evolution, biological anthropology, Craniometry (scientific measurement of skulls) and craniofacial attributes, Criminology and Forensics, Phrenology, Physiognomy, as well as Personality and mental typology (2). The fundamental components of an individual's identity are traditionally classified as age, gender, stature, and race, with gender and stature being of paramount importance (5). Research has established a clear biological connection between stature and all body parts (6). Numerous investigations have been undertaken to estimate stature using various body parts, encompassing the hands, trunk, entire spinal column, upper and lower limbs, individual long and short bones, feet, and footprints (7). Furthermore, different cephalo-facial indices such as head circumference, facial length, facial breadth, nasal height, nasal width, among others, represent clinical anthropometrical characteristics applicable to stature estimation (8). However, limited research has been conducted regarding stature estimation from facial and nasal dimensions in relation to gender. The development of gender-specific regression formulae is essential for accurate stature determination. The present study aims to establish regression equations for estimation of stature from age, facial height and nasal height of participants.

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Materials and Methods:

This study was conducted at Uttar Pradesh University of Medical Sciences (UPUMS), Saifai, Etawah, India, after obtaining institutional ethical clearance and informed consent from all participants. A total of 324 subjects, comprising 162 males and 162 females, were randomly selected using simple random sampling.

The study employed specific inclusion and exclusion criteria to ensure a representative and healthy sample population. The inclusion criteria consisted of apparently healthy male and female students and staff, aged 18-50 years, who were able to stand erect for measurement of standing height. Additionally, participants had to be free from spinal and skeletal deformities of the limbs, reside in Western Uttar Pradesh, India, and have no physical deformity or abnormality. In contrast, individuals with physical deformities that could affect body height were excluded from the study. Furthermore, subjects who were unwilling to provide consent to participate in the study were also excluded.

All the measurement was taken with the subject in a well-illuminated room, in a relaxed condition with the head in the anatomical position.

Height Measurement: Height was measured from vertex to floor by a stadiometer. The subjects were said to stand erect with heel together and backs straight as possible so that his heels, buttocks, shoulders and the head touched the rod of the stadiometer.

Facial Height: It measures the straight distance mm between N = nasion (point of intersection of the frontonasal and intranasal sutures) and Gn = gnation (the most anterior-inferior point of the chin contour).

Nasal height: It was the distance measured from the nasion to the subnasale. Distance between two points of the nose were taken with a Digital Vernier Caliper with accuracy of 0.01mm

Statistical Analysis:

Data were entered into Microsoft office Excel 2010 and analyzed using Statistical Package for Social Sciences, version 16.0 (SPSS, Inc., Chicago, IL, USA). Under descriptive statistics, minimum, maximum, mean and Standard Deviation were calculated for continuous variables. Pearson Correlations coefficients (r) tests was used to find correlation between Age, stature (cm), Facial Height (mm), Nasal Height (mm) in gender separately. Multivariate regression model is to estimate or predict the stature (cm) having the other information's such as Age, Facial Height (mm), Nasal Height (mm), etc. The model is expressed as, $y = \beta0 + \beta1.x1 + \beta2.x2 + \ldots.. + \beta n.xn$. Here y is the stature, x1,x2,…xn are the independent variables, and beta's are the regression coefficients. Statistical significance was assessed at $P < 0.05$.

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Results

Table 1: Descriptive statistic of stature and facial & nasal height of participants

Gender		**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Male	Age	20.00	50.00	32.28	9.26
	stature (cm)	159.00	189.00	171.92	6.64
	Facial Height (mm)	108.00	143.00	121.98	9.90
	Nasal Height (mm)	51.00	67.00	61.29	4.39
Female	Age	20.00	47.00	30.52	8.20
	stature (cm)	151.00	185.00	167.11	5.83
	Facial Height (mm)	102.00	140.00	117.23	9.42
	Nasal Height (mm)	43.00	64.00	56.94	4.72

The descriptive statistics presented in Table 1 and figure 1-4 provide an overview of the demographic characteristics and physical measurements of the male and female participants. The age range for both males and females is 20-50 years, with males having a slightly higher mean age (32.28 years) compared to females (30.52 years). The standard deviation for age is higher in males (9.26 years) than in females (8.20 years), indicating greater variability in age among males.

In terms of stature, the mean height for males (171.92 cm) is higher than that for females (167.11 cm), which is consistent with general population trends. The standard deviation for stature is relatively low in both males (6.64 cm) and females (5.83 cm), indicating relatively homogeneous stature measurements within each gender group. The facial and nasal height measurements also show differences between males and females. The mean facial height is higher in males (121.98 mm) than in females (117.23 mm), while the mean nasal height is also higher in males (61.29 mm) than in females (56.94 mm). The standard deviations for facial and nasal height are relatively consistent across genders, ranging from 4.39 mm to 9.90 mm.

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Figure 1: Average age (in years) distribution of participants

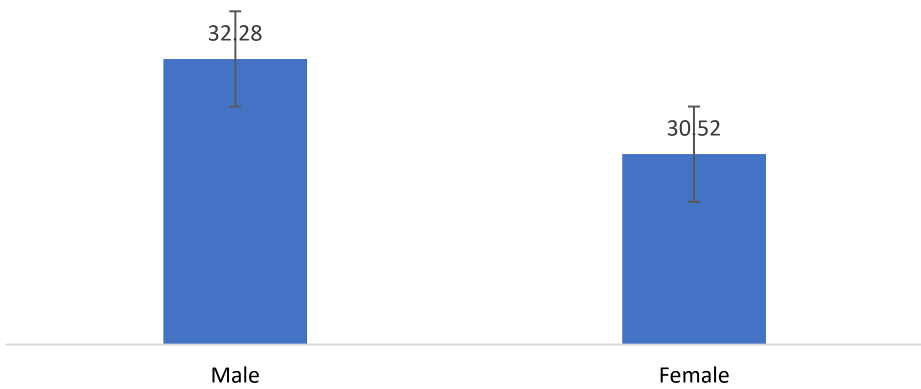

Figure 2: Average stature (cm) distribution of participants

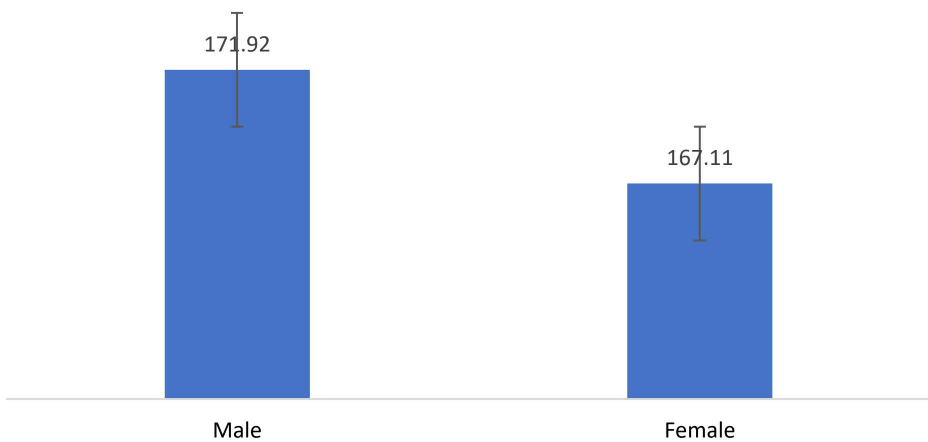

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Figure 3: Average Facial Height (mm) distribution of participants

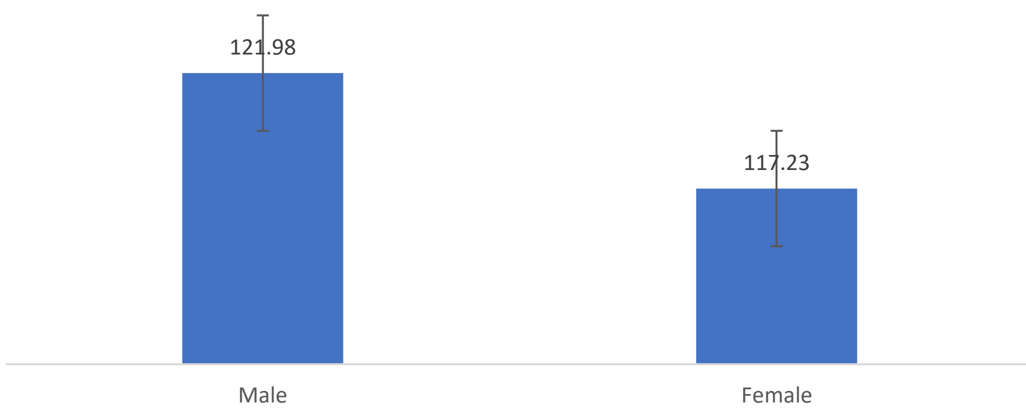

Figure 4: Average Nasal Height (mm) distribution of participants

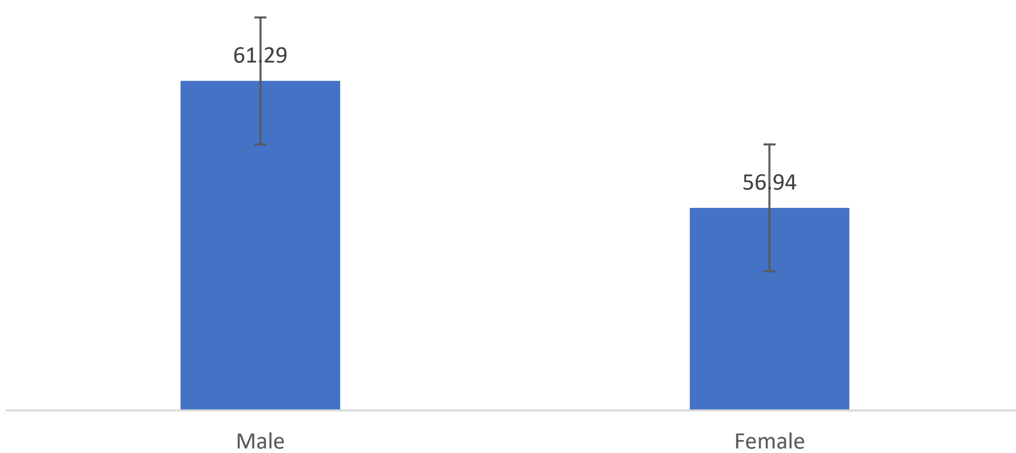

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Figure 5(a): Scatter plot showing trend between Age (in years) and Height (cm) in male.

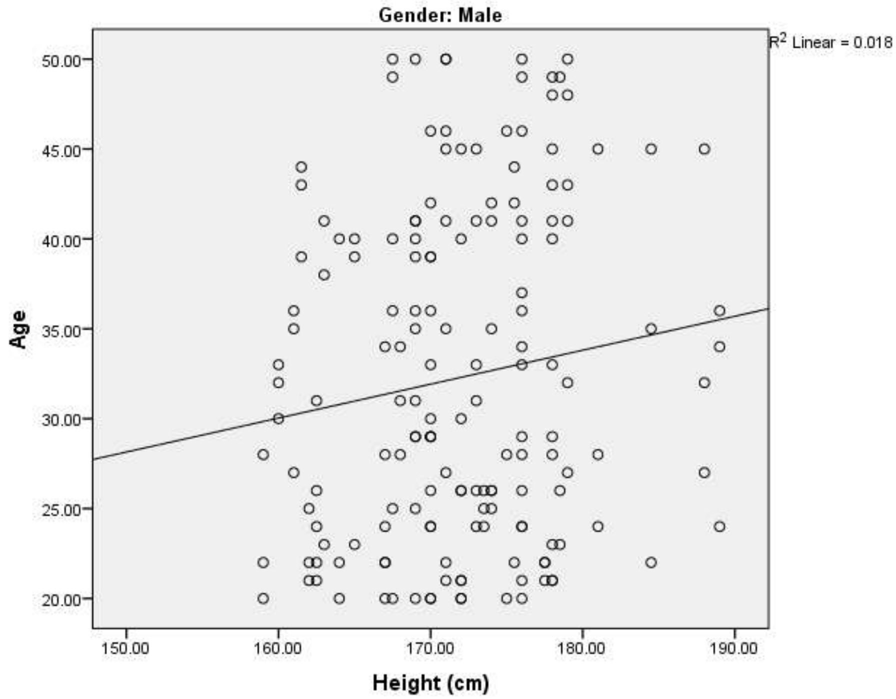
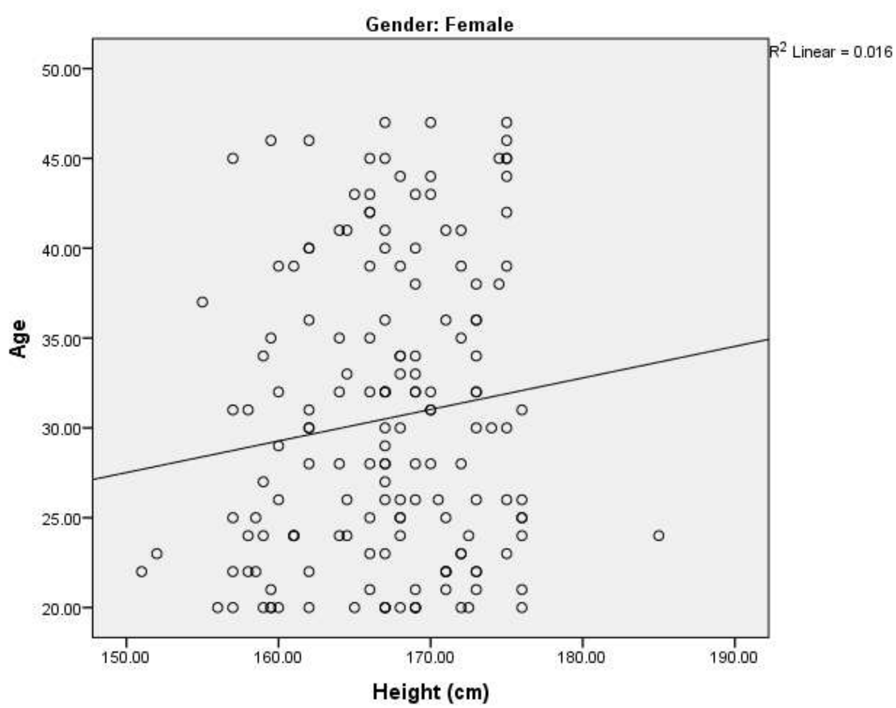


Figure 5(b): Scatter plot showing trend between Age (in years) and Height (cm) in female.



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The scatter plots in Figure 5(a) and 5(b) illustrate the relationship between age and height in males and females, respectively. The R-squared values, which measure the strength of the relationship, are extremely low: 0.018 for males and 0.016 for females. Age is not a significant predictor of height in this population. Height typically stabilizes in early adulthood, and age-related changes in height are relatively small.

Figure 6(a): Scatter plot showing trend between Facial Height (mm) and Height (cm) in male.

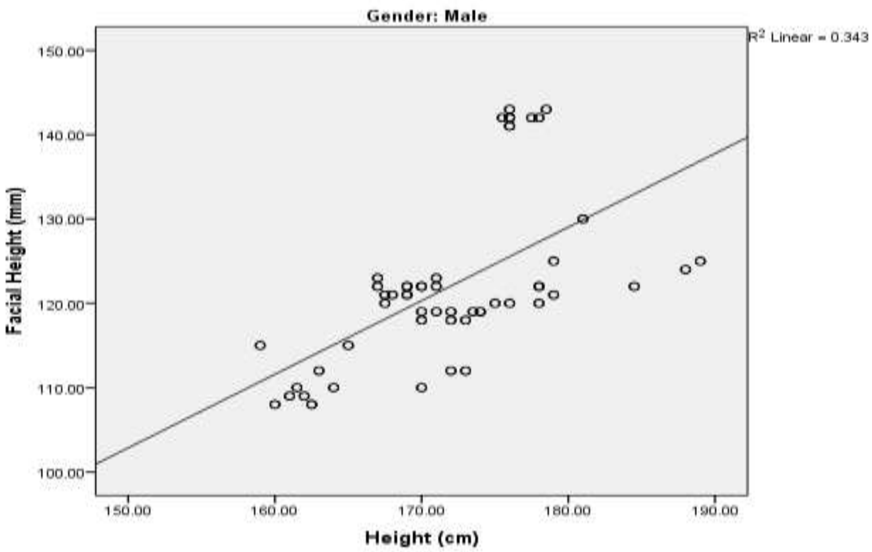
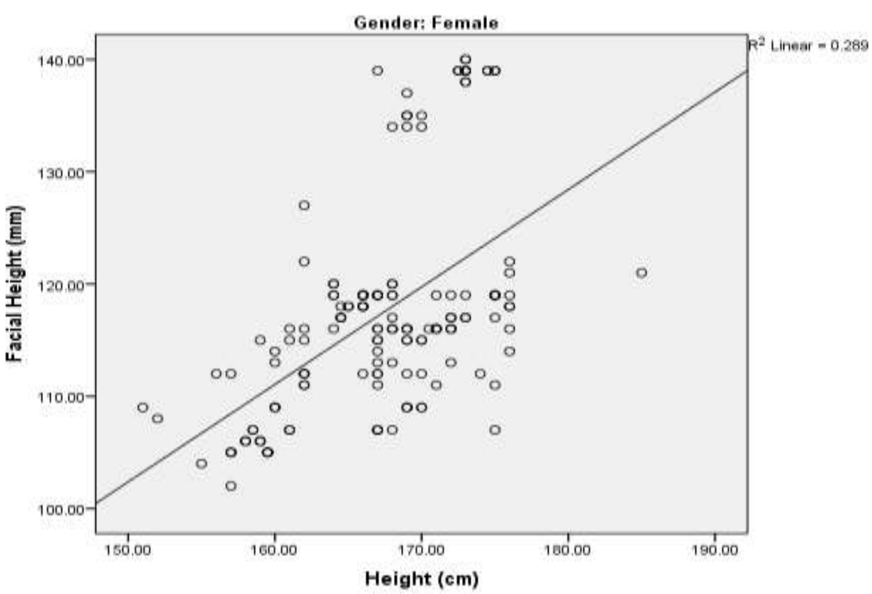


Figure 6(b): Scatter plot showing trend between Facial Height (mm) and Height (cm) in female.



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The scatter plots in Figure 6(a) and 6(b) illustrate the relationship between facial height and overall height in males and females, respectively. The R-squared values indicate that a significant proportion of the variation in overall height can be explained by facial height: 34.3% in males and 28.9% in females. This suggests that facial height is a relatively strong predictor of overall height, although other factors also contribute to individual variations in height. This relationship can be useful in anthropometric and forensic applications, where facial height measurements can provide valuable information about an individual's overall stature.

Figure 7(a): Scatter plot showing trend between Nasal Height (mm) and Height (cm) in male.

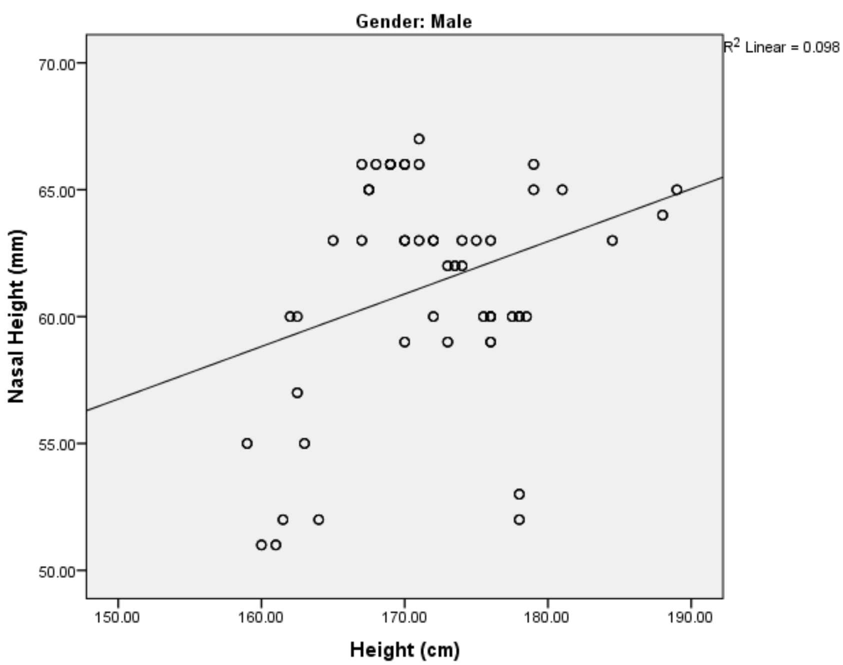

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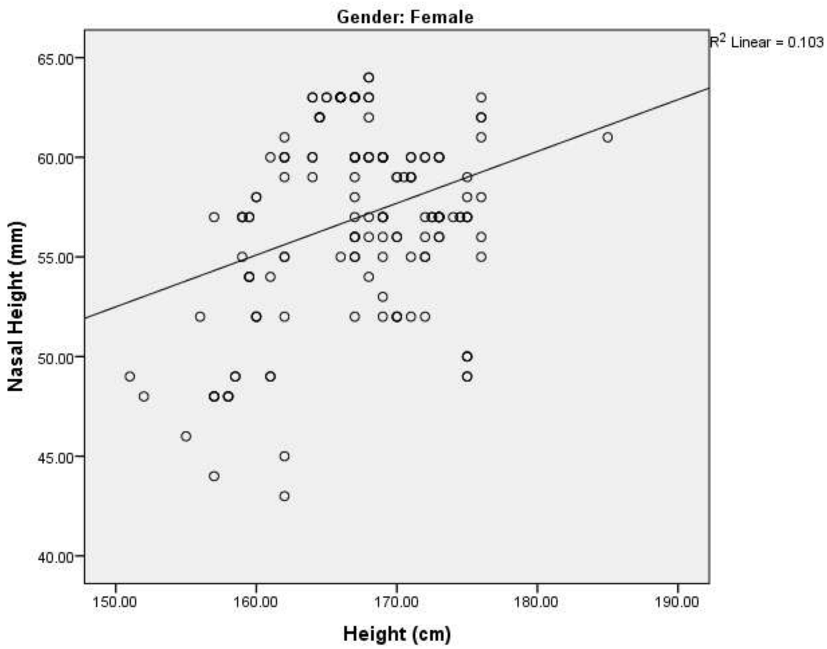
Figure 7(b): Scatter plot showing trend between Nasal Height (mm) and Height (cm) in female.



The scatter plots in Figure 7(a) and 7(b) illustrate the relationship between nasal height and overall height in males and females, respectively. The R-squared values indicate that only a small proportion of the variation in overall height can be explained by nasal height: 9.8% in males and 10.3% in females. This suggests that nasal height is not a strong predictor of overall height. As a result, nasal height measurements may not be a reliable indicator of overall stature.

Table 2: Pearson Correlations coefficients between Stature (cm) with Age (in years), Facial Height (mm) & Nasal Height (mm) in both gender separately.

Gender			**Age (in years)**	**Facial Height (mm)**	**Nasal Height (mm)**
Male	Stature (cm)	Pearson Correlation (r)	0.136	0.585	0.313
		p-value	0.086	<0.001	<0.001
Female	Stature (cm)	Pearson Correlation (r)	0.125	0.537	0.321
		p-value	0.113	<0.001	<0.001

The table 2 presents the correlation coefficients between stature and three variables: age, facial height, and nasal height, separately for males and females. The correlation between stature and age is weak and non-significant in both males ($r = 0.136$, $p = 0.086$) and females ($r = 0.125$, $p = 0.113$). This suggests that age is not a significant predictor of stature in this population. The correlation between stature and facial height is strong and significant in both males ($r = 0.585$, $p < 0.001$) and females ($r = 0.537$, $p < 0.001$). This indicates that facial height is a good predictor

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of stature, and individuals with greater facial height tend to have greater stature. The correlation between stature and nasal height is moderate and significant in both males (r = 0.313, p < 0.001) and females (r = 0.321, p < 0.001). This suggests that nasal height is also a predictor of stature, although the relationship is not as strong as that between facial height and stature. Overall, the results suggest that facial height is the strongest predictor of stature, followed by nasal height, while age is not a significant predictor.

Table 3: Multivariate regression model is to estimate the stature (cm) with respect to Age, Facial Height (mm) & Nasal Height (mm).

Gender	Model	**Unstandardized Coefficients**		**p-value**	**R Square**
		B	**Std. Error**		
Male	(Constant)	108.59	7.05	0.00	0.38
	Age	0.05	0.05	0.30	
	Facial Height (mm)	0.36	0.04	0.00	
	Nasal Height (mm)	0.29	0.10	0.00	
Female	(Constant)	114.67	6.04	0.00	0.34
	Age	0.06	0.05	0.18	
	Facial Height (mm)	0.30	0.04	0.00	
	Nasal Height (mm)	0.27	0.08	0.00	

Regression equation:

Y (stature; male) = 108.594 + 0.047.(age) + 0.361.(facial height) + 0.290.(nasal height)

Y (stature; female) = 114.666 + 0.062.(age) + 0.300.(facial height) + 0.270.(nasal height)

Table 3 shows the regression equations provide a mathematical representation of the relationship between stature and its predictors (age, facial height, and nasal height) for males and females. For males, the predicted stature is 108.594 cm, with additional increments based on age, facial height, and nasal height. Specifically, for every year increase in age, stature increases by 0.047 cm, although age is not a significant predictor. In contrast, facial height and nasal height are significant predictors, with every mm increase corresponding to a 0.361 cm and 0.290 cm increase in stature, respectively.

For females, the predicted stature is 114.666 cm, with similar increments based on age, facial height, and nasal height. While age is not a significant predictor, every year increase in age corresponds to a 0.062 cm increase in stature. Facial height and nasal height are again significant predictors, with every mm increase corresponding to a 0.300 cm and 0.270 cm increase in stature, respectively.

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Discussion:

There is definitive biological correlation of stature with body parts such as extremities, head, trunk and vertebral column.(11,12) Many studies have been conducted for estimation of stature from percutaneous measurements of various body parts such as arm, leg, feet, finger, etc.(13,14) However, few studies are available for stature estimation from face alone.(15,16) It is an established fact 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.(17) In the context of Demographic Overview, present study reported similar findings with previous studies. This suggests a broader age range among male participants, which may influence the overall stature estimation (18). Present study recorded mean stature for males was at 171.92 cm, while females averaged 167.11 cm. This aligns with studies that typical population trends where males are generally taller than females (19,20). Moreover, facial and nasal height measurements further highlight gender differences in the present study. The standard deviations for these measurements, indicating consistent measurement reliability across genders (18,21). These findings highlight the importance of considering gender-specific measurements in stature estimation. The significant differences in nasal and facial heights suggest that these parameters can be reliable indicators for predicting stature, particularly in forensic contexts where such measurements may be the only available data (18,22). The scatter plots indicate a very weak correlation between age and height. Likely due to the stabilization of height in early adulthood and minimal age-related changes thereafter. Such findings align with existing literature that indicates height typically stabilizes after adolescence, making age a less relevant factor in stature estimation (18,19). The present study's conclude that age is not a significant predictor of stature is supported by other literature, which often finds weak correlations between age and stature in various populations (18). This suggests that while age may influence physical development, it does not serve as a reliable metric for estimating stature. In contrast, facial height can explain a significant portion of the variation in overall height, suggesting its utility in anthropometric and forensic applications. The findings support the notion that facial measurements can provide valuable understandings into an individual's stature, which is crucial for forensic identification and anthropological studies (18,20). The analysis of nasal height in relation to overall height, suggesting that it may not be a reliable indicator for stature estimation. The limited predictive power of nasal height could be attributed to the multifactorial nature of height determination, where various anatomical and genetic factors play a more significant role (19,22). Additionally, A study by Dinakaran et al. (2021) found a significant positive correlation between stature and nasal height among females ($P = 0.57$) (19). However, the correlation was weaker in males (18). This make parallel comparison with the present study's findings, where nasal height is a moderate predictor of stature. The correlation between stature and facial height in the present study is consistent with findings from other research, which also indicates strong relationships between facial dimensions and stature (23,24). This supports the view that facial height is a reliable indicator of stature.

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Furthermore, Agnihotri et al (2011) (6) studied on 150 young and healthy students. The stature and fourteen cephalo-facial dimensions were measured on each subject by using standard anthropometric instruments. It was remarked that the stature and craniofacial measurements of males were significantly higher than that of females, except for nasal height where no significant difference was observed ($p > 0.05$). The correlation coefficients of all cephalo-facial dimensions were less than 0.5. It means the estimation of stature is not reliable with the help of cephalo-facial. Another study conducted by Ese Anibor et al (2011) (25) on 200 subjects and reported that the mouth width increases with height. Craniofacial parameters might be useful in determining stature. Craniofacial parameters were sexually dimorphic. Thus, craniofacial parameters might be used in identifying an individual's gender. Therefore, a practical alternative is to develop new standards that utilize different parts of the skeleton. However, direct measurement of stature is not possible in the bed ridden patients with spinal deformities or who are wheelchair bound due to some accidental cases, unable to stand straight due to physical deformities, or structural defects such as kyphoscoliosis and neuromuscular weakness. In such circumstances, an estimate of body height has to be derived from other reliable anthropometric indicators, such as hand and foot lengths, leg length, length of the sternum, vertebral column length, sitting height, arm span, and facial measurements etc (26).

Conclusion:

This study emphasizes the significance of facial and nasal dimensions in estimating stature, particularly in forensic and medical contexts. The findings highlight the importance of anthropometric indicators in predicting age-related loss in body height. While age plays a limited role in stature estimation, facial and nasal measurements emerge as critical factors. These results align with previous research, emphasizing the strong positive correlation between stature and facial measurements.

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