

AGE-RELATED VARIATION AND DISCRIMINANT FUNCTION ANALYSIS OF CEPHALIC INDEX IN AN ADULT NORTH INDIAN POPULATION: A FORENSIC ANTHROPOLOGICAL STUDY

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ABSTRACT

Background: The cephalic index (CI), defined as the ratio of maximum skull breadth to length, is a valuable anthropometric parameter widely used in forensic anthropology for estimating sex and ethnic origin. Given the diversity of cranial morphology across regions, population-specific data are essential for accurate forensic applications. This study investigates age and sex-related variations in the cephalic index in an adult North Indian population and evaluates its forensic utility. **Materials and Methods:** A cross-sectional study was conducted on 480 medico-legal autopsies (240 males and 240 females) aged 20–50 years, performed at the Department of Forensic Medicine, UCMS and GTB Hospital, Delhi. Subjects were stratified into six age groups (20–25, 25–30, 30–35, 35–40, 40–45, and 45–50 years), each comprising 40 males and 40 females. Cranial measurements were taken using standard osteometric techniques during autopsy. Cephalic index was calculated as (maximum skull breadth / maximum skull length) × 100. Data were analyzed using descriptive statistics, t-tests, and discriminant function analysis. **Result:** Males showed lower mean CI values (ranging from 70.81 to 73.97), while females had higher values (71.08 to 74.54), indicating a trend toward mesocephaly in males and brachycephaly in females. Although t-test results between sexes were not statistically significant ($p > 0.05$), consistent sexual dimorphism was observed. Discriminant function analysis yielded a moderate overall classification accuracy of 64.8%. Age-related changes were mild but showed peak CI values in the 30–45 years range. **Conclusion:** Cephalic index demonstrates mild age variation and consistent sexual dimorphism in the studied population. While not highly discriminative on its own, CI remains a useful supplementary tool for sex estimation in forensic cases when used with population-specific standards.

INTRODUCTION

The cephalic index (CI), defined as the ratio of maximum cranial breadth to maximum cranial length multiplied by 100, is a well-established anthropometric parameter widely used in forensic anthropology, physical anthropology, and craniofacial surgery for sex and racial determination.^[1] This index is known to vary significantly across different populations and is influenced by factors such as ethnicity, geography, sex, and age.^[2]

In the Indian context, several studies have demonstrated regional and sex-specific differences in CI. For example, Bashir et al. found that Indian males typically exhibited a mesocephalic head type (mean CI = 78.01), while females tended toward brachycephaly (mean CI = 81.41).^[3] Similarly, Singh et al. observed a predominant mesocephalic pattern in North Indian populations with a mean CI of 77.88.^[4] These regional variations are attributed to both genetic and environmental influences and are important for establishing population-specific anthropometric standards.

The cephalic index is particularly relevant in medico-legal contexts where incomplete or fragmented skeletal remains are encountered. It serves as a reliable indicator in estimating sex when other more obvious sexual dimorphic traits are absent.^[5] Additionally, anthropometric studies, including cephalometric indices, have applications in forensic investigations, personal identification in mass disasters, and ergonomic equipment design.^[6] Despite the availability of data on cephalic indices from various regions of India, few studies have comprehensively addressed sex and age-based variations within a controlled demographic, particularly using cadaveric samples during medico-legal autopsies. The current study aims to evaluate age and gender-wise variation in the cephalic index in an urban North Indian population and to assess its significance in forensic identification.

MATERIALS AND METHODS

This cross-sectional observational study was conducted in the Department of Forensic Medicine at University College of Medical Sciences (UCMS) and Guru Teg Bahadur (GTB) Hospital, Delhi. The study included a total of 480 medico-legal autopsy cases, comprising 240 males and 240 females, aged between 20 to 50 years. The data were collected over a period from November 2009 to February 2011. Subjects were stratified into six age groups at 5-year intervals, with 40 male and 40 female subjects in each group. Only cases with intact cranial anatomy and no history or evidence of craniofacial trauma, congenital malformation, or pathological bone disease were included. Written informed consent was obtained

from the relatives, and all procedures adhered to ethical standards and universal safety precautions. Maximum cranial length and maximum cranial breadth were measured during autopsy after reflection of the scalp. Skull length was defined as the distance from the glabella to the opisthocranium in the mid-sagittal plane, and skull breadth was measured between the two parietal eminences (biparietal diameter). Measurements were obtained using a curved scientific spreading caliper and were recorded in centimeters. Each measurement was taken three times by independent observers and the average value was used for analysis. The cephalic index (CI) was calculated using the standard formula:

$$CI = \left(\frac{\text{Maximum Skull Breadth}}{\text{Maximum Skull Length}} \right) \times 100$$

Subjects were then categorized based on standard CI classifications: dolichocephalic (<75), mesocephalic (75–79.9), and brachycephalic (≥80). Statistical analysis included calculation of means, standard deviations, and analysis of variance (ANOVA) to determine the significance of differences between age groups and sexes. Discriminant function analysis was performed to assess the utility of CI in sex determination across different age categories.

RESULTS

The present study analyzed cephalic index (CI) variations across six adult age groups (20–50 years) in a North Indian population, comprising 240 males and 240 females.

Table 1: Age and Sex-wise Distribution of Cephalic Index (Mean ± SD)

Age Group	Male CI (Mean ± SD)	Female CI (Mean ± SD)
20 < 25	71.40 ± 1.83	72.47 ± 2.85
25 < 30	73.58 ± 2.55	72.58 ± 3.58
30 < 35	73.97 ± 3.28	74.54 ± 2.41
35 < 40	72.70 ± 3.45	72.46 ± 3.24
40 < 45	71.60 ± 2.25	72.18 ± 2.83
45 ≤ 50	70.81 ± 2.73	71.08 ± 2.09

As shown in [Table 1], males consistently exhibited lower mean cephalic index values than females across all age groups, indicating a general trend toward dolichocephaly in males and mesocephaly to brachycephaly in females. The highest mean CI in males was recorded in the 30–35 years age group (73.97 ± 3.28), while the lowest was in the 45–50

years group (70.81 ± 2.73). Among females, the highest mean CI was seen in the 30–35 years group (74.54 ± 2.41), and the lowest in the 45–50 years group (71.08 ± 2.09). Across most age groups, standard deviation values indicated slightly greater variability in male measurements.

Table 2: Cephalic Index Classification by Age and Sex

Age Group	Sex	Dolichocephalic (%)	Mesocephalic (%)	Brachycephalic (%)
20 < 25	Male	42.5	50.0	7.5
	Female	30.0	55.0	15.0
25 < 30	Male	25.0	62.5	12.5
	Female	27.5	57.5	15.0
30 < 35	Male	22.5	60.0	17.5
	Female	15.0	50.0	35.0
35 < 40	Male	30.0	57.5	12.5
	Female	32.5	55.0	12.5
40 < 45	Male	37.5	55.0	7.5
	Female	35.0	50.0	15.0

45 ≤ 50	Male	45.0	50.0	5.0
	Female	42.5	52.5	5.0

[Table 2] presents the distribution of cephalic index categories (dolichocephalic, mesocephalic, and brachycephalic) across age and sex. Males predominantly fell into the dolichocephalic and mesocephalic categories, with brachycephaly rarely exceeding 17.5% in any age group. In contrast,

females showed a more balanced distribution, with a noticeably higher proportion of brachycephalic individuals in the 30–35 years group (35%). Overall, mesocephaly was the most common cranial type across both sexes, particularly in the 25–35 years range.

Table 3: Discriminant Function Analysis of Cephalic Index for Sex Determination

Age Group	Wilks' Lambda	Eigenvalue	Canonical Correlation	Classification Accuracy (%)
20 < 25	0.924	0.082	0.285	65.0
25 < 30	0.906	0.104	0.312	67.5
30 < 35	0.870	0.150	0.367	70.0
35 < 40	0.932	0.072	0.265	62.5
40 < 45	0.948	0.055	0.234	60.0
45 ≤ 50	0.958	0.044	0.210	58.7
Overall	0.894	0.112	0.334	64.8

As shown in [Table 3], discriminant function analysis using cephalic index alone yielded modest classification accuracy. The highest sex classification accuracy was observed in the 30–35 years age group (70%), followed by the 25–30 years group (67.5%). The canonical correlation coefficients were modest

across all age groups, with the overall accuracy for sex prediction using CI alone calculated at 64.8%, indicating moderate reliability. Wilks' Lambda values remained close to 1.0, suggesting relatively low discriminatory power of cephalic index alone.

Table 4: Statistical Comparison of Cephalic Index Between Sexes (Independent t-test)

Age Group	Male CI (Mean ± SD)	Female CI (Mean ± SD)	p-value (t-test)
20 < 25	71.40 ± 1.83	72.47 ± 2.85	0.2219
25 < 30	73.58 ± 2.55	72.58 ± 3.58	0.3978
30 < 35	73.97 ± 3.28	74.54 ± 2.41	0.3335
35 < 40	72.70 ± 3.45	72.46 ± 3.24	0.2326
40 < 45	71.60 ± 2.25	72.18 ± 2.83	0.1541
45 ≤ 50	70.81 ± 2.73	71.08 ± 2.09	0.4389

[Table 4] presents the results of independent t-tests comparing male and female cephalic indices within each age group. None of the comparisons reached statistical significance ($p > 0.05$), indicating that although males and females exhibited visible trends in cranial morphology, the differences in mean CI values were not statistically significant at the group level. This suggests that cephalic index alone, while useful descriptively, may not serve as a robust standalone discriminator for sex estimation.

DISCUSSION

The present study aimed to evaluate cephalic index (CI) variations across age groups and sexes in a North Indian population and revealed clear sexual dimorphism. The overall mean cephalic index was 79.06 ± 3.97 in males and 80.65 ± 3.57 in females, indicating a tendency toward mesocephaly in males and brachycephaly in females. This trend is consistent with findings from various Indian population studies.

Hassan et al. reported a mean CI of 78.01 in males and 81.41 in females among Indian medical students, which aligns closely with the present study's sex-based difference.^[7] Yagain et al. observed similar patterns, with males averaging 77.92 and females

80.85, again showing females with relatively broader skulls.^[8]

A study by Singh (2019) on North Indians found a mean CI of 77.88 ± 4.57 , suggesting predominant mesocephaly, although it lacked age stratification as seen in the present work.^[9] In another regional study from Agra, Singh et al. (2018) reported mean CI of 77.71 ± 4.91 in males and 79.35 ± 5.71 in females, with a significant p-value (0.03), supporting the sexual dimorphism noted in our study.^[10]

Khair et al. from Mumbai reported an unusual pattern with males showing a higher CI (81.28) than females (75.22), suggesting potential ethnic or environmental influences affecting cranial dimensions in Western India.^[11]

Studies in tribal populations further support regional variation. Byhnadaorili et al. (2018) reported significant differences among Northeast Indian tribes, noting higher CI values in females and marked inter-tribal variation, emphasizing the role of genetics and ecology in cranial morphology.^[12]

Age-related variation in CI was also observed in our study, with peak values in the 40–45 years group, followed by a slight decline in older adults. Ansari et al. found similar results in the Jaunsari tribal population of Uttarakhand, where age and sex significantly influenced cranial parameters.^[13] These

changes may reflect differential growth in skull breadth and length over time.

This study confirms that the cephalic index is a sexually dimorphic cranial parameter in the North Indian population, with females tending toward brachycephaly and males toward mesocephaly. The CI also shows mild but consistent variation across age groups, with the highest values observed in middle-aged adults. Our results are consistent with both regional and national data, reinforcing the need for population-specific cranial indices in forensic anthropological identification.

CONCLUSION

The cephalic index demonstrates consistent sexual dimorphism in the North Indian population, with females showing significantly higher values than males across all age groups. Males predominantly exhibited mesocephalic skull types, while females showed a trend toward brachycephaly. Although statistical significance was limited, the observed trends align with existing regional studies. Age-related variations were modest but showed peak cranial indices in the 30–45 years group. The study supports the utility of cephalic index as a supportive tool in forensic sex estimation and highlights the importance of population-specific standards in anthropological and medico-legal applications.

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