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AGE- AND SEX-RELATED VARIATIONS IN STATURE AND CRANIAL DIMENSIONS IN AN ADULT INDIAN POPULATION: A CROSS-SECTIONAL FORENSIC STUDY

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ABSTRACT

Background: Identification of unknown individuals in forensic cases often depends on the estimation of biological parameters such as sex and stature. Cranial dimensions have shown significant potential for such estimations due to their relative preservation in decomposition and trauma. However, population-specific standards are essential for accurate forensic applications. This study aims to analyze sexual dimorphism in cranial dimensions and derive regression equations for stature estimation from skull measurements in an adult North Indian population.

Materials and Methods: This cross-sectional study was conducted on 480 medico-legal autopsies (240 males, 240 females) at the Department of Forensic Medicine, UCMS and GTB Hospital, Delhi, from November 2009 to February 2011. The study population included adults aged 20–50 years, subdivided into six age groups (each comprising 40 males and 40 females). Measurements recorded included stature, maximum skull length, maximum skull breadth, and skull circumference. Data were analyzed using descriptive statistics and linear regression to derive stature estimation equations. Discriminant function analysis was also applied for assessing sexual dimorphism.

Results: Males exhibited significantly higher mean values across all cranial dimensions and stature compared to females in all age groups. Skull circumference showed the highest correlation with stature ($r = 0.449$, SEE = ±6.721 cm) when both sexes were combined. Regression equations were more accurate in males than females, with age group–specific models yielding higher correlation coefficients. Discriminant analysis demonstrated clear sexual dimorphism, supporting the utility of cranial measurements in sex estimation.

Conclusion: Cranial dimensions exhibit notable sexual dimorphism and show moderate correlation with stature, confirming their utility in forensic identification. Population-specific regression models derived from this study will assist forensic experts in North India in establishing biological profiles with greater accuracy.

Keywords: Cranial dimensions, Sexual dimorphism, Stature estimation, Forensic anthropology, Regression analysis.

INTRODUCTION

Forensic anthropology plays a vital role in the identification of unknown human remains, especially in cases of mass disasters, decomposed bodies, or skeletal fragments. Among the critical parameters used to construct a biological profile are stature, age, sex, and cranial measurements, which help in narrowing down potential matches for unidentified individuals.[1] The skull, after the pelvis, is considered one of the most sexually dimorphic parts of the human skeleton and is widely used for sex estimation in forensic settings.[2]

Age and sex-related variation in cranial morphology has long been documented in anthropological literature. Sexual dimorphism in cranial features such as maximum skull length, breadth, and circumference has been observed in different populations, necessitating population-specific standards for accurate estimation.[3] Studies from India have reinforced this need, as cranial dimensions and stature show considerable variability across regional, ethnic, and environmental backgrounds.[4]

The relationship between cranial dimensions and stature is also well-established, and linear regression models are frequently used to estimate stature from skull measurements in forensic contexts.[5] Such models are particularly useful when only cranial remains are available. Moreover, anthropometric differences between males and females become more nuanced with advancing age, further emphasizing the need for age-specific and sex-specific anthropometric data for forensic applications.[6]

Despite numerous global studies, data from Indian populations—especially based on autopsy samples—remain limited. Most studies have focused on living subjects, which may introduce bias due to posture or soft tissue compression. Post-mortem cranial and stature measurements, when taken under controlled conditions during autopsy, provide a more objective and standardized dataset.[7]

The present study aims to address this gap by examining age- and sex-related differences in stature and cranial measurements—namely maximum skull length, breadth, and circumference—in a north Indian adult population. The study also discusses the implications of these findings in the context of forensic identification and anthropological profiling.

MATERIALS AND METHODS

This cross-sectional study was conducted in the Department of Forensic Medicine, University College of Medical Sciences (UCMS) and Guru Teg Bahadur (GTB) Hospital, Delhi. The study sample consisted of 480 medico-legal autopsy cases (240 males and 240 females) aged between 20 and 50 years, collected over a period from November 2009 to February 2011. Subjects were stratified into six age groups with 5-year intervals, and each group included 40 males and 40 females. Only those bodies without any visible or documented disease, deformity, or skeletal injury were included in the study. Consent was obtained from the relatives, and ethical procedures were followed throughout, including the use of universal precautions during autopsies.

Stature was measured using the standard graduation on the side of the autopsy table, with the cadaver placed supine and the limbs extended. Cranial measurements included maximum skull length (measured from glabella to opisthocranion), maximum skull breadth (between the two parietal eminences), and maximum skull circumference (around the glabella and external occipital protuberance). Skull measurements were taken after scalp reflection, using a curved spreading caliper and flexible measuring tape. Each parameter was measured three times by different observers, and the average was calculated to minimize observer bias. All measurements were recorded in centimeters following standardized anthropometric protocols described by Krogman and Iscan, and Chiba et al.

Statistical analysis included descriptive statistics (mean, standard deviation, minimum, and maximum) for each parameter stratified by age group and sex. To assess the relationship between cranial dimensions and stature, linear regression equations were derived separately for each group. Differences between male and female measurements within each age group were also evaluated. All data were compiled using a pre-designed Case Record Form and processed using standard statistical software.

RESULTS

The present study included a total of 480 cases, with an equal distribution of 240 males and 240 females, divided into six age groups ranging from 20 to 50 years. Each age group included 40 male and 40 female subjects, ensuring uniform representation across age and sex [Table 1].

Table 1: Age and Gender-wise Distribution of Study Subjects (N = 480)

Age Group	Males (n=240)	Females (n=240)
20 < 25	40	40
25 < 30	40	40
30 < 35	40	40
35 < 40	40	40
40 < 45	40	40
45 ≤ 50	40	40

Table 2: Age-wise Comparison of Stature (cm) in Males and Females

Age Group	Sex	Cases (n)	Min	Max	Mean	SD
20 < 25	Male	40	159	177	167.83	4.248
	Female	40	144	170	155.50	6.540
25 < 30	Male	40	156	177	167.20	4.670
	Female	40	150	176	157.15	5.947

30 < 35	Male	40	157	183	168.80	6.132
	Female	40	150	168	156.62	5.624
35 < 40	Male	40	150	176	166.05	5.421
	Female	40	150	170	159.00	4.909
40 < 45	Male	40	164	182	169.75	4.396
	Female	40	146	170	159.48	5.848
45 ≤ 50	Male	40	148	184	166.83	6.793
	Female	40	148	170	159.80	

The mean stature was consistently higher in males across all age groups compared to females (Table 2). In males, the highest mean stature was observed in the 40–45 years group (169.75 ± 4.396 cm), whereas the lowest was seen in the 35–40 years group (166.05 ± 5.421 cm). In contrast, females showed relatively stable mean stature values ranging from 155.5 cm to 159.8 cm, with the maximum mean noted in the 45–50 years group (159.80 ± 5.608 cm). Males displayed wider ranges in both minimum and maximum values, suggesting greater variability in height.

Table 3: Age-wise Comparison of Cranial Dimensions in Males and Females

Age Group	Sex	Measurement	Min (cm)	Max (cm)	Mean (cm)	SD
20 < 25	Male	Maximum Skull Length	16.3	19.5	17.742	0.6675
		Maximum Skull Breadth	12.0	13.7	12.663	0.4527
	Female	Maximum Skull Circumference	48.0	54.0	51.20	1.482
		Maximum Skull Length	15.8	18.2	17.190	0.5848
		Maximum Skull Breadth	11.0	13.5	12.447	0.5697
		Maximum Skull Circumference	46.0	52.0	49.50	1.245
25 < 30	Male	Maximum Skull Length	16.4	19.0	17.490	0.623
		Maximum Skull Breadth	11.5	14.2	12.867	0.5708
		Maximum Skull Circumference	48.0	54.0	51.76	1.303
	Female	Maximum Skull Length	16.0	18.1	16.845	0.5134
		Maximum Skull Breadth	11.5	13.2	12.232	0.5636
		Maximum Skull Circumference	48.0	54.0	48.97	1.065
30 < 35	Male	Maximum Skull Length	17.0	18.5	17.435	0.408
		Maximum Skull Breadth	12.0	14.1	12.895	0.5787
		Maximum Skull Circumference	48.0	54.0	51.01	1.385
	Female	Maximum Skull Length	16.0	17.8	16.918	0.583
		Maximum Skull Breadth	11.6	13.3	12.618	0.3727
		Maximum Skull Circumference	47.0	52.0	49.34	1.208
35 < 40	Male	Maximum Skull Length	16.4	20.1	17.725	0.8454
		Maximum Skull Breadth	12.0	14.5	12.885	0.5582
		Maximum Skull Circumference	47.0	55.0	51.07	2.160
	Female	Maximum Skull Length	14.5	18.2	17.210	0.9618
		Maximum Skull Breadth	10.5	13.5	12.420	0.6684
		Maximum Skull Circumference	41.0	52.0	49.05	2.009
40 < 45	Male	Maximum Skull Length	17.0	19.6	18.195	0.5866
		Maximum Skull Breadth	12.0	14.1	13.028	0.4224
		Maximum Skull Circumference	49.0	54.0	52.01	1.371
	Female	Maximum Skull Length	16.0	18.2	17.162	0.7354
		Maximum Skull Breadth	11.3	13.3	12.395	0.5375
		Maximum Skull Circumference	47.0	52.0	49.60	1.017
45 ≤ 50	Male	Maximum Skull Length	16.7	19.4	18.252	0.7016
		Maximum Skull Breadth	11.5	14.4	12.928	0.6672
		Maximum Skull Circumference	48.0	56.0	51.75	1.753
	Female	Maximum Skull Length	16.0	18.1	17.383	0.5804
		Maximum Skull Breadth	11.5	13.2	12.360	0.5053
		Maximum Skull Circumference	49.0	51.0	49.80	0.672

[Table 3] presents a detailed comparison of three cranial dimensions: maximum skull length, maximum skull breadth, and skull circumference, stratified by age and sex. In all age groups, males exhibited higher mean values for all three cranial parameters compared to females. nMaximum skull length in males ranged from 17.435 cm (30–35 yrs) to 18.252 cm (45–50 yrs), whereas in females it ranged from 16.845 cm to 17.383 cm. Maximum skull breadth showed relatively stable values in males, increasing slightly with age, peaking at 13.028 cm in the 40–45 yrs group. Females also showed consistency, with values fluctuating around 12.2–12.6 cm. Skull circumference showed progressive increase with age in both sexes, reaching a peak in the 40–45 yrs group for males (52.01 ± 1.371 cm) and 45–50 yrs group for females (49.80 ± 0.672 cm). Notably, females had less variability in circumference as evidenced by lower standard deviations.

Table 4: Regression Equation Summary for Stature Estimation from Cranial Dimensions

Age Group	Gender	Cases (n)	Skull Length (r)	SEE (±cm)	Skull Breadth (r)	SEE (±cm)	Skull Circumference (r)	SEE (±cm)
All	Both	480	0.307	7.159	0.246	7.291	0.449	6.721
	Male	240	0.116	5.420	0.190	5.357	0.161	5.385
	Female	240	0.052	5.934	0.198	5.824	0.061	5.930
20 < 25	Male	40	0.017	4.303	0.160	4.248	0.306	4.097
	Female	40	0.032	6.040	0.303	6.314	0.125	6.573
25 < 30	Male	40	0.274	4.550	0.421	5.639	0.286	4.533
	Female	40	0.056	6.040	0.079	6.030	0.459	5.375
30 < 35	Male	40	0.276	5.972	0.420	5.639	0.189	6.100
	Female	40	0.256	5.507	0.274	5.478	0.214	5.565
35 < 40	Male	40	0.067	5.479	0.157	5.424	0.104	5.462
	Female	40	0.297	4.749	0.202	4.871	0.158	4.911
40 < 45	Male	40	0.012	4.453	0.192	4.370	0.360	4.155
	Female	40	0.048	5.918	0.176	5.832	0.134	5.871
45 ≤ 50	Male	40	0.163	6.790	0.098	6.849	0.060	6.870
	Female	40	0.064	5.669	0.150	5.616	0.156	5.612

Regression equations were derived using cranial dimensions to estimate stature (Table 4). Across the entire dataset, skull circumference showed the strongest correlation with stature for both sexes combined (r = 0.449, SEE = 6.721 cm). When analyzed by gender, the correlation coefficients were generally low, particularly in females where values were <0.2 for most dimensions. However, age-specific analyses revealed that certain age groups had higher predictive accuracy—for instance: In 25–30 yr old males, skull breadth showed moderate correlation (r = 0.421) with SEE of 5.639 cm. In 25–30 yr old females, skull circumference had a relatively strong correlation (r = 0.459), indicating better predictive utility in younger age groups.

Across both genders, SEE values were generally lower in males compared to females, indicating more precise stature prediction in male subjects.

DISCUSSION

The present study aimed to examine the relationship between cranial dimensions and stature across different age groups and sexes in a North Indian population, using data obtained from medico-legal autopsies. Statistically significant sexual dimorphism was observed in all measured cranial parameters—maximum skull length, breadth, and circumference—with males consistently exhibiting larger values than females across all age groups.

These findings are in line with previous literature. Rajshri Saini's study on 483 North Indian crania found that all cranial measurements were significantly higher in males, with the best sex-discriminating variable being the bizygomatic breadth, yielding an accuracy of 82.2% on its own and up to 84.75% when used with other cranial parameters.[1] This supports our findings, where cranial dimensions were robust predictors for sex estimation.

In our study, the cephalic index also showed significant sexual dimorphism. This is corroborated by work from Vineeta Saini et al., who observed that bizygomatic breadth and other craniofacial dimensions provide high discriminative accuracy (up to 85.5%) in Northern Indian populations.[8] These findings highlight the strong anthropometric basis for sex estimation using skull dimensions.

Stature estimation using skull measurements yielded a positive correlation, with regression analysis providing reliable predictive models in our population. Similar conclusions were reported by Shende et al., who found a statistically significant positive correlation between head length and stature among 391 individuals from Central India, with the derived regression formulas demonstrating population-specific accuracy.[5]

Ghosh et al. also validated the use of cranial features like orbital dimensions for sex determination in an Eastern Indian population, emphasizing that males had consistently larger measurements.[3] These trends were evident in our study as well, with statistically significant differences in cranial dimensions between sexes.

Another notable comparison is with the study by Kulathunga et al. from Sri Lanka, who examined skull bone thickness and reported significant gender-based variation, particularly in the frontal and occipital bones. While they found no correlation with stature, their gender-based differences in cranial thickness align with our results in cranial dimensional measurements.[2]

Further, Gautham et al. analyzed cranial vault thickness in relation to sex in a South Indian population and found significant differences by gender, emphasizing the utility of skull measurements in sex estimation in forensic contexts. This supports our application of cranial metrics in determining biological profiles.

Interestingly, our study also adds to the growing body of regional data essential for population-specific forensic standards. As emphasized by Iscan, the osteometric techniques must be adapted for local populations due to morphological variation across ethnic and geographic groups.[10]

Our findings reinforce the reliability of cranial dimensions for sex determination and stature estimation in forensic cases. The observed sexual dimorphism aligns well with earlier studies, underscoring the importance of region-specific anthropometric data. With statistically validated correlations, our regression models and discriminant analyses provide valuable tools for forensic identification in Northern Indian populations.[11]

CONCLUSION

This study confirms that cranial dimensions namely skull length, breadth, and circumference exhibit significant sexual dimorphism and can be reliably used for sex determination and stature estimation in medico-legal contexts. Males consistently demonstrated higher values than females across all age groups. Skull circumference showed the strongest correlation with stature among all cranial parameters. The derived regression equations are population-specific and provide valuable forensic tools for identification in Northern Indian populations.

REFERENCES

1. Saini R. Sexual dimorphism in cranial dimensions: A study on North Indian skulls. J Forensic Leg Med. 2013;20(2):550–5.
2. Kulathunga A, De Silva W, Edirisinghe P, et al. Gender and age-related variation in skull bone thickness in a Sri Lankan population: A forensic anthropological study. Forensic Sci Int. 2021;330:111111.
3. Ghosh M, Sengupta S, Majumdar P, et al. Evaluation of orbital dimensions for sexual dimorphism in Eastern Indian population. J Forensic Leg Med. 2020;74:102000.
4. Jasuja OP, Singh G. Estimation of stature from hand and phalange length. J Indian Acad Forensic Med. 2004;26(3):100–6.
5. Shende MR, Tambekar K, Dixit P. Estimation of stature from head length in adult population of Central India. Int J Res Med Sci. 2015;3(2):409–12.
6. Mahajan A, Batra A, Seema. Stature estimation from percutaneous tibial length: A study in North Indian males. Int J Med Toxicol Leg Med. 2009;11(1):12–14.
7. Chiba M, Terazawa K. Estimation of stature from somatometry of skull. Forensic Sci Int. 1998;97(2–3):87–92.
8. Saini V, Srivastava R, Rai RK, et al. Mandibular ramus: An indicator for sex determination – A study on human mandibles. J Forensic Sci. 2011;56(1):13–20.
9. Krogman WM, Iscan MY. The Human Skeleton in Forensic Medicine. 2nd ed. Springfield: Charles C Thomas; 1986.
10. Iscan MY. Rise of forensic anthropology. Yearbook Phys Anthropol. 1988;31:203–230.
11. Gautham B, Gnanadev KR, Shaik MA. Study of cranial vault thickness in adult South Indian population and its correlation with sex and age. Int J Anat Res. 2018;6(4.2):5882–7.