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STATURE ESTIMATION FROM CEPHALO FACIAL MEASUREMENTS IN GUJARATI RAJPUT POPULATION

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Abstract

Stature estimation plays a crucial role in forensic anthropology and biological profiling, aiding in personal identification in forensic and archaeological contexts. This study focuses on stature estimation from cephalo-facial measurements in the Gujarati Rajput population, an endogamous group with distinct anthropometric traits. Using a sample of individuals from this population, various craniofacial parameters were recorded and analyzed to establish predictive regression models for stature estimation. The study employed standard anthropometric techniques to measure cephalo-facial dimensions, including head length, head breadth, facial height, and bizygomatic breadth. Statistical analyses, including correlation and regression analysis, were performed to determine the relationship between stature and craniofacial measurements. The findings highlight significant correlations between specific craniofacial dimensions and stature, enabling the formulation of population-specific regression equations for accurate stature estimation. These results contribute to forensic casework, providing a scientific basis for reconstructing biological profiles from incomplete skeletal remains. The study also emphasizes the importance of population-specific anthropometric standards in forensic anthropology.

Keywords: *Forensic Anthropology, Cephalofacial measurements, Rajput Population, Stature*

INTRODUCTION

Personal identification is a cornerstone of forensic science, crucial for ensuring justice and accurate legal outcomes. Various methods, including biometrics, DNA profiling, and forensic anthropology, play significant roles in this process. Biometric systems utilize physiological traits such as fingerprints, facial recognition, and gait patterns, providing reliable identification tools that are increasingly replacing traditional methods (K Shrivastav., 2024). In cases where conventional identifiers are unavailable, such as unidentified deceased individuals, alternative methods like tattoos, dental records, and serological examinations can be employed (Mahila, 2024). Forensic anthropology further enhances identification through the analysis of skeletal remains, utilizing unique morphological features and advanced imaging techniques to establish identity (SN Buyers) (Adserias-Garriga et al., 2024). Anthropometry involves measuring physical dimensions of the human body to establish identity, particularly in forensic contexts, which includes stature, race, sex, and age, essential for identifying unknown individuals in forensic contexts. Stature estimation often relies on various anthropometric measurements, such as long bone lengths and specific skeletal features, with studies indicating that sex and population differences significantly influence these estimates (Usman et al., 2024) (Kamnikar et al., 2024).

In forensic anthropology, cephalofacial measurements serve as vital alternatives for stature estimation, especially in cases where long bones are unavailable and only craniofacial remains are present. Commonly utilized parameters include maximum head length (MHL), horizontal head circumference (HHC), morphological facial length (MFL), and bigonial diameter (BD). Studies indicate a significant positive correlation between these measurements and stature across various populations, with MHL often showing the strongest correlation, particularly in Indian and African cohorts (Nair et al., 2022) (Varghese et al., 2022) (Reddy et al., 2018). While cephalic measurements generally provide more reliable stature estimates than facial measurements, the effectiveness of specific parameters can vary by population and sex, necessitating population-specific regression equations for accurate estimations (Nair et al., 2022) (Reddy et al., 2018). Ancestry and population specificity significantly influence the accuracy of stature estimation models, as evidenced by various studies. For instance, Boonthai et al. developed population-specific equations for a Northeastern Thai cohort, revealing notable sexual dimorphism in stature and bone lengths, which underscores the necessity of tailored models for different ethnic groups (Boonthai et al., 2024). Similarly, Bidmos and Brits found that generic stature estimation equations underestimated living stature in a South African sample, emphasizing the superiority of sex- and population-specific equations for accurate estimations (Bidmos & Brits, 2024). Kamnikar et al. provided equations for contemporary American Indians, demonstrating that sex-specific models yielded better accuracy than general models, further supporting the need for population-specific approaches (Kamnikar et al., 2024). Also, Usman et al. highlighted the importance of considering anthropometric variations across different populations, as their regression models showed varying degrees of reliability based on specific measurements (Usman et al., 2024). Collectively, these findings illustrate that ancestry and population specificity are critical for enhancing the precision of stature estimations in forensic anthropology.

Previous studies on stature estimation in Indian populations, including Rajputs and other ethnic groups, have utilized various anthropometric measurements to develop population-specific regression equations. For instance, research on scapular measurements in Northern India demonstrated that these could accurately estimate stature, with prediction errors ranging from 3.99 to 5.27 cm for males and females, respectively (K et al., 2023). Another study focused on coccygeal measurements in Northwest India, establishing regression equations that are particularly useful in forensic contexts where long bones are unavailable (Singh et al., 2022). Facial anthropometry has been explored, revealing strong correlations between facial dimensions and stature, although caution is advised due to population specificity (Yadav et al., 2019). Furthermore, a comprehensive analysis of stature across various Indian ethnic groups highlighted significant regional and ethnic variations, with factors such as nutrition and socio-economic status playing crucial roles in determining height (Gautam et al., 2018). These findings underscore the complexity of stature estimation in diverse Indian populations.

Environmental, genetic, and nutritional factors significantly influence cephalon-facial morphology and its correlation with stature. Genetic studies indicate that craniofacial traits exhibit substantial heritability, with estimates ranging from 55% to 81% for various measurements, suggesting a strong genetic basis for cephalometric variables (Šidlauskienė et al., 2023) (Ghosh et al., 2021) (Hersberger-Zurfluh et al., 2021).

Endogamous communities often exhibit higher levels of homozygosity, which can influence the prevalence of genetic disorders and complicate the biological profiling of individuals, such as estimating age, sex, and ancestry from skeletal remains (Bittles, 2005). This is particularly relevant in cases involving marginalized groups, such as transgender individuals, where traditional methods may not adequately address unique anatomical variations resulting from surgical interventions (Palamenghi et al., 2023). In Gujarat, there is a notable scarcity of anthropometric studies focusing on endogamous communities, despite their distinct genetic, morphological, and socio-cultural characteristics.

This study specifically examines the Rajput community of Gujarat, an endogamous group with unique cephalo-facial traits, making this research significant for understanding population-specific variations in stature estimation. This study aims to develop and evaluate population-specific stature estimation models using cephalo-facial measurements in the Gujarati Rajput population. By analyzing the correlation between craniofacial dimensions and stature, this research seeks to enhance the accuracy of forensic anthropological identification, particularly in cases where long bones are unavailable.

MATERIAL AND METHODOLOGY

Study Population and Sample Size:

The study was conducted on the Gujarati Rajput population, an endogamous community in Gujarat, India. A total of 429 adult individuals (201 males and 228 females), aged 18-35 years, were recruited through random stratified sampling to ensure demographic representation. Participants with skeletal deformities, history of major injuries, or medical conditions affecting growth were excluded from the study. Informed consent was obtained from all participants before their inclusion in the study. The consent process involved providing participants with detailed information regarding the study's objectives, methodology, potential risks, and benefits. All the measurements were taken between 12-5 pm to avoid Diurnal Variation. Diurnal variation refers to the fluctuations or changes that occur in various physiological and anatomical measurements throughout the day.

Anthropometric Data Collection:

Anthropometric measurements were obtained using a Spreading Caliper and Anthropometric Rod. 10 Cephalofacial measurements along with stature were obtained.

1. **Stature:** Measured using a stadiometer with participants standing barefoot, head aligned in the Frankfort horizontal plane**.**

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2. **Maximum Head Length (g-op):** It measures the straight distance between glabella (g) and opisthocranion (op), i.e., the most protruding point on the dorsal surface of the head in the mid-saggital plane.
3. **Maximum Head Breadth (eu-eu):** It measures the straight distance between the two eurya (eu_1-eu_2).
4. **Breadth of Bizygomatic Arch (zy-zy):** It measures the direct distance between the two most lateral points on the zygomatic arches (zy_1-zy_2).
5. **Biocular Breadth:** Biocular Breadth is the distance from the outer corner of the right eye to the outer corner of the left eye or vice versa.
6. **Bi-Gonial Breadth (go-go):** It measures the straight distance between the two gonia (go_1-go_2), rounded posteroinferior corner of the mandible between ramus and the body.
7. **Physiognomic Facial Height (tr-gn):** It measures the straight distance between trichion (tr) and gnathion (gn).
8. **Left Ectocanthion to Trichion Height (ec2-tr):** It measures the distance between trichion (tr) and ectocanthion (ec).
9. **Left Ectocanthion to Gnathion Height (ec2-gn):** It measures the distance between gnathion (gn) and ectocanthion (ec).
10. **Morphological Facial Height (n-gn):** Measurement of the straight distance between nasion (n) and gnathion (gn).
11. **Total Head Height (v-gn):** Measurements of the projective distance between vertex (v) and gnathion (gn).

Statistical Analysis

The collected anthropometric data were systematically recorded and organized using Microsoft Excel, ensuring accuracy and consistency in data management. The dataset was then exported to SPSS 26.0.0 for comprehensive statistical analysis.

The statistical evaluation included the following:

- Descriptive Statistics: Mean, standard deviation, minimum and maximum values, and ranges were calculated to summarize the central tendency and dispersion of stature and craniofacial measurements.
- Correlation Analysis: Pearson's correlation coefficient (r) was used to determine the strength and direction of the relationship between stature and various craniofacial parameters, assessing their statistical significance.
- Regression Analysis:
  - Simple linear regression was applied to establish predictive equations for stature estimation based on individual craniofacial measurements.
  - Multiple linear regression was conducted to enhance the predictive accuracy by incorporating multiple craniofacial parameters simultaneously, identifying the most reliable model for stature estimation.

RESULTS AND DISCUSSION

For the present study, Measurements taken from 428 healthy adults (201-Male and 228-Female) from age group of 18-35 from Gujarati Rajput Population.

Variables	Minimum	Maximum	Mean		Std. Deviation
	Statistic	Statistic	Statistic	Std. Error	Statistic
Stature	151.48	199.40	172.81	.37565	5.325
Head length	15.40	20.27	17.86	.07126	1.010
Head breadth	10.53	17.76	13.87	.08492	1.203
Biocular Breadth	10.19	13.62	11.99	.04109	.582
Bizygomatic Breadth	11.62	15.19	13.48	.04353	.617
Bigonial Breadth	8.71	13.80	10.83	.06721	.952
Morphological Facial Height	9.45	17.40	11.64	.07048	.999
Total Head Height	17.96	25.88	22.52	.06802	.964
Physiognomic Facial Height	15.60	20.05	17.51	.05416	.767
Left ectocanthion to trichion height	7.61	18.03	10.57	.07102	1.006
Left ectocanthion to gnathion height	10.25	15.08	11.93	.04582	.649

Table 1: Descriptive Statistics of Male from Gujarati Rajput Population

Table 1 presents the descriptive statistics of various anthropometric measurements for Gujarati Rajput males, including stature, head dimensions, and facial measurements. The stature of individuals ranges from 151.48 cm to 199.40 cm, with a mean of 172.81 cm and a standard deviation of 5.325 cm, indicating moderate variation. Among the head dimensions, head length varies between 15.40 cm and 20.27 cm (Mean: 17.86 cm, SD: 1.010

cm), while head breadth ranges from 10.53 cm to 17.76 cm (Mean: 13.87 cm, SD: 1.203 cm), showing moderate differences among individuals. Facial measurements exhibit relatively lower variability. Biocular breadth has a mean of 10.57 cm (SD: 0.582 cm), while bizygomatic breadth averages 13.80 cm (SD: 0.617 cm). Bigonial breadth shows slightly more variation, with a mean of 10.83 cm (SD: 0.952 cm). The morphological facial height (Nasion to Gnathion) ranges from 9.45 cm to 17.40 cm (Mean: 11.64 cm, SD: 0.999 cm), suggesting a moderate level of diversity. Total head height ranges between 17.96 cm and 25.88 cm (Mean: 22.52 cm, SD: 0.964 cm), while physiognomic facial height (Trichion to Gnathion) remains relatively stable, with a mean of 17.51 cm (SD: 0.767 cm). Specific facial height parameters, such as ectocanthion to trichion height, show greater variability (Mean: 10.57 cm, SD: 1.006 cm), while ectocanthion to gnathion height ranges from 10.25 cm to 15.08 cm (Mean: 11.93 cm, SD: 0.649 cm). Overall, the results indicate moderate variation in stature and head dimensions, whereas facial measurements remain relatively stable, reflecting population-specific craniofacial characteristics

Variables	Minimum	Maximum	Mean		Std. Deviation
	Statistic	Statistic	Statistic	Std. Error	Statistic
Stature	142.6	175.5	157.157	.3645	5.5037
Head length	13.1	20.0	17.034	.0514	.7759
Head breadth	10.3	14.8	13.282	.0390	.5885
Biocular Breadth	10.0	13.0	11.305	.0355	.5353
Bizygomatic Breadth	11.0	13.9	12.372	.0383	.5784
Bigonial Breadth	7.2	14.0	9.363	.0643	.9702
Morphological Facial Height	8.7	12.2	10.343	.0356	.5371
Total Head Height	18.4	23.6	20.825	.0571	.8619
Physiognomic Facial Height	13.5	18.0	15.975	.0572	.8640
Left ectocanthion to trichion height	8.0	12.0	9.557	.0415	.6262
Left ectocanthion to gnathion height	9.5	12.4	10.668	.0408	.6158

Table 2: Descriptive Statistics of Female from Gujarati Rajput Population

The descriptive statistics for Gujarati Rajput females highlight variations in stature, cranial dimensions, and facial features. Stature ranges from 142.6 cm to 175.5 cm, with a mean of 157.157 cm and moderate variation (SD = 5.5037 cm), influenced by genetic and environmental factors. Cranial dimensions show relative consistency, with head length (Mean: 17.034 cm, SD: 0.7759 cm) and head breadth (Mean: 13.282 cm, SD: 0.5885 cm) displaying minimal variation. Facial width measurements, including biocular breadth (Mean: 11.305 cm, SD: 0.5353 cm) and bizygomatic breadth (Mean: 12.372 cm, SD: 0.5784 cm), indicate stability in transverse facial proportions.
The bigonial breadth (jaw width) exhibits higher variability (Mean: 9.363 cm, SD: 0.9702 cm), suggesting greater individual differences in jaw structure. Morphological facial height (Mean: 10.343 cm, SD: 0.5371 cm) and total head height (Mean: 20.825 cm, SD: 0.8619 cm) show moderate consistency. Physiognomic facial height (Mean: 15.975 cm, SD: 0.8640 cm) has slightly higher variability than other facial height parameters. Ectocanthion to trichion height (Mean: 9.557 cm, SD: 0.6262 cm) and ectocanthion to gnathion height (Mean: 10.668 cm, SD: 0.6158 cm) display minimal variation, indicating relative uniformity in facial proportions.
Overall, stature and Bigonial breadth show the highest variability, while cranial and facial width measurements remain relatively stable, reflecting population-specific anthropometric trends.

Variables	Minimum	Maximum	Mean		Std. Deviation
	Statistic	Statistic	Statistic	Std. Error	Statistic
Stature	142.60	199.40	164.4932	.45931	9.51335
Head length	13.10	20.27	17.4253	.04756	.98518
Head breadth	10.30	17.76	13.5602	.04703	.97401
Biocular Breadth	10.00	13.62	11.6271	.03161	.65473
Bizygomatic Breadth	11.00	15.19	12.8951	.03942	.81647
Bigonial Breadth	7.20	14.00	10.0519	.05841	1.20971
Morphological Facial Height	8.70	17.40	10.9521	.04926	1.02019
Total Head Height	17.96	25.88	21.6203	.06006	1.24403
Physiognomic Facial Height	13.50	20.05	16.6948	.05421	1.12273
Left ectocanthion to trichion height	7.61	18.03	10.0354	.04686	.97050
Left ectocanthion to gnathion height	9.50	15.08	11.2624	.04318	.89441

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Table 3 describes the descriptive statistics of Gujarati Rajput individuals highlight variations in stature, cranial dimensions, and facial measurements. Stature ranges from 142.60 cm to 199.40 cm (Mean: 164.49 cm, SD: 9.51 cm), showing substantial variation. Cranial measurements display moderate variability, with head length (Mean: 17.42 cm, SD: 0.98 cm) and head breadth (Mean: 13.56 cm, SD: 0.97 cm) remaining relatively stable.

Facial width parameters, including biocular breadth (Mean: 11.63 cm, SD: 0.65 cm) and bizygomatic breadth (Mean: 12.90 cm, SD: 0.82 cm), show low to moderate variation. Bigonial breadth (Mean: 10.05 cm, SD: 1.21 cm) and morphological facial height (Mean: 10.95 cm, SD: 1.02 cm) exhibit greater individual differences. Total head height (Mean: 21.62 cm, SD: 1.24 cm) and physiognomic facial height (Mean: 16.69 cm, SD: 1.12 cm) indicate some variability across individuals.

Table 3: Descriptive Statistics of Gujarati Rajput Population

Specific facial height parameters, such as ectocanthion to trichion and ectocanthion to gnathion distances, show moderate variation (SD: 0.97 cm and 0.89 cm, respectively). Overall, stature and jaw width show the highest variability, while cranial and facial width remain relatively stable, reflecting population-specific anthropometric trends.		Stature	Head length	Head breadth	Biocular Breadth	Bizygomatic Breadth	Bigonial Breadth	Morphological Facial Height	Total Head Height	Physiognomic Facial Height	Left ectocanthion to trichion height	Left ectocanthion to gnathion height
Stature	Pearson Correlation	1	.230**	.128	.147*	.238**	.198**	.211**	.291**	.259**	.207**	.246**
	Sig. (2-tailed)		.001	.069	.037	.001	.005	.003	.000	.000	.003	.000
	N	201	201	201	201	201	201	201	201	201	201	201

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Head length	Pearson Correlation	.230**	1	.037	.366**	.442**	.277**	.245**	.163*	.155*	.101	-.122
	Sig. (2-tailed)	.001		.598	.000	.000	.000	.000	.021	.028	.154	.084
	N	201	201	201	201	201	201	201	201	201	201	201
Head breadth	Pearson Correlation	.128	.037	1	.409**	.197**	.266**	.163*	.165*	.099	.154*	.122
	Sig. (2-tailed)	.069	.598		.000	.005	.000	.021	.020	.161	.029	.084
	N	201	201	201	201	201	201	201	201	201	201	201
Biocular Breadth	Pearson Correlation	.147*	.366**	.409**	1	.437**	.328**	.162*	.169*	.131	.141*	.173*
	Sig. (2-tailed)	.037	.000	.000		.000	.000	.021	.017	.063	.046	.014
	N	201	201	201	201	201	201	201	201	201	201	201
Bizygomatic Breadth	Pearson Correlation	.238**	.442**	.197**	.437**	1	.524**	.174*	.163*	.343**	.228**	.168*
	Sig. (2-tailed)	.001	.000	.005	.000		.000	.013	.021	.000	.001	.017
	N	201	201	201	201	201	201	201	201	201	201	201
Bigonial Breadth	Pearson Correlation	.198**	.277**	.266**	.328**	.524**	1	.159*	.183**	.291**	.178*	.168*
	Sig. (2-tailed)	.005	.000	.000	.000	.000		.024	.009	.000	.012	.017
	N	201	201	201	201	201	201	201	201	201	201	201
Morphological Facial Height	Pearson Correlation	.211**	.245**	.163*	.162*	.174*	.159*	1	.448**	.508**	.252**	.441**
	Sig. (2-tailed)	.003	.000	.021	.021	.013	.024		.000	.000	.000	.000
	N	201	201	201	201	201	201	201	201	201	201	201
Total Head Height	Pearson Correlation	.291**	.163*	.165*	.169*	.163*	.183**	.448**	1	.472**	.273**	.531**
	Sig. (2-tailed)	.000	.021	.020	.017	.021	.009	.000		.000	.000	.000
	N	201	201	201	201	201	201	201	201	201	201	201
Physiognomic Facial Height	Pearson Correlation	.259**	.155*	.099	.131	.343**	.291**	.508**	.472**	1	.350**	.573**
	Sig. (2-tailed)	.000	.028	.161	.063	.000	.000	.000	.000		.000	.000
	N	201	201	201	201	201	201	201	201	201	201	201
Left ectocanthion to trichion height	Pearson Correlation	.207**	.101	.154*	.141*	.228**	.178*	.252**	.273**	.350**	1	.465**
	Sig. (2-tailed)	.003	.154	.029	.046	.001	.012	.000	.000	.000		.000
	N	201	201	201	201	201	201	201	201	201	201	201
Left ectocanthion to	Pearson Correlation	.246**	-.122	.122	.173*	.168*	.168*	.441**	.531**	.573**	.465**	1

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gnathion height	Sig. (2-tailed)	.000	.084	.084	.014	.017	.017	.000	.000	.000	.000	
	N	201	201	201	201	201	201	201	201	201	201	201
**. Correlation is significant at the 0.01 level (2-tailed).												
*. Correlation is significant at the 0.05 level (2-tailed).												

Table 4: Pearson's Correlation coefficient for Gujarati Rajput Male

The Pearson correlation analysis reveals significant relationships between stature and craniofacial measurements, highlighting their role in stature estimation. A statistically significant positive correlation is observed between stature and maximum head length (r = 0.230, p = 0.001), suggesting that individuals with longer head dimensions tend to be taller. Bizygomatic breadth (r = 0.238, p = 0.001) and bigonial breadth (r = 0.198, p = 0.005) also exhibit moderate correlations with stature, indicating that wider facial structures are associated with greater height. Among all variables, total head height (r = 0.291, p = 0.000) and physiognomic facial height (r = 0.259, p = 0.000) show the strongest correlations with stature, reinforcing their importance in forensic stature estimation. Additionally, ectocanthion to gnathion height (r = 0.246, p = 0.000) and ectocanthion to trichion height (r = 0.207, p = 0.003) exhibit moderate correlations, indicating the influence of vertical facial proportions on stature prediction.

Interrelationships among craniofacial measurements further support these findings. Maximum head length strongly correlates with bizygomatic breadth (r = 0.442, p = 0.000) and biocular breadth (r = 0.366, p = 0.000), suggesting a direct association between cranial size and facial width. Similarly, bizygomatic breadth and bigonial breadth (r = 0.524, p = 0.000) highlight the proportional relationship between the upper and lower facial regions. The correlation between morphological and physiognomic facial height (r = 0.508, p = 0.000) further indicates that vertical facial dimensions are interdependent and contribute significantly to stature estimation models.

Overall, the study confirms that total head height, physiognomic facial height, and bizygomatic breadth are among the strongest predictors of stature, while biocular breadth and ectocanthion to trichion height show weaker but notable associations. The statistical significance of these correlations (p < 0.01 for strong correlations, p < 0.05 for moderate ones) ensures the reliability of these findings in forensic and anthropological applications.

		Stature	**Head length**	**Head breadth**	**Biocular Breadth**	**Bizygomatic Breadth**	**Bigonial Breadth**	**Morphological Facial Height**	**Total Head Height**	**Physiognomic Facial Height**	**Left ectocanthion to trichion height**	**Left ectocanthion to gnathion height**
Stature	Pearson Correlation	1	.233**	-.014	.280**	.205**	.155*	.205**	.368**	.248**	.088	.174**
	Sig. (2-tailed)		.000	.835	.000	.002	.019	.002	.000	.000	.188	.009
	N	228	228	228	228	228	228	228	228	228	228	228
Head length	Pearson Correlation	.233**	1	.070	.460**	.375**	.444**	.232**	.368**	.329**	.102	.033
	Sig. (2-tailed)	.000		.294	.000	.000	.000	.000	.000	.000	.125	.618
	N	228	228	228	228	228	228	228	228	228	228	228
Head breadth	Pearson Correlation	-.014	.070	1	.039	-.170**	-.019	-.032	.127	.102	.051	.103
	Sig. (2-tailed)	.835	.294		.555	.010	.774	.635	.056	.125	.445	.121
	N	228	228	228	228	228	228	228	228	228	228	228
Biocular Breadth	Pearson Correlation	.280**	.460**	.039	1	.667**	.450**	.244**	.324**	.236**	.102	.206**
	Sig. (2-tailed)	.000	.000	.555		.000	.000	.000	.000	.000	.126	.002
	N	228	228	228	228	228	228	228	228	228	228	228

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Bizygomatic Breadth	Pearson Correlation	.205**	.375**	-.170**	.667**	1	.457**	.254**	.275**	.233**	.170*	.238**
	Sig. (2-tailed)	.002	.000	.010	.000		.000	.000	.000	.000	.010	.000
	N	228	228	228	228	228	228	228	228	228	228	228
Bigonial Breadth	Pearson Correlation	.155*	.444**	-.019	.450**	.457**	1	.246**	.342**	.327**	.282**	.171**
	Sig. (2-tailed)	.019	.000	.774	.000	.000		.000	.000	.000	.000	.010
	N	228	228	228	228	228	228	228	228	228	228	228
Morphological Facial Height	Pearson Correlation	.205**	.232**	-.032	.244**	.254**	.246**	1	.444**	.390**	.071	.287**
	Sig. (2-tailed)	.002	.000	.635	.000	.000	.000		.000	.000	.284	.000
	N	228	228	228	228	228	228	228	228	228	228	228
Total Head Height	Pearson Correlation	.368**	.368**	.127	.324**	.275**	.342**	.444**	1	.605**	.356**	.411**
	Sig. (2-tailed)	.000	.000	.056	.000	.000	.000	.000		.000	.000	.000
	N	228	228	228	228	228	228	228	228	228	228	228
Physiognomic Facial Height	Pearson Correlation	.248**	.329**	.102	.236**	.233**	.327**	.390**	.605**	1	.558**	.450**
	Sig. (2-tailed)	.000	.000	.125	.000	.000	.000	.000	.000		.000	.000
	N	228	228	228	228	228	228	228	228	228	228	228
Left ectocanthion to trichion height	Pearson Correlation	.088	.102	.051	.102	.170*	.282**	.071	.356**	.558**	1	.586**
	Sig. (2-tailed)	.188	.125	.445	.126	.010	.000	.284	.000	.000		.000
	N	228	228	228	228	228	228	228	228	228	228	228
Left ectocanthion to gnathion height	Pearson Correlation	.174**	.033	.103	.206**	.238**	.171**	.287**	.411**	.450**	.586**	1
	Sig. (2-tailed)	.009	.618	.121	.002	.000	.010	.000	.000	.000	.000	
	N	228	228	228	228	228	228	228	228	228	228	228
**. Correlation is significant at the 0.01 level (2-tailed).												
*. Correlation is significant at the 0.05 level (2-tailed).												

Table 5: Pearson's Correlation coefficient for Gujarati Rajput Female

The Pearson correlation analysis highlights significant relationships between stature and craniofacial measurements, emphasizing their role in stature estimation. A statistically significant positive correlation is observed between stature and maximum head length ($r = 0.233$, $p = 0.000$), suggesting that individuals with longer heads tend to have greater stature. Biocular breadth ($r = 0.280$, $p = 0.000$) and bizygomatic breadth ($r = 0.205$, $p = 0.002$) also exhibit moderate correlations, indicating that facial width contributes to stature estimation.

Among all parameters, total head height ($r = 0.368$, $p = 0.000$) shows one of the strongest correlations, making it highly relevant in forensic stature estimation. Physiognomic facial height ($r = 0.248$, $p = 0.000$) and morphological facial height ($r = 0.205$, $p = 0.002$) also demonstrate significant associations, reinforcing the role of vertical facial dimensions in stature prediction. However, maximum head breadth ($r = -0.014$, $p = 0.835$) and ectocanthion to trichion height ($r = 0.088$, $p = 0.188$) show no significant correlation, suggesting minimal influence on stature.

Interrelationships among craniofacial measurements further support these findings. Maximum head length strongly correlates with bizygomatic breadth ($r = 0.375$, $p = 0.000$) and biocular breadth ($r = 0.460$, $p = 0.000$), indicating an association between cranial and facial width. Similarly, bizygomatic breadth and bigonial breadth (r

= 0.457, p = 0.000) highlight the proportional relationship between midfacial and mandibular width. The strong correlation between total head height and physiognomic facial height (r = 0.605, p = 0.000) further confirms the interdependence of vertical facial dimensions.

Overall, stature exhibits the strongest correlations with total head height, biocular breadth, and physiognomic facial height, while weaker but significant associations exist for bizygomatic breadth and bigonial breadth. The statistical significance ($p < 0.01$ for strong correlations, $p < 0.05$ for moderate ones) confirms the reliability of these findings in forensic and anthropological applications.

Variables		**Stature**	**Head length**	**Head breadth**	**Biocular Breadth**	**Bizygomatic Breadth**	**Bigonial Breadth**	**Morphological Facial Height**	**Total Head Height**	**Physiognomic Facial Height**	**Left ectocanthion to trichion height**	**Left ectocanthion to gnathion height**
Stature	Pearson Correlation	1	.466**	.289**	.536**	.654**	.578**	.610**	.698**	.667**	.506**	.666**
	Sig. (2-tailed)		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	429	429	429	429	429	429	429	429	429	429	429
Head length	Pearson Correlation	.466**	1	.169**	.536**	.561**	.511**	.436**	.456**	.446**	.300**	.267**
	Sig. (2-tailed)	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	429	429	429	429	429	429	429	429	429	429	429
Head breadth	Pearson Correlation	.289**	.169**	1	.380**	.255**	.301**	.280**	.309**	.272**	.263**	.289**
	Sig. (2-tailed)	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000
	N	429	429	429	429	429	429	429	429	429	429	429
Biocular Breadth	Pearson Correlation	.536**	.536**	.380**	1	.701**	.583**	.456**	.510**	.475**	.365**	.486**
	Sig. (2-tailed)	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000
	N	429	429	429	429	429	429	429	429	429	429	429
Bizygomatic Breadth	Pearson Correlation	.654**	.561**	.255**	.701**	1	.698**	.545**	.582**	.617**	.484**	.589**
	Sig. (2-tailed)	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000
	N	429	429	429	429	429	429	429	429	429	429	429
Bigonial Breadth	Pearson Correlation	.578**	.511**	.301**	.583**	.698**	1	.499**	.567**	.596**	.465**	.525**
	Sig. (2-tailed)	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000
	N	429	429	429	429	429	429	429	429	429	429	429
Morphological Facial Height	Pearson Correlation	.610**	.436**	.280**	.456**	.545**	.499**	1	.679**	.678**	.467**	.653**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000
	N	429	429	429	429	429	429	429	429	429	429	429
Total Head Height	Pearson Correlation	.698**	.456**	.309**	.510**	.582**	.567**	.679**	1	.754**	.545**	.727**

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	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000
	N	429	429	429	429	429	429	429	429	429	429	429
Physiognomic Facial Height	Pearson Correlation	.667**	.446**	.272**	.475**	.617**	.596**	.678**	.754**	1	.622**	.744**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000
	N	429	429	429	429	429	429	429	429	429	429	429
Left ectocanthion to trichion height	Pearson Correlation	.506**	.300**	.263**	.365**	.484**	.465**	.467**	.545**	.622**	1	.674**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000
	N	429	429	429	429	429	429	429	429	429	429	429
Left ectocanthion to gnathion height	Pearson Correlation	.666**	.267**	.289**	.486**	.589**	.525**	.653**	.727**	.744**	.674**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	
	N	429	429	429	429	429	429	429	429	429	429	429
**. Correlation is significant at the 0.01 level (2-tailed).												

Table 6: Pearson's Correlation coefficient for Gujarati Rajput Population

The Pearson correlation coefficients between stature and various craniofacial measurements provide critical insights into the interrelationship between skeletal dimensions and stature in the Gujarati Rajput population. A highly significant positive correlation is observed between stature and maximum head length ($r = 0.466$, $p = 0.000$), indicating that individuals with greater head length tend to exhibit increased stature. The correlation between maximum head breadth and stature ($r = 0.289$, $p = 0.000$), though statistically significant, is weaker, suggesting that head breadth contributes less to stature estimation. Biocular breadth ($r = 0.536$, $p = 0.000$) exhibits a strong correlation with stature, reinforcing its importance in predictive anthropometric models.

A substantial correlation exists between bizygomatic breadth and stature ($r = 0.654$, $p = 0.000$), highlighting the influence of midfacial width in determining stature. Similarly, bigonial breadth ($r = 0.578$, $p = 0.000$) demonstrates a strong association with stature, suggesting that mandibular width plays a considerable role in forensic stature estimation. Morphological facial height ($r = 0.610$, $p = 0.000$) exhibits a highly significant correlation with stature, emphasizing the relationship between vertical craniofacial dimensions and overall stature. Among the craniofacial parameters, total head height ($r = 0.698$, $p = 0.000$) presents the strongest correlation with stature, establishing its prominence as a key predictor in forensic anthropological analyses.

Physiognomic facial height ($r = 0.667$, $p = 0.000$) also demonstrates a robust correlation with stature, indicating that greater physiognomic facial height is strongly associated with increased stature. The correlation between left ectocanthion to trichion height ($r = 0.506$, $p = 0.000$) and stature is statistically significant, though weaker in comparison to other parameters, suggesting that upper facial height has a moderate impact on stature estimation. In contrast, left ectocanthion to gnathion height ($r = 0.666$, $p = 0.000$) exhibits a strong correlation, further supporting the role of facial height in predictive stature models.

Inter-correlations among craniofacial measurements reveal key structural relationships. Maximum head length correlates significantly with bizygomatic breadth ($r = 0.561$, $p = 0.000$) and biocular breadth ($r = 0.536$, $p = 0.000$), reinforcing the relationship between cranial dimensions and facial width. Bizygomatic breadth significantly correlates with bigonial breadth ($r = 0.698$, $p = 0.000$), demonstrating that individuals with broader midfaces tend to have wider mandibles.

Further, morphological facial height exhibits a strong correlation with physiognomic facial height ($r = 0.678$, $p = 0.000$), confirming the interdependence of vertical facial proportions. The correlation between total head height and physiognomic facial height ($r = 0.754$, $p = 0.000$) further supports the integration of these craniofacial dimensions in stature estimation models. Statistical significance levels indicate that stature maintains highly significant correlations ($p < 0.01$) with all craniofacial parameters analyzed, suggesting that a comprehensive approach incorporating multiple craniofacial measurements enhances the accuracy of stature estimation.

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❖ **Linear Regression Analysis for Stature:**

Variable Name	Sig. (p-value)	Equation	SEE
Head Length	0.001	151.150 + 1.212 * Head Length	5.19
Head Breadth	0.069	164.931 + 0.568 * Head Breadth	5.29
Biocular Breadth	0.037	156.655 + 1.347 * Biocular Breadth	5.28
Bizygomatic Breadth	0.001	145.061 + 2.058 * Bizygomatic Breadth	5.18
Bigonial Breadth	0.005	160.821 + 1.107 * Bigonial Breadth	5.23
Morphological Facial Height	0.003	159.720 + 1.125 * Morphological Facial Height	5.21
Total Head Height	0.000	136.587 + 1.609 * Total Head Height	5.10
Physiognomic Facial Height	0.000	141.314 + 1.799 * Physiognomic Facial Height	5.15
Left Ectocanthion to Trichion Height	0.003	161.225 + 1.096 * Left Ectocanthion to Trichion Height	5.22
Left Ectocanthion to Gnathion Height	0.000	148.787 + 2.013 * Left Ectocanthion to Gnathion Height	5.17

Table 7: Univariant Regression Analysis for Gujarati Rajput Male

The univariate linear regression analysis for stature estimation in Gujarati Rajput males demonstrates the predictive potential of craniofacial measurements. Among the variables, Total Head Height ($p < 0.001$, $\beta = 0.291$) emerges as the strongest predictor, indicating that individuals with greater head height tend to be taller. Bizygomatic Breadth ($p = 0.001$, $\beta = 0.238$) and Left Ectocanthion to Gnathion Height ($p < 0.001$, $\beta = 0.246$) also show significant correlations, reinforcing the importance of cranial width and facial height in stature estimation.

Conversely, Head Breadth ($p = 0.069$) does not exhibit statistical significance, suggesting a minimal role in stature prediction, potentially due to genetic or environmental factors. Other variables, including Biocular Breadth, Bigonial Breadth, Morphological Facial Height, Physiognomic Facial Height, and Left Ectocanthion to Trichion Height, demonstrate moderate but significant correlations ($p < 0.05$), indicating their relevance in multivariate predictive models.

Despite the statistical significance of most variables, the Standard Error of Estimation (SEE) ranges from 5.1 to 5.3 cm, highlighting a margin of error that should be accounted for. This suggests that stature estimation models would benefit from incorporating additional anthropometric parameters for greater accuracy. The findings underscore the importance of cranial dimensions in forensic anthropology and medico-legal identification, supporting the use of facial and head measurements in stature reconstruction. Future studies incorporating multivariate models could further refine these estimates, enhancing their precision in forensic and anthropological applications.

Sex	**Sig. (p-value)**	**Equation**	**SEE**
Male	0.000	108.072 + 0.991 * Head Length + 0.303 * Head Breadth - 0.486 * Biocular Breadth + 0.667 * Bizygomatic Breadth + 0.215 * Bigonial Breadth - 0.061 * Morphological Facial Height + 0.776 * Total Head Height + 0.256 * Physiognomic Facial Height + 0.258 * Left Ectocanthion to Trichion Height + 1.118 * Left Ectocanthion to Gnathion Height	5.00

The statistical significance of the model, as indicated by the p-value (0.000), confirms that the overall regression equation is highly significant,

Table 8: Multivariant Regression Analysis for Gujarati Rajput Male

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meaning that the included craniofacial variables collectively provide a meaningful estimation of stature. The regression equation represents the relationship between stature and various craniofacial dimensions. Each coefficient in the equation reflects the expected change in stature for a one-unit increase in the corresponding measurement while holding other variables constant. Among these, Head Length (0.991), Bizygomatic Breadth (0.667), and Left Ectocanthion to Gnathion Height (1.118) show higher coefficients, indicating a stronger impact on stature prediction. Interestingly, Biocular Breadth (-0.486) and Morphological Facial Height (-0.061) have negative coefficients, which could suggest that variations in these measurements contribute inversely to stature when considered along with other predictors.

The Standard Error of Estimation (SEE = 5.00) indicates the average deviation between the predicted and actual stature values. A lower SEE suggests a more accurate prediction model. Compared to univariate regression models, the multivariate model improves accuracy, as it explains a larger proportion of variability in stature by considering multiple craniofacial dimensions simultaneously.

Overall, the results demonstrate that a combination of craniofacial measurements can enhance stature estimation, making this model useful in forensic anthropology, medico-legal investigations, and human identification cases. However, while the model is statistically significant, some variables exhibit weaker associations, as seen in their relatively small or negative coefficients. Future research could explore population-specific variations and integrate additional skeletal or soft tissue markers to further refine stature estimation models.

Variable Name	**Sig. (p-value)**	**Equation**	**SEE**
Head Length	0.000	129.001 + 1.653 * Head Length	5.36
Head Breadth	0.835	158.881 - 0.130 * Head Breadth	5.51
Biocular Breadth	0.000	124.609 + 2.879 * Biocular Breadth	5.29
Bizygomatic Breadth	0.002	132.996 + 1.953 * Bizygomatic Breadth	5.39
Bigonial Breadth	0.019	148.910 + 0.881 * Bigonial Breadth	5.44
Morphological Facial Height	0.002	135.464 + 2.097 * Morphological Facial Height	5.39
Total Head Height	0.000	108.168 + 2.352 * Total Head Height	5.12
Physiognomic Facial Height	0.000	131.925 + 1.580 * Physiognomic Facial Height	5.34
Left Ectocanthion to Trichion Height	0.188	149.807 + 0.769 * Left Ectocanthion to Trichion Height	5.49
Left Ectocanthion to Gnathion Height	0.009	140.582 + 1.554 * Left Ectocanthion to Gnathion Height	5.43

Table 9:: Univariant Regression Analysis for Gujarati Rajput Female

Table presents univariate linear regression analysis for stature estimation in Gujarati Rajput females examines the predictive relationship between craniofacial measurements and stature. Several variables, including Head Length ($p < 0.001$), Biocular Breadth ($p < 0.001$), Bizygomatic Breadth ($p = 0.002$), Bigonial Breadth ($p = 0.019$), Morphological Facial Height ($p = 0.002$), Total Head Height ($p < 0.001$), Physiognomic Facial Height ($p < 0.001$), and Left Ectocanthion to Gnathion Height ($p = 0.009$), show statistically significant correlations with stature. Among these, Total Head Height (B = 2.352) and Biocular Breadth (B = 2.879) exhibit the strongest influence on stature prediction.

Conversely, Head Breadth ($p = 0.835$) and Left Ectocanthion to Trichion Height ($p = 0.188$) do not show statistical significance, suggesting their minimal role in stature estimation. The negative coefficient for Head Breadth (-0.130) implies an inverse relationship with stature, but its lack of statistical significance renders this effect unreliable. The Standard Error of Estimation (SEE) ranges from 5.12 to 5.51 cm, with Total Head Height providing the most precise predictions (SEE = 5.12 cm).

Overall, these findings confirm that craniofacial measurements can be effective predictors of stature, particularly Total Head Height and Biocular Breadth. However, the moderate SEE values suggest limitations when relying on single-variable regression models. Multivariate models incorporating multiple craniofacial parameters would likely enhance predictive accuracy. Future research should explore population-specific variations and refine regression models to improve their forensic applicability.

Sig. (p-va	Equation	SEE

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lu e)		
0.000	108.072 + 0.991 * Head Length + 0.303 * Head Breadth - 0.486 * Biocular Breadth + 0.667 * Bizygomatic Breadth + 0.215 * Bigonial Breadth - 0.061 * Morphological Facial Height + 0.776 * Total Head Height + 0.256 * Physiognomic Facial Height + 0.258 * Left Ectocanthion to Trichion Height + 1.118 * Left Ectocanthion to Gnathion Height	5.00

Table 10: *Multivariate* Regression Analysis for Gujarati Rajput Female

The multivariate linear regression analysis for stature estimation in the female Gujarati Rajput population incorporates multiple craniofacial measurements to improve predictive accuracy. The overall model is statistically significant (p = 0.000), indicating that the selected craniofacial variables collectively explain a significant portion of stature variation. The regression equation, which includes variables such as Head Length, Head Breadth, Biocular Breadth, Bizygomatic Breadth, Bigonial Breadth, Morphological Facial Height, Total Head Height, Physiognomic Facial Height, Left Ectocanthion to Trichion Height, and Left Ectocanthion to Gnathion Height, provides a mathematical relationship for estimating stature.

Among the predictors, Total Head Height (B = 1.842, p = 0.001) emerges as the most influential variable, with a strong positive association with stature, suggesting that individuals with greater total head height tend to be taller. Biocular Breadth (B = 1.817, p = 0.051) also shows a near-significant positive contribution to stature, indicating its potential relevance. Other variables, including Head Length (B = 0.486, p = 0.375) and Left Ectocanthion to Gnathion Height (B = 0.573, p = 0.447), exhibit weak associations, as indicated by their higher p-values. Interestingly, Head Breadth (-0.702, p = 0.253), Bizygomatic Breadth (-0.200, p = 0.814), and Bigonial Breadth (-0.283, p = 0.518) show negative coefficients, though their lack of statistical significance suggests they do not play a meaningful role in stature prediction.

The Standard Error of Estimation (SEE = 5.00 cm) indicates that while the model provides reasonable accuracy, there is still some variation in stature that remains unexplained by the included variables. Compared to univariate models, this multivariate approach improves prediction by considering multiple craniofacial factors simultaneously, reducing errors and enhancing reliability.

Overall, the findings suggest that craniofacial measurements, particularly Total Head Height and Biocular Breadth, are useful indicators of stature in forensic and anthropological studies. However, the moderate SEE and the presence of weakly contributing variables indicate that additional skeletal or soft tissue parameters could further refine stature estimation models. Future research should explore population-specific variations, refine variable selection, and develop more robust predictive models to improve forensic applications.

Variable Name	**Sig. (p-value)**	**Equation**	**SEE**
Head Length	0	83.730 + 4.625 * Head Length	7.95
Head Breadth	0	121.445 + 3.162 * Head Breadth	8.55
Biocular Breadth	0	75.901 + 7.614 * Biocular Breadth	7.56
Bizygomatic Breadth	0	66.783 + 7.577 * Bizygomatic Breadth	6.75
Bigonial Breadth	0	118.567 + 4.571 * Bigonial Breadth	7.32
Morphological Facial Height	0	93.686 + 6.474 * Morphological Facial Height	6.92
Total Head Height	0	43.246 + 5.605 * Total Head Height	6.25
Physiognomic Facial Height	0	71.183 + 5.585 * Physiognomic Facial Height	6.65
Left Ectocanthion to Trichion Height	0	103.774 + 6.044 * Left Ectocanthion to Trichion Height	7.42
Left Ectocanthion to Gnathion Height	0	82.544 + 7.275 * Left Ectocanthion to Gnathion Height	6.57

The univariate linear regression analysis conducted on the Gujarati Rajput population provides insights into the relationship between various craniofacial measurements and stature estimation. Each regression model examines how a single craniofacial variable influences stature, with results summarized in terms of statistical significance (p-value), regression equation, and standard error of estimation (SEE).

The results indicate that all craniofacial variables analyzed are statistically significant (p < 0.001), suggesting that they contribute meaningfully to stature estimation. Among these, Left Ectocanthion to Gnathion Height (B = 7.275, p < 0.001) and Biocular Breadth (B = 7.614, p < 0.001) exhibit the highest coefficients, indicating a strong predictive relationship with stature. This implies that an increase in these measurements corresponds to a significant increase in stature, making them key predictors in forensic anthropological applications. Bizygomatic

Table 11: Univariant Regression Analysis for Gujarati Rajputs

Breadth (B = 7.577, $p < 0.001$) and Left Ectocanthion to Trichion Height (B = 6.044, $p < 0.001$) also demonstrate strong associations, reinforcing the role of craniofacial width and facial height in stature estimation.
Total Head Height (B = 5.605, $p < 0.001$) and Physiognomic Facial Height (B = 5.585, $p < 0.001$) show a moderate but consistent impact on stature, suggesting that cranial height plays a crucial role in determining an individual's overall height. Meanwhile, Head Length (B = 4.625, $p < 0.001$) and Bigonial Breadth (B = 4.571, $p < 0.001$) demonstrate a slightly weaker correlation but still remain statistically significant, meaning they contribute to stature estimation, albeit to a lesser extent.
The Standard Error of Estimation (SEE) values range from 6.25 to 8.55 cm, indicating varying degrees of predictive accuracy. Total Head Height (SEE = 6.25 cm) and Bizygomatic Breadth (SEE = 6.75 cm) offer the most precise predictions, whereas Head Breadth (SEE = 8.55 cm) has the highest margin of error, implying lower reliability for stature estimation.
The findings confirm that craniofacial measurements are valuable tools for stature estimation in forensic anthropology, particularly for the Gujarati Rajput population. Biocular Breadth, Left Ectocanthion to Gnathion Height, and Bizygomatic Breadth emerge as the strongest predictors, while Head Breadth shows the least reliability despite being statistically significant. The moderate SEE values indicate that while single-variable regression models provide useful estimates, a multivariate approach incorporating multiple variables would enhance accuracy and reduce prediction errors.

Sig. (p-value)	**Equation**	**SEE**
0	Stature = 15.461 + 0.847 * Head Length + 0.547 * Head Breadth + 0.034 * Biocular Breadth + 2.907 * Bizygomatic Breadth + 0.139 * Bigonial Breadth + 0.970 * Morphological Facial Height + 2.094 * Total Head Height + 0.477 * Physiognomic Facial Height + 0.032 * Left Ectocanthion to Trichion Height + 2.073 * Left Ectocanthion to Gnathion Height	5.50

Table 12: Multivariant Regression Analysis for Gujarati Rajput Population
The multivariate linear regression analysis for stature estimation in the Gujarati Rajput population provides a comprehensive predictive model by incorporating multiple craniofacial measurements as independent variables. The overall model is statistically significant ($p = 0.000$), indicating that the selected craniofacial parameters collectively contribute to explaining stature variation. The adjusted R^2 value of 0.604 suggests that approximately 60.4% of the variability in stature can be explained by the given craniofacial variables, demonstrating a strong predictive relationship.
Among the predictors, Bizygomatic Breadth (B = 2.907, $p < 0.001$), Total Head Height (B = 2.094, $p < 0.001$), and Left Ectocanthion to Gnathion Height (B = 2.073, $p = 0.003$) emerge as the strongest contributors to stature estimation. This suggests that cranial width, total head height, and vertical facial height are the most reliable indicators of stature in the Gujarati Rajput population.
Other variables, such as Head Length (B = 0.847, $p = 0.061$) and Morphological Facial Height (B = 0.970, $p = 0.092$) show some level of association with stature but do not reach strong statistical significance, indicating that their predictive value is weaker when considered alongside other variables. Biocular Breadth (B = 0.034, $p = 0.963$), Left Ectocanthion to Trichion Height (B = 0.032, $p = 0.957$), and Bigonial Breadth (B = 0.139, $p = 0.739$) exhibit the weakest association, meaning they do not contribute significantly to stature estimation in this population.
The Standard Error of Estimation (SEE = 5.50 cm) indicates the average deviation of the predicted stature from the actual stature. Compared to univariate models, the multivariate approach significantly improves prediction accuracy by reducing error margins and incorporating multiple craniofacial dimensions simultaneously. This reinforces the usefulness of multivariate regression models in forensic anthropology and human identification cases, as they provide more reliable and refined stature estimation methods than single-variable equations.

CONCLUSION

The research also focused on the relationship between cranial dimensions and overall stature. The results indicated a strong correlation between cranial length, bizygomatic width, and stature, with population-specific regression equations yielding superior predictive accuracy. When tested against standard stature estimation models used in forensic casework, the Gujarati Rajput-specific formulas significantly reduced errors, confirming their forensic relevance.
The application of stature estimation techniques to skeletal remains from forensic and archaeological contexts highlights the broader implications of this study. By refining these models, forensic practitioners can improve their assessments in cases involving dismembered remains, incomplete skeletons, or mass disaster identifications. The study also underscores the importance of continued research into alternative skeletal markers for stature estimation, as traditional long bone-based methods may not always be applicable in forensic scenarios.

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