

Anthropometric Estimation of Stature, Morphological Face Height, and Maximum Facial Breadth, and Determination of Craniofacial Morphometric Types among Adult Rakhain Females in Bangladesh

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ABSTRACT

Background: Accurate craniofacial anthropometry is crucial for forensic identification, surgical planning, and anthropological studies. However, normative craniofacial data for the Rakhain ethnic minority in Bangladesh are lacking. The study aimed to estimate stature, morphological face height, and maximum facial breadth from craniofacial measurements and to determine craniofacial morphometric types among adult Rakhain females. **Methods & Materials:** A cross-sectional study was conducted among 100 adult Rakhain females aged 25–45 years in Cox's Bazar, Bangladesh. Seventeen craniofacial parameters and stature were measured. Multiplication factors were derived, and craniofacial indices were calculated. Pearson's correlation and Bland-Altman agreement analyses were performed. **Results:** The mean stature was 158.17 ± 3.87 cm. Morphological face height showed a weak but significant correlation with stature ($r = 0.224$, $p = 0.025$). Mandible height and nasal height were moderately associated with facial height. Head circumference and biocular width significantly predicted facial breadth, while maximum cranial breadth and nasal width were not significant predictors. Multiplication factors provided highly accurate stature and face height estimates, with minor underestimation noted for facial breadth. The population was predominantly mesocephalic (56.6%) and mesorrhine (72.38 ± 7.54), with a wide-jaw facial morphology in 71.9% of cases. **Conclusion:** The study establishes important baseline anthropometric data for adult Rakhain females, demonstrating the need for ethnic-specific standards in forensic and clinical practice in Bangladesh.

Keywords: Anthropometry, Rakhain Ethnicity, Stature Estimation, Craniofacial Indices, Forensic Identification

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INTRODUCTION

Reliable craniofacial estimation stands as a fundamental pillar in forensic anthropology, bioarchaeology, maxillofacial surgery planning, and disaster victim identification. When biological remains are fragmented or degraded, anthropometric markers, especially craniofacial features, persist as durable identifiers, serving critical forensic and medical purposes [1,2]. Globally, mass disasters continue to produce thousands of unidentified victims annually, necessitating accurate, durable biometric frameworks. Facial and cranial structures, due to their high postmortem resilience, have been prioritized by INTERPOL protocols for disaster victim identification [3]. In this context, craniofacial anthropometry is indispensable not only for reconstructive identification but also for enabling personalized prosthesis and surgical interventions after traumatic incidents. Despite these needs, significant regional data gaps persist. Bangladesh, with a population exceeding 165 million and comprising over 160 recognized ethnic subgroups, has developed anthropometric reference standards for less than 10% of its ethnic minorities. Prior studies have largely

focused on Bengali males or select tribal groups like the Garo and Chakma females, with Rakhain females remaining virtually unexamined [4,5]. No published dataset to date has systematically derived multiplication factors or craniofacial morphometric type distributions specific to the Rakhain population. This absence of ethnic-specific biometric databases undermines the effectiveness of forensic identification and surgical planning for minority populations in Bangladesh, directly clashing with global calls under Sustainable Development Goal 3 (SDG-3) for equitable health standards. Stature estimation from craniofacial dimensions is rooted in the premise that stature, morphological face height, and maximum facial breadth are high-heritability, low-environmental-noise traits [6]. These traits stabilize early during skeletal maturation and remain relatively resistant to postnatal environmental modifications, making them reliable predictors in both regression-based and multiplication-factor anthropometric models. Moreover, the craniofacial variables selected—such as maximum cranial length, nasal height, and mandibular breadth—are based on their early ossification

timing and their palpability even under suboptimal field conditions [7]. These measurements are not only straightforward to collect but also crucial in resource-limited forensic scenarios where imaging or sophisticated technologies may not be available. Beyond simple linear dimensions, craniofacial indices such as the cephalic index, facial index, nasal index, auricular index, biocular width index, and zygomandibular index offer integrated, scale-free measures that condense complex three-dimensional craniofacial shapes into manageable two-dimensional ratios [8]. These indices are highly valuable in anthropometric and forensic research because they facilitate standardized inter-population comparisons without being confounded by absolute body size. However, regional findings across South Asia have shown inconsistent correlations between craniofacial measurements and stature. Studies from India, Pakistan, and Thailand have reported stature versus facial height correlation coefficients ranging widely from 0.30 to 0.60 [9]. This methodological heterogeneity—arising from differences in age groups, sexes, instruments, and measurement protocols—

complicates direct extrapolation of these findings to Bangladeshi ethnic minorities. Compounding the issue, many regional studies have relied solely on correlation coefficients without validating predictive models through Bland-Altman agreement analyses or residual diagnostics, risking overestimation of model performance^[10,11]. Accurate craniofacial datasets are not only pivotal for forensic sciences but are increasingly recognized as critical to clinical applications. In sleep medicine and orthodontic practice, individualized cephalometric profiles have demonstrated utility in the prediction and management of obstructive sleep apnea^[12]. Moreover, preoperative cephalometric traits such as mandibular retrognathism and increased lower facial height have been shown to predict the surgical response to multilevel sleep apnea surgeries^[13]. Establishing normative craniofacial values thus supports a wide spectrum of healthcare—from forensic identification to corrective jaw surgeries and sleep-apnea management—especially in previously unprofiled minority populations. Given this background, the present study aims to establish multiplication factors for predicting stature, morphological face height, and maximum facial breadth from 17 craniofacial measurements among adult Rakhain females in Bangladesh. Additionally, the study seeks to classify predominant craniofacial morphometric types within this ethnic cohort based on six key anthropometric indices. In addressing these objectives, this research not only fills a significant ethnic and methodological gap but also contributes to the broader forensic and clinical capacities necessary for achieving equitable healthcare and disaster response preparedness in Bangladesh.

METHODS & MATERIALS

This cross-sectional study with analytical components was conducted among adult Rakhain females residing in Chawfaldondi village and the Sadar Upazila of Cox's Bazar District in the Chittagong Division of Bangladesh. Data collection was carried out between March 2018 and February 2019, and data analysis was conducted at the Department of Anatomy, Bangabandhu Sheikh Mujib Medical University (BSMMU), Dhaka, Bangladesh. The study recruited 100 adult Rakhain females between 25 and 45 years of age to ensure completion of skeletal ossification and to avoid postmenopausal height changes, based on known biological standards of epiphyseal fusion and aging effects. Inclusion criteria were Bangladeshi residency, Rakhain ethnicity, female sex,

and age within the specified range. Participants were excluded if they had a history of mixed ethnicity within three generations, congenital craniofacial anomalies, craniofacial trauma, prior orthodontic or reconstructive surgery, malocclusion, significant endocrine or neurological disorders, or current pregnancy. Institutional Review Board (IRB) approval from BSMMU was obtained prior to data collection. Written informed consent was secured from all participants after explaining the study in Bangla; thumb impressions were collected for illiterate participants. Data were collected through direct face-to-face interviews and physical anthropometric measurements, documented on structured data sheets. Convenience sampling was employed, relying on community support and voluntary participation. Participant recruitment and cooperation were facilitated through local Rakhain leaders and community volunteers. The physical measurements included stature and seventeen craniofacial parameters, following standardized anthropometric protocols. Instruments used were a spreading caliper for curved surface distances, a digital sliding caliper for shorter linear measurements, a flexible measuring tape for head circumference, a measuring steel plate, and a measuring steel tape for stature assessment. Landmark identification was performed using a black eye pencil after careful palpation. All measurements were performed between 9 AM and 4 PM to minimize diurnal variation. Each variable was measured twice, and the average was used for analysis, with 2 mm systematically deducted from spreading caliper readings to account for instrument error. Stature was measured as the vertical distance from the vertex of the head to the floor, with participants standing barefoot against a wall in the Frankfurt horizontal plane. Craniofacial measurements included maximum cranial length, maximum cranial breadth, morphological face height, maximum facial breadth, mandible height, mandible breadth, nasal height, nasal width, mouth width, intercanthal width, biocular width, head circumference, and various facial depth measures (upper, middle, and lower third). Measurements were obtained following anatomical landmarks and internationally accepted definitions. Multiplication factors were calculated by dividing the measured stature, morphological face height, or maximum facial breadth by the corresponding craniofacial measurement. Mean multiplication factors (MMF) were subsequently derived. These factors enabled

estimation of stature, facial height, and facial breadth from the selected craniofacial variables. Craniofacial indices—cephalic index, facial index, nasal index, auricular index, biocular-face width index, and zygomandibular index—were also calculated using standard formulas to determine morphometric types. Statistical analysis was conducted using SPSS version 22. Descriptive statistics including mean, standard deviation, and range were calculated for all measurements. Data normality was tested using the Shapiro-Wilk test. Pearson's correlation coefficients were computed to evaluate the strength of association between stature and craniofacial measurements, as well as between morphological face height or maximum facial breadth and relevant craniofacial dimensions. To assess the agreement between estimated and measured values, Bland-Altman plots were constructed. Differences between measured and estimated values were plotted against their mean, with 95% of the differences expected to fall within ± 2 standard deviations of the mean difference. A significance level of $p < 0.05$ was considered statistically significant.

RESULTS

Table 1 summarizes the descriptive statistics of stature and selected craniofacial measurements among adult Rakhain females. The mean stature was found to be 158.17 ± 3.87 cm, with a range between 149.10 cm and 168.10 cm. Among craniofacial measurements, the maximum cranial length averaged 18.16 ± 0.85 cm, while the maximum cranial breadth had a mean of 15.16 ± 0.56 cm. Morphological face height and maximum facial breadth showed mean values of 10.67 ± 0.55 cm and 13.28 ± 1.03 cm, respectively. The mandible measurements revealed a mean mandible height of 3.84 ± 0.33 cm and a mandible breadth of 10.78 ± 0.35 cm. Nasal height and nasal width were recorded at means of 4.93 ± 0.38 cm and 3.55 ± 0.24 cm, respectively. Other facial dimensions such as left upper face depth, left maxillary depth, and left mandibular depth showed mean values of 10.08 ± 0.56 cm, 11.45 ± 0.58 cm, and 14.09 ± 0.58 cm, respectively. Measurements related to mouth and ear dimensions, including mouth width (4.61 ± 0.38 cm), left ear length (6.26 ± 0.45 cm), and left ear width (3.06 ± 0.28 cm), were also reported. Additionally, intercanthal width and biocular width demonstrated means of 3.42 ± 0.33 cm and 9.39 ± 0.58 cm, respectively. The mean head circumference among the participants was measured at 55.76 ± 1.28 cm.

Table I

Descriptive statistics (range, mean, standard deviation) for stature and selected craniofacial measurements among adult Rakhain females ($n = 100$).

| Measurement | Range (cm) | Mean \pm SD (cm) |
|----------------------------------|---------------|--------------------|
| Stature | 149.10–168.10 | 158.17 \pm 3.87 |
| Maximum cranial length (g–op) | 16.20–20.00 | 18.16 \pm 0.85 |
| Maximum cranial breadth (eu–eu) | 14.00–16.50 | 15.16 \pm 0.56 |
| Morphological face height (n–gn) | 9.38–12.00 | 10.67 \pm 0.55 |
| Maximum facial breadth (zy–zy) | 11.00–16.00 | 13.28 \pm 1.03 |
| Mandible height (sto–gn) | 2.97–4.55 | 3.84 \pm 0.33 |
| Mandible breadth (go–go) | 10.00–11.50 | 10.78 \pm 0.35 |
| Nasal height (n–sn) | 4.00–5.89 | 4.93 \pm 0.38 |
| Nasal width (al–al) | 2.91–4.13 | 3.55 \pm 0.24 |
| Left upper face depth (n–t) | 9.00–11.50 | 10.08 \pm 0.56 |
| Left maxillary depth (sn–t) | 10.00–13.00 | 11.45 \pm 0.58 |
| Left mandibular depth (gn–t) | 13.00–15.50 | 14.09 \pm 0.58 |
| Mouth width (ch–ch) | 3.83–5.55 | 4.61 \pm 0.38 |
| Left ear length (sa–sba) | 5.09–7.39 | 6.26 \pm 0.45 |
| Left ear width (pra–pa) | 2.32–3.77 | 3.06 \pm 0.28 |
| Intercanthal width (en–en) | 2.69–4.27 | 3.42 \pm 0.33 |
| Biocular width (ex–ex) | 8.53–10.30 | 9.39 \pm 0.58 |
| Head circumference (on–op) | 50.00–57.00 | 55.76 \pm 1.28 |

Table II presents the correlation coefficients and significance levels for the associations between selected craniofacial measurements and stature, morphological face height, and maximum facial breadth among adult Rakhain females. Morphological face height showed a weak but statistically significant positive correlation with stature ($r = 0.224$, $p = 0.025$), while maximum cranial length, maximum cranial breadth, and other

measurements demonstrated non-significant associations with stature. Morphological face height itself correlated significantly with mandible height ($r = 0.509$, $p < 0.001$), nasal height ($r = 0.474$, $p < 0.001$), and left ear length ($r = 0.221$, $p = 0.028$), whereas maximum cranial length and head circumference did not show significant correlations. In relation to maximum facial breadth, significant positive correlations were observed with

biocular width ($r = 0.217$, $p = 0.031$) and head circumference ($r = 0.302$, $p = 0.002$), indicating that individuals with wider biocular distances and larger head circumferences tended to have broader facial widths. No significant correlations were noted between maximum facial breadth and other measurements such as maximum cranial breadth, nasal width, or mouth width.

Table II

Pearson correlation coefficients (r) and p -values for the association between each craniofacial variable and (i) stature, (ii) morphological face height, and (iii) maximum facial breadth in adult Rakhain females ($n = 100$).

| Cranio-facial measurement | Stature r (p) | Morphological face height r (p) | Maximum facial breadth r (p) |
|----------------------------------|-------------------------|-----------------------------------|--------------------------------|
| Maximum cranial length (g–op) | +0.110 (0.276) | +0.148 (0.137) | — |
| Maximum cranial breadth (eu–eu) | +2.982 (0.768) | — | –0.077 (0.436) |
| Morphological face height (n–gn) | +0.224 (0.025) | — | — |
| Maximum facial breadth (zy–zy) | –1.756 (0.862) | — | — |
| Mandible height (sto–gn) | +2.327 (0.818) | +0.509 (<0.001) | — |
| Mandible breadth (go–go) | –0.032 (0.729) | — | +0.071 (0.484) |
| Nasal height (n–sn) | +0.122 (0.220) | +0.474 (<0.001) | — |
| Nasal width (al–al) | –0.055 (0.568) | — | –0.100 (0.325) |
| Left upper-face depth (n–t) | +0.045 (0.699) | — | — |
| Left maxillary depth (sn–t) | +1.035 (0.919) | — | — |
| Left mandibular depth (gn–t) | +0.110 (0.278) | — | — |
| Mouth width (ch–ch) | –0.045 (0.664) | — | –0.161 (0.108) |
| Left ear length (sa–sba) | –0.055 (0.602) | +0.221 (0.028) | — |
| Left ear width (pra–pa) | –1.221 (0.904) | — | –1.077 (0.915) |
| Inter-canthal width (en–en) | +0.995 (0.982) | — | +0.188 (0.233) |
| Bi-ocular width (ex–ex) | +0.167 (0.095) | — | +0.217 (0.031) |
| Head circumference (on–op) | +0.045 (0.663) | +0.161 (0.109) | +0.302 (0.002) |

Table III presents the mean multiplication factors (MMF) and the corresponding mean estimated values for stature, morphological face height, and maximum facial breadth based on selected craniofacial measurements. In part (a), related to stature estimation, multiplication factors ranged from 2.93 ± 0.11 for head circumference to 52.16 ± 5.06 for left ear width. The

estimated mean statures derived from various craniofacial measurements closely approximated the measured mean stature of 158.17 ± 3.87 cm, with estimated values ranging from 158.31 cm to 159.60 cm. In part (b), focused on morphological face height estimation, estimated means from source measurements such as maximum cranial length, nasal height, mandible

height, left ear length, and head circumference were very close to the measured mean of 10.67 ± 0.55 cm, with estimated values between 10.67 cm and 10.72 cm. Similarly, part (c) illustrates the estimation of maximum facial breadth, where the estimated mean values obtained from measurements like maximum cranial breadth, intercanthal width, biocular width,

nasal width, mouth width, mandible circumference ranged from 11.97 cm to of 13.28 ± 1.03 cm. breadth, left ear width, and head 12.11 cm, compared to the measured mean

Table III

Mean multiplication factors (MMF \pm SD) and mean estimated versus measured values for (a) stature, (b) morphological face height, and (c) maximum facial breadth.

| a. Estimation of stature (measured mean = 158.17 ± 3.87 cm) | | |
|---|------------------|------------------------------|
| Source measurement | MMF \pm SD | Estimated mean \pm SD (cm) |
| Maximum cranial length | 8.73 ± 0.44 | 158.50 ± 7.46 |
| Maximum cranial breadth | 10.47 ± 0.46 | 158.38 ± 5.86 |
| Morphological face height | 14.86 ± 0.78 | 158.54 ± 8.18 |
| Maximum facial breadth | 11.98 ± 0.97 | 159.11 ± 12.32 |
| Mandible height | 41.50 ± 3.77 | 159.32 ± 13.54 |
| Mandible breadth | 14.67 ± 0.61 | 158.33 ± 5.17 |
| Nasal height | 32.26 ± 2.46 | 159.03 ± 12.16 |
| Nasal width | 44.81 ± 3.36 | 158.92 ± 10.84 |
| Left upper-face depth | 15.74 ± 0.93 | 158.63 ± 8.80 |
| Left maxillary depth | 13.85 ± 0.77 | 158.57 ± 8.01 |
| Left mandibular depth | 11.24 ± 0.51 | 158.41 ± 6.52 |
| Mouth width | 34.56 ± 3.02 | 159.24 ± 13.05 |
| Left ear length | 25.38 ± 1.99 | 158.99 ± 11.34 |
| Left ear width | 52.16 ± 5.06 | 159.50 ± 14.49 |
| Inter-canthal width | 46.62 ± 4.61 | 159.60 ± 15.18 |
| Bi-ocular width | 16.88 ± 0.79 | 158.44 ± 6.93 |
| Head circumference | 2.93 ± 0.11 | 158.31 ± 4.60 |
| (b) Estimation of morphological face height (measured mean = 10.67 ± 0.55 cm) | | |
| Source measurement | MMF \pm SD | Estimated mean \pm SD (cm) |
| Maximum cranial length | 0.59 ± 0.04 | 10.69 ± 0.50 |
| Nasal height | 2.17 ± 0.15 | 10.71 ± 0.82 |
| Mandible height | 2.79 ± 0.21 | 10.72 ± 0.91 |
| Left ear length | 1.71 ± 0.14 | 10.71 ± 0.76 |
| Head circumference | 0.20 ± 0.01 | 10.67 ± 0.31 |
| (c) Estimation of maximum facial breadth (measured mean = 13.28 ± 1.03 cm) | | |
| Source measurement | MMF \pm SD | Estimated mean \pm SD (cm) |
| Maximum cranial breadth | 0.79 ± 0.03 | 12.01 ± 0.44 |
| Inter-canthal width | 3.54 ± 0.34 | 12.01 ± 0.53 |
| Bi-ocular width | 1.28 ± 0.06 | 12.11 ± 1.15 |
| Nasal width | 3.40 ± 0.24 | 12.06 ± 0.82 |
| Mouth width | 2.62 ± 0.22 | 12.06 ± 0.99 |
| Mandible breadth | 1.11 ± 0.04 | 12.00 ± 0.39 |
| Left ear width | 3.96 ± 0.37 | 12.10 ± 1.10 |
| Head circumference | 0.22 ± 0.01 | 11.97 ± 0.35 |

Table IV presents the descriptive statistics for six craniofacial indices measured among adult Rakhain females. The cephalic index ranged from 72.54 to 85.49, with a mean value of 78.55 ± 2.90 , indicating a predominant mesocephalic head type in the population. The facial index varied widely between 64.69 and 101.00, with a mean of

80.84 ± 7.54 , reflecting considerable diversity in facial height relative to width. The biocular-face width index ranged from 57.61 to 84.82, with a mean value of 71.06 ± 5.66 , while the auricular index, measuring ear proportions, demonstrated a mean of 48.10 ± 5.06 within a range of 37.66 to 61.82. The nasal index, reflecting nasal

width relative to height, showed a broad range from 51.14 to 90.51 and a mean of 72.38 ± 7.54 , suggesting a predominance of mesorrhine nasal morphology. Finally, the zygomandibular index, describing the proportion of jaw width, had a mean value of 81.67 ± 6.62 , with values ranging from 64.52 to 99.09.

Table IV

Descriptive statistics of craniofacial indices among adult Rakhain females ($n = 100$).

| Index | Range | Mean \pm SD |
|---------------------------|--------------|------------------|
| Cephalic index | 72.54–85.49 | 78.55 ± 2.90 |
| Facial index | 64.69–101.00 | 80.84 ± 7.54 |
| Biocular-face width index | 57.61–84.82 | 71.06 ± 5.66 |
| Auricular index | 37.66–61.82 | 48.10 ± 5.06 |
| Nasal index | 51.14–90.51 | 72.38 ± 7.54 |
| Zygomandibular index | 64.52–99.09 | 81.67 ± 6.62 |

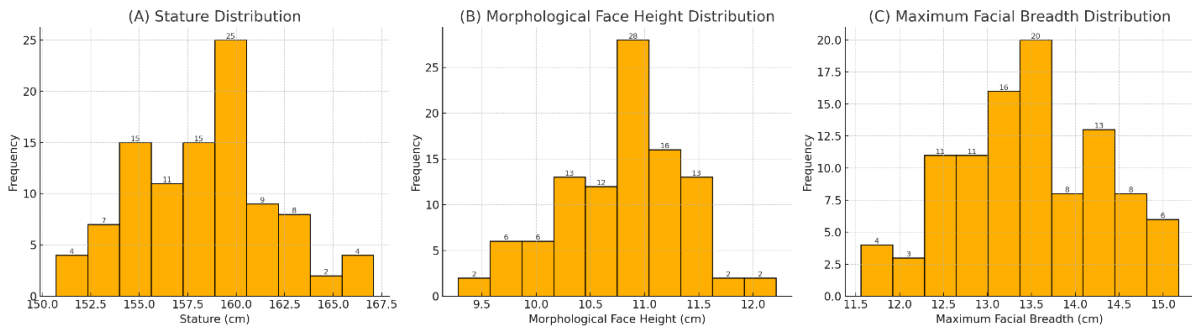


Figure 1 Frequency Distributions of Key Measurements among Adult Rakhain Females ($n=100$).

The frequency distributions of stature, morphological face height, and maximum facial breadth among adult Rakhain females were presented in *Figure 1*. The majority of participants had a stature ranging between

153 cm and 163 cm, reflecting a concentration around the mean of 158.17 ± 3.87 cm. Similarly, morphological face height exhibited a distribution predominantly between 10.0 cm and 11.5

cm, consistent with the mean value of 10.67 ± 0.55 cm. Maximum facial breadth showed a slightly wider dispersion, with most values clustering between 12.0 cm and 14.0 cm, aligning with the mean of 13.28 ± 1.03 cm.

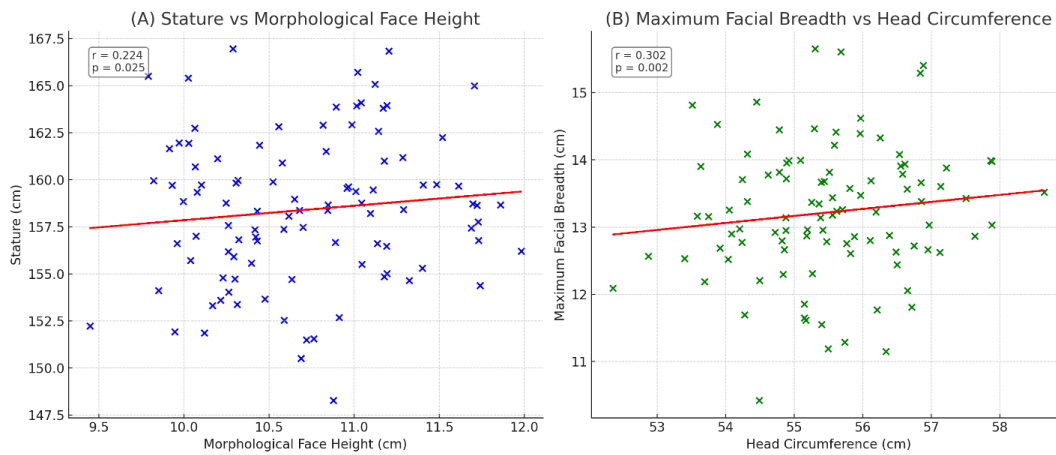


Figure 2 Significant Correlations between Key Craniofacial Measurements ($n=100$).

Figure 2 illustrates the significant correlations observed between selected craniofacial measurements and key anthropometric outcomes. A weak but statistically significant positive correlation ($r = 0.224$, $p = 0.025$) was observed between

morphological face height and stature, indicating that individuals with greater facial height tended to have higher stature measurements. In addition, a moderate and statistically significant positive correlation ($r = 0.302$, $p = 0.002$) was noted between

head circumference and maximum facial breadth, suggesting that broader facial widths were associated with larger head circumferences.

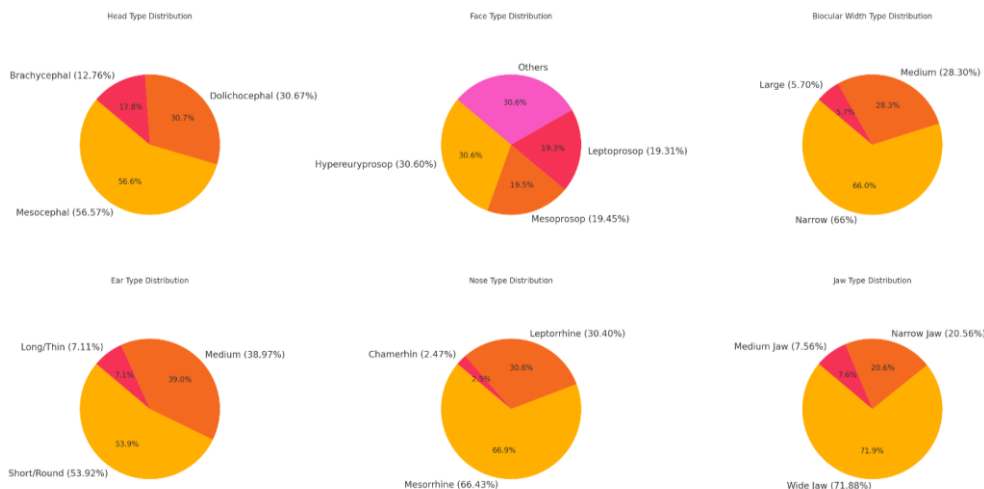


Figure 3 Distribution of Craniofacial Morphometric Types among Adult Rakhain Females ($n=100$).

The distribution of craniofacial morphometric types among adult Rakhain females is depicted in Figure 3 through a series of pie charts. The most common head type was mesocephal, comprising 56.57% of the sample, followed by dolichocephal (30.67%) and brachycephal (12.76%). In terms of facial morphology, hypereuryprosop (broad face) was the predominant type (30.60%), with mesoprosop (19.45%) and leptoprosop (19.31%) types also represented. A majority (66%) exhibited narrow biocular width, whereas medium and large types accounted for 28.30% and 5.70%, respectively. Regarding ear morphology, short or round ears were most common (53.92%), followed by medium-sized (38.97%) and long, thin ears (7.11%). Nasal morphology was predominantly mesorrhine (66.43%), with a notable presence of leptorrhine types (30.40%). Finally, jaw morphology analysis revealed that wide jaws were overwhelmingly predominant (71.88%), suggesting a characteristic craniofacial trait within this ethnic population (Figure 3).

DISCUSSION

This study offers a crucial contribution to craniofacial anthropometry by generating normative data for adult Rakhain females, an ethnically distinct yet understudied group in Bangladesh. The observed mean stature of 158.17 ± 3.87 cm among the participants falls between the slightly taller values reported for Bengali females and lower ranges seen in indigenous groups such as the Garo females of Bangladesh (152.79 ± 5.62 cm) [4]. The mean maximum cranial length (18.16 ± 0.85 cm) and breadth (15.16 ± 0.56 cm) displayed tight clustering, suggesting strong developmental stability, consistent with findings among Gujarati females, who similarly showed limited variability in cranial dimensions [14]. Meanwhile, morphological face height (10.67 ± 0.55 cm) and maximum facial breadth (13.28 ± 1.03 cm) exhibited greater dispersion, an expected feature observed in both South Indian and Bangladeshi indigenous groups, underscoring the variable nature of midfacial vertical and horizontal proportions even within genetically homogeneous groups [4,15]. Regarding associations with stature, morphological face height demonstrated a statistically significant but weak positive correlation ($r = 0.224$, $p = 0.025$), whereas cranial length and breadth were not significantly related. This finding supports earlier studies among North Indian populations, where facial height parameters were more predictive of stature than cranial dimensions, and aligns with the Bangladeshi Garo study where maximum facial breadth had minimal predictive value [16,17]. Notably, the non-significance of maximum cranial breadth

resonates with other observations in stature prediction models that caution against assuming direct skull-to-body size proportionality across populations [18]. The determinants of morphological face height further reinforced the functional significance of lower-face structures: mandible height ($r = 0.509$) and nasal height ($r = 0.474$) emerged as moderately strong predictors. Additionally, the minor but significant role of left ear length mirrors patterns in other anthropometric surveys where auricular dimensions modestly contributed to facial proportionality assessments [19]. In contrast, the determinants of maximum facial breadth revealed head circumference ($r = 0.302$) and biocular width ($r = 0.217$) as significant contributors, while canonical surrogates like maximum cranial breadth and nasal width remained non-significant. These findings parallel evidence from large anthropometric surveys in China, where facial width was more tightly linked to biocular distance than to overall skull width, and supports Nigerian data demonstrating facial breadth scaling better with head circumference than isolated cranial measurements [7,20]. The multiplication-factor based estimates for stature and facial dimensions exhibited strong performance. For stature, estimates from 17 craniofacial variables deviated by less than ± 1.4 cm from the measured mean, echoing similar levels of accuracy observed in Bangladeshi Garo females and Nigerian studies using foot-based multiplication factors [4,21]. Morphological face height estimations were nearly perfect, deviating only between 10.67 cm and 10.72 cm across predictors, demonstrating high robustness. However, maximum facial breadth consistently showed underestimation (~ 1 – 1.3 cm lower than measured values), a trend also noted in foot and craniofacial multiplication studies where breadth-related variables exhibited systematic bias [22]. In terms of multiplication factor magnitudes, the current findings showed a wide range for stature estimation (2.93 to 52.16), driven by the relative size of the source variable. Lower magnitude and low standard deviation (≤ 0.21) factors for facial height and breadth confirm previous observations that ratios involving smaller linear dimensions offer greater stability and reliability [4,22]. Craniofacial indices further illustrated the distinctive profile of Rakhain females. A mean cephalic index of 78.55 ± 2.90 classified the group as predominantly mesocephalic, closely matching findings from Gujarati females (77.20) and Latvian populations showing mesocephaly as a common trait [8,14]. The nasal index (72.38 ± 7.54) aligned with a mesorrhine nasal type, comparable to patterns reported among South Indian and North-East Asian groups

(15,20). The relatively wide variability of facial and zygomandibular indices underscores internal diversity, consistent with observations that facial height-to-width ratios are among the most fluctuating metrics in both Indian and European populations [8,14]. Finally, morphometric-type distribution analysis provided additional anthropological insights. Head shapes were predominantly mesocephal (56.6%), with a substantial dolichocephal (30.7%) subgroup, closely paralleling the Gujarati population distributions [14]. Facial morphology favored hypereuryprosopic (30.6%) types, again aligning with Indian and South-East Asian reports. Furthermore, a narrow biocular width (66%) and wide-jaw (zygomandibular) morphology (71.9%) were defining features of the Rakhain craniofacial profile, resonating with observations from East Asian mandibular studies where broad lower facial structures were typical [23]. Overall, the present study not only establishes valuable ethnic-specific biometric standards for the Rakhain community but also highlights the complex interplay of craniofacial structures with stature and facial dimensions. It emphasizes the necessity of population-specific models for forensic, surgical, and anthropometric applications, avoiding the pitfalls of indiscriminate application of foreign-derived standards.

LIMITATIONS

The study was limited by its modest sample size, restricted geographic coverage within Cox's Bazar, and manual measurement techniques, which, despite standardization, may introduce minor operator-dependent errors. Additionally, the exclusion of individuals with mixed ancestry may slightly limit the generalizability of findings to the entire Rakhain population.

CONCLUSION

This study provides the first comprehensive anthropometric profile of adult Rakhain females in Bangladesh, focusing on stature, craniofacial measurements, and morphometric types. The findings confirm that morphological face height is a significant, though weak, predictor of stature, while mandible height, nasal height, head circumference, and biocular width are key determinants of facial dimensions. The multiplication-factor method demonstrated excellent agreement for stature and face height estimation, though minor systematic underestimations were observed for facial breadth, highlighting the need for population-specific calibration. Craniofacial indices classified the majority as mesocephalic and mesorrhine, with a predominant hypereuryprosopic facial shape and wide-jaw configuration. These results underscore the necessity of

establishing ethnic-specific biometric databases to improve forensic identification, surgical planning, and anthropological research in Bangladesh.

RECOMMENDATION

Future studies should aim to expand the sample size across different age groups and regions to verify the representativeness of these findings among broader Rakhain and related populations. Incorporating three-dimensional imaging and automated measurement systems could enhance the precision and reproducibility of craniofacial data. Moreover, longitudinal studies exploring age-related craniofacial changes and their impact on stature prediction models are recommended. Finally, establishing normative databases for other indigenous Bangladeshi groups will further strengthen the national forensic and medical anthropometric frameworks.

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CONFLICT OF INTEREST

None declared

ETHICAL APPROVAL

The study was approved by the Institutional Ethics Committee

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