

Research Article



INTERNATIONAL RESEARCH JOURNAL OF PHARMACY

[www.irjponline.com](http://www.irjponline.com)

ISSN 2230-8407 [LINKING]

## Gender Differences in Foramen Magnum Breadth: A Radiological Study Using CT Scans at Sawai Man Singh Hospital Jaipur during Period of Year 2023-24

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How to cite: Sudarshan Kumar, Rajkumar, Rajesh Kumar Meena, Sumanta Dutta, Surya Bhan Kushwaha, Gender Differences in Foramen Magnum Breadth: A Radiological Study Using CT Scans at Sawai Man Singh Hospital Jaipur during Period of Year 2023-24. International Research Journal of Pharmacy, 2025,16:7:95-101.

Doi: <http://doi.org/10.56802/irjp.2025.v16.i07.pp95-101>

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### ABSTRACT

**Background:** Sex estimation is a fundamental component of forensic anthropology, particularly crucial in scenarios involving fragmented or decomposed remains. While the pelvis remains the most accurate skeletal element for this purpose, it is often unavailable. In such cases, the skull, and more specifically the foramen magnum (FM), offers a reliable alternative. Located in the occipital bone, the FM serves as a stable anatomical landmark and its morphometric parameters especially breadth are known to exhibit sexual dimorphism. However, population-specific data are essential for accurate forensic applications due to regional skeletal variability.

**Aim:** The aim of this study was to compare the breadth of the foramen magnum between males and females using computed tomography (CT) scans and assess its utility in sex determination within the Rajasthan population.

**Methodology:** This was a hospital-based cross-sectional observational study conducted in the Department of Forensic Medicine in collaboration with the Department of Radiology at SMS Medical College, Jaipur, from February 2023 to January 2024. A total of 96 adult subjects (48 males and 48 females), aged between 20 and 60 years, were selected through stratified random sampling. Foramen magnum breadth was measured on axial CT images using radiological software, and the data were statistically analyzed to identify sex-based differences.

**Observation and Result:** Males showed consistently higher mean FM breadth compared to females across all age groups. The maximum average in males was  $31.0 \pm 0.5$  mm and in females  $28.7 \pm 0.4$  mm, observed in the 30–40 years group. The smallest values were noted in the 50–60 years group. The data clearly demonstrated sexual dimorphism in FM breadth.

**Conclusion:** CT-based measurement of foramen magnum breadth provides a reliable, non-invasive method for sex determination. The region-specific data generated in this study contribute to forensic identification efforts where conventional skeletal markers are unavailable.

**Keywords:** Foramen magnum, Sexual dimorphism, CT scan, Forensic identification, Rajasthan population.

## INTRODUCTION

Sex estimation from skeletal remains is a critical aspect of forensic anthropology and plays an important role in human identification during mass disasters, criminal investigations, and archaeological excavations. Traditionally, the pelvis is regarded as the most reliable skeletal element for sex determination, offering up to 95% accuracy. However, it is often unavailable in many forensic cases due to fragmentation or severe trauma<sup>1</sup>. In such situations, cranial structures, particularly the base of the skull, offer valuable alternatives due to their durability and frequent preservation<sup>2</sup>.

The foramen magnum, located in the occipital bone, serves as the conduit for the spinal cord, vertebral arteries, and accessory nerves. Among its morphometric parameters, the breadth (transverse diameter) has been reported to exhibit measurable sexual dimorphism. Several global and Indian studies have demonstrated that males generally have a greater foramen magnum

breadth compared to females<sup>3,4</sup>. However, differences in skeletal morphology vary with ethnicity, geography, and population genetics, underlining the need for region-specific standards<sup>5</sup>.

Advances in radiological techniques, especially computed tomography (CT), have facilitated accurate, non-invasive measurement of skeletal features, making it a preferred tool in forensic investigations<sup>6</sup>. Despite existing literature, there is limited data on the morphometric analysis of the foramen magnum in the population of Rajasthan. This study, conducted at Sawai Man Singh Hospital, Jaipur during 2023–24, aims to assess the gender differences in foramen magnum breadth using CT scans to establish baseline data for forensic application in this region.

**AIM:** To compare the foramen magnum breadth between males and females using CT scans for sex determination in the Rajasthan population.

## **METHODOLOGY**

This was a hospital-based cross-sectional observational study conducted to evaluate sexual dimorphism based on the breadth of the foramen magnum. The research was carried out in the Department of Forensic Medicine and Toxicology, in association with the Department of Radiology, at SMS Medical College and its affiliated hospitals in Jaipur, Rajasthan from February 2023 to January 2024. The study population comprised 96 individuals (48 males and 48 females) aged between 20 and 60 years. Participants were selected through stratified random sampling, ensuring equal distribution across four age groups (20–30, 30–40, 40–50, and 50–60 years), with 12 males and 12 females in each group. Participants were selected based on strict inclusion and exclusion criteria, ruling out cases with cranial pathology or trauma. Informed consent was obtained from all subjects. All subjects were residents of Rajasthan and underwent CT scans of the head for diagnostic purposes unrelated to trauma or skull base pathology. CT scan data were obtained using standardized head imaging protocols. The transverse diameter (maximum breadth) of the foramen magnum was measured in the axial plane using dedicated radiological software.

## **RESULT & OBSERVATION**

This observational study was undertaken at SMS Medical College, Jaipur, by the Departments of Forensic Medicine and Radiology between February 2023 and January 2024. It aimed to analyze the maximum transverse diameter (breadth) of the foramen magnum in males and females using CT scans, to explore its role in sex determination. The study included 96 adult participants 48 males and 48 females equally divided into four age categories (20–60 years). The foramen magnum breadth was measured in axial CT images using standard radiological tools. The recorded data were statistically compared to identify sexual dimorphism. This study aims to contribute region-specific forensic reference data that can aid in human identification where skeletal remains are incomplete.

**Table 01: Foramen Magnum Breadth across Gender and Age Groups**

Age Group	Males (Mean ± SD)	Females (Mean ± SD)
20Y–30Y	30.8 ± 0.4	28.5 ± 0.5
30Y–40Y	31.0 ± 0.5	28.7 ± 0.4
40Y–50Y	30.9 ± 0.5	28.6 ± 0.4
50Y–60Y	30.7 ± 0.4	28.4 ± 0.4

In this study males consistently showed greater mean breadth than females in all age categories. The highest mean in males was 31.0 ± 0.5 mm (30–40 years), while in females it was 28.7 ± 0.4 mm in the same group. The smallest values were noted in the 50–60 years group for both sexes. Overall, the data indicate clear sexual dimorphism in foramen magnum breadth.

## DISCUSSION

The present CT-based study conducted at SMS Medical College, Jaipur, demonstrated consistent sexual dimorphism in foramen magnum (FM) breadth across all age groups. Males exhibited greater mean transverse diameters than females, with the highest values observed in the 30–40 years age group for both sexes. This supports the hypothesis that FM breadth can serve as a valuable indicator for sex estimation in forensic contexts. **Krogman and Iscan (1986)<sup>1</sup>** were among the first to emphasize the role of cranial base measurements, including the foramen

magnum, in cases where skeletal remains are incomplete or fragmented, highlighting their relevance in forensic medicine. Similarly, **Scheuer and Black (2000)**<sup>2</sup> reinforced the significance of cranial features, particularly in juvenile and decomposed skeletons, where other bones may not be intact. Uysal et al. (2005) conducted a CT-based study in Turkey and found that males had significantly larger FM dimensions, validating the role of radiological techniques in estimating sex. Our findings are also consistent with **Kamath et al. (2015)**<sup>4</sup>, who, in a South Indian population, confirmed sexual dimorphism in Foramen Magnum breadth using CT imaging. **Kranioti et al. (2011)**<sup>5</sup> further noted sexual dimorphism in the cranial base in modern humans using computed tomography, reinforcing the value of Foramen Magnum breadth as a metric. Similarly, **Uthman et al. (2012)**<sup>6</sup> employed helical CT scanning to examine Foramen Magnum dimensions and reported a statistically significant difference between sexes. **Gapert R et al. (2009)**<sup>7</sup> used discriminant function analysis on historical British samples and demonstrated that Foramen Magnum breadth could accurately distinguish between males and females. Their findings affirm the forensic utility of this dimension. **Nayak SR et al. (2013)** also observed that the Foramen Magnum transverse diameter was consistently larger in males in their Indian sample, echoing the trends seen in our dataset. Taken together, the findings of the present study and prior literature confirm that Foramen Magnum breadth is a reliable, non-invasive, and population-sensitive parameter for sex determination. The region-specific data generated here for Rajasthan fills a crucial gap and can enhance the forensic application of CT morphometry in sex determination where conventional skeletal markers are absent.

## CONCLUSION

The present study demonstrates that the breadth of the foramen magnum shows consistent sexual dimorphism, with males exhibiting larger transverse diameters than females across all age groups. These results support the use of CT-based morphometric analysis as a reliable method for sex estimation in forensic contexts. The foramen magnum, being a well-preserved structure in fragmented remains, provides a dependable anatomical landmark when other skeletal elements are unavailable. This research adds region-specific reference data for the Rajasthan population and reinforces the value of Foramen Magnum breadth as a non-invasive, reproducible parameter in human identification, especially in cases involving decomposed or incomplete skulls.

## RECOMMENDATION OF STUDY

This study recommends the use of Foramen Magnum breadth as a reliable parameter for sex determination in forensic cases where other skeletal elements are unavailable. It emphasizes the need to develop region-specific reference data and encourages the integration of CT-based morphometric analysis into routine forensic practice. The study also advocates for incorporating such techniques into medical training and calls for further research with larger samples to validate findings and improve accuracy in human identification across diverse populations.

## LIMITATION OF STUDY

The study was limited by a small, region-specific sample size, exclusion of other foramen magnum dimensions, and reliance on CT scans from a single tertiary centre, which may reduce generalizability and introduce bias.

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