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Morphometric Study of the Foramen Magnum in Adult Human Skulls of Central India: A Cross-Sectional Osteological Analysis

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Abstract:

Background: The foramen magnum (FM) is a crucial anatomical structure at the base of the skull, transmitting vital neurovascular elements. Variations in its size and shape are relevant in neurosurgical access, forensic identification, and radiological assessment.

Objective: To analyze the morphometric dimensions and shape variations of the foramen magnum in adult human skulls of Central India and to assess any sexual dimorphism.

Methods: A cross-sectional osteological study was conducted on 120 adult human skulls (60 male, 60 female) of known sex obtained from medical colleges in Central India. Parameters including anteroposterior diameter, transverse diameter, and FM index were measured using digital calipers. Shapes were classified as oval, round, egg-shaped, tetragonal, and irregular. Data were analyzed using descriptive statistics and independent *t*-tests.

Results: The mean anteroposterior diameter was 34.8 ± 2.6 mm in males and 33.2 ± 2.1 mm in females ($p = 0.001$). The mean transverse diameter was 28.1 ± 1.9 mm in males and 26.8 ± 1.8 mm in females ($p = 0.003$). The most common shape was oval (40%), followed by round (28.3%). The FM index was significantly higher in males, indicating sexual dimorphism.

Conclusion: Morphometric variations of the foramen magnum, including sex differences, are important for surgical planning, anthropological studies, and forensic identification. The predominance of the oval shape in this population provides relevant baseline data for future studies.

Keywords: Foramen magnum, Skull base, Morphometry, Sex determination, Osteology, Central India

Introduction

The foramen magnum (FM) is a large oval or circular opening at the base of the skull through which the medulla oblongata, vertebral arteries, and spinal components pass. It serves as a vital communication portal between the cranial cavity and vertebral canal. Given its importance in clinical neurosurgery, especially in procedures involving the craniovertebral junction, accurate knowledge of its dimensions and shape is essential (1,2).

FM morphology is also used in forensic anthropology for sex determination and reconstructive surgery. Morphometric studies from various populations have revealed wide ethnic and geographical variation in FM dimensions and shapes (3–6). However, there is limited data on Central Indian populations, and even fewer studies have explored sex-specific differences.

This study aims to provide detailed morphometric data on the FM from skulls of known sex and Central Indian origin, contributing valuable baseline data for anatomists, clinicians, and forensic experts.

Materials and Methods

Study Design and Setting

This descriptive cross-sectional study was conducted in the Department of Anatomy at three medical colleges.

Sample Selection

A total of 120 adult human dry skulls of known sex were included—60 males and 60 females. Skulls with deformities, fractures, or developmental abnormalities in the occipital bone or FM region were excluded.

Measurements

The following parameters were measured using a digital Vernier caliper (accuracy ±0.01 mm):

- **Anteroposterior diameter (APD)**: Basion to opisthion
- **Transverse diameter (TD)**: Maximum width perpendicular to APD
- **Foramen Magnum Index (FMI)**: (TD / APD) × 100

FM shapes were classified visually as:

- Oval
- Round
- Egg-shaped
- Tetragonal
- Irregular

Each measurement was recorded by two independent observers, and the average of three readings was used.

Statistical Analysis

All data were entered in Microsoft Excel and analyzed using SPSS version 25.0. Mean ± SD were calculated for continuous variables. Independent t-test was applied to compare means between sexes. Chi-square test was used for shape distribution. $P < 0.05$ was considered statistically significant

Results

1. **Anteroposterior and Transverse Diameters**

Table 1 presents the FM dimensions. The mean **anteroposterior diameter** was significantly greater in males (34.8 ± 2.6 mm) compared to females (33.2 ± 2.1 mm) ($p = 0.001$). Similarly, the **transverse diameter** was higher in males (28.1 ± 1.9 mm) than females (26.8 ± 1.8 mm) ($p = 0.003$).

Table 1: Morphometric Dimensions of Foramen Magnum in Males and Females (Mean ± SD)

Parameter	Males (n=60)	Females (n=60)	p-value
Anteroposterior diameter (mm)	34.8 ± 2.6	33.2 ± 2.1	0.001*
Transverse diameter (mm)	28.1 ± 1.9	26.8 ± 1.8	0.003*
Foramen Magnum Index (%)	80.75 ± 5.3	80.72 ± 4.8	0.962

*Independent t-test applied; $p < 0.05$ considered statistically significant.

2. **Foramen Magnum Index (FMI)**

Although the FMI was marginally higher in males, the difference was not statistically significant ($p = 0.962$), indicating proportionally similar FM shapes between sexes.

3. **Shape Distribution**

Table 2 shows the distribution of FM shapes. The oval shape was most common (48/120, 40%), followed by round (34/120, 28.3%) and egg-shaped (20/120, 16.7%). Chi-square test did not reveal significant sex differences in shape distribution ($p = 0.214$).

Table 2: Distribution of Foramen Magnum Shapes by Sex

Shape	Males (n = 60)	Females (n = 60)	Total (n = 120)	p-value
Oval	26 (43.3%)	22 (36.7%)	48 (40.0%)	0.214
Round	16 (26.7%)	18 (30.0%)	34 (28.3%)	
Egg-shaped	10 (16.7%)	10 (16.7%)	20 (16.7%)	
Tetragonal	5 (8.3%)	6 (10.0%)	11 (9.2%)	
Irregular	3 (5.0%)	4 (6.7%)	7 (5.8%)	

Discussion

This study provides baseline data on the foramen magnum's morphometry in Central Indian adult skulls. The mean AP and transverse diameters were higher in males, confirming sexual dimorphism, which aligns with findings from studies in North India, Nigeria, and Turkey (7–10).

The FM index helps determine shape—values <81 suggest a dolichotreme (elongated) type, while >81 suggest brachytreme (broad). In this study, the majority were borderline dolichotreme to mesotreme, consistent with global averages (11,12).

The oval shape was the most frequent, similar to Indian, Turkish and Iranian skull studies (13–15), while round and egg-shaped foramina followed in frequency.

From a surgical standpoint, FM dimensions are vital in posterior cranial fossa decompressions. Smaller FM may complicate access or cause crowding of neurovascular structures (16). In forensic anthropology, FM morphometry assists in sex estimation and racial profiling (17–18).

Limitations

- Lack of age-related data
- Only dry bones used; no soft tissue correlation
- Sample size limited to 120 skulls

Future studies should explore radiological correlations (CT/MRI), 3D modeling, and population-wide variations.

Conclusion

The study confirms the presence of sexual dimorphism in the morphometry of the foramen magnum in the Central Indian population. The oval shape was most prevalent, and significant differences were noted in AP and transverse diameters between sexes. These anatomical insights are crucial for neurosurgeons, anthropologists, and forensic experts.

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