Craniometric analysis of foramen magnum with reference to occipital condyles for the determination of sex using dry human skulls

D. Angel Fastina Mary¹, K. Yuvaraj Babu², Karthik Ganesh Mohanraj*²

INTRODUCTION

Identification of an individual is of utmost importance in conditions of natural calamities or man-made disasters.¹ In such cases, the damaged dead bodies or its remains or the skeletal parts and bones found post a question of identification. For doing so, the determination of gender of the remains is the first line of delineation. Apart from these situations, the identification of sex from human remains a primary importance in forensic medicine, especially in criminal investigations, in the identification of missing persons, in anthropology, and in attempts at reconstructing the lives of ancient populations.² Thus, the determination of sex is statistically the most important criterion, as it immediately excludes nearly half of the population.

Identifying fresh dead bodies is relatively easy when compared with identifying decomposed and skeletonized human remains.³ When the skeletal remains found are complete, gender identification of the bones become easy. However, if the skeletal framework is fragmented and incomplete, then sexing of such remains becomes a major problem for identification. The human skull is considered as one of the most reliable bones for sex determination next to the pelvic bone.⁴ In the skull, several features can be used to assess the sex of the individual, and one such osseous landmark is the foramen magnum. Hence, foramen magnum is one of the bony features used to differentiate the sex of the skull found.⁴ Thus, it is assessed alone or together with the adjacent structures in sexing of the individual.

KEY WORDS: Anthropology, Dry human skull, Foramen magnum, Occipital condyle, Sex

ABSTRACT

Introduction: The foramen magnum is a large opening in the base of the skull at the posterior cranial fossa. The dimensions of the foramen magnum are clinically important because the vital structures passing through it may endure compression such as in the cases of foramen magnum herniation and meningiomas. The longitudinal and transverse diameter (TD) and also the area of foramen magnum are higher in males than in females. Therefore, its dimensions could be used to establish the gender in several medicolegal conditions. Materials and Methods: A total of 50 dry human skull bones were obtained. All measurements were taken by Vernier caliper to the nearest of 0.1 mm. Morphometrical measurements of the foramen magnum such as the distance between basion and midpoint of anterior margin of occipital condyle, distance between opisthion and mid-point of posterior margin of occipital condyle, longitudinal diameter (LD), TD, and area of the foramen magnum were calculated. Results: The mean LD of foramen magnum was 35.48 mm in male and 34.15 mm in female. The mean TD of foramen magnum in male was 29.96 mm and in female was 27.74 mm. The mean area of foramen magnum in male was 871.46 mm² and in female was 803.42 mm². Conclusion: A high significant difference was observed between the two sexes. The dimension of the foramen magnum is clinically important because of the vital structures passing through it. Apart from its clinical significance, it is also useful in anthropology, forensic medicine, etc., for the determination of sex.
The foramen magnum is a large opening in the base of the skull at the posterior cranial fossa. It is roughly oval in shape and wider behind, with the greatest diameter being the anteroposterior. It contains several vital structures such as the terminal part of the medulla oblongata, a pair of vertebral arteries, and spinal accessory nerves. The dimensions of the foramen magnum are clinically important because the vital structures passing through it may endure compression such as in the cases of foramen magnum herniation and meningiomas. Morphometry of the foramen magnum is even important before the cutting off the foramen magnum lesions. The diameters and area of the foramen magnum are greater in males than in females, and hence, its dimensions can be used to determine sex in different critical situations such as medicolegal investigations.

Foramen magnum measures approximately 3.5 cm anteroposteriorly and about 3 cm wide. The foramen magnum is surrounded by different parts of the occipital bone, such as anteriorly the basilar part, posteriorly and superiorly the squamous part, and on the lateral sides the condylar part. On each side, its anterolateral margin is tapered by occipital condyles, and hence, the foramen magnum is narrow in the anterior part. The anterior border of the foramen magnum is somewhat thickened which lies between the anterior ends of the condyles. The posterior half of the foramen magnum is thin and semicircular.

A study on the dimensions of foramen magnum demonstrated that, in male skulls, the average of anteroposterior diameter was 3.55 ± 0.28 cm, the average of the transverse diameter (TD) was 2.46 ± 0.19 cm and average of the area of foramen magnum was 8.19 ± 0.94 cm². In female skulls, the averages of anteroposterior diameter, TD, and area of foramen magnum were 3.20 ± 0.28 cm, 2.71 ± 0.16 cm, and 71 ± 0.90 cm² respectively. This study explained that, in male skulls, anteroposterior diameter, TD, and area of the foramen magnum were significantly higher than the female skulls.

The results of several other studies on the morphometry of foramen magnum confirmed that the mean anteroposterior diameter, TD, and area of foramen magnum are lower in females than in males. Thus, the present study focuses on the longitudinal diameter (LD), TD, and the area of the foramen magnum with reference to occipital condyle to determine the sex of the skull.

MATERIALS AND METHODS

A total of 50 dry human skull bones were obtained from the Department of Anatomy, Saveetha Dental College and Hospitals, Chennai. Sex of each skull was determined by the classic anatomical bony features, and the age of the skulls was grossly determined by observing the fusion of closure of sutures. All measurements were taken by Vernier caliper to the nearest of 0.1 mm.

Morphometrical Measurements of the Foramen Magnum

Measure-1
- Distance between basion and mid-point of anterior margin of occipital condyle
- Distance between opisthion and mid-point of posterior margin of occipital condyle.

Measure-2
- LD - distance between basion and opisthion
- TD - maximum distance between two lateral margin.

Area of the foramen magnum - AREA (A) = ¼ × p × w × h

Figure 1 shows the morphometric measurements of the foramen magnum.

RESULTS

The LD of the foramen magnum in males ranged from 28.34 to 39.26 mm with an average of 35.48 ± 0.46 as mean ± SD, and in females, it was 27.56–37.15 mm with an average of 34.15 ± 0.75 mm. The TD of the foramen magnum in males ranged from 27.24 to 32.19 mm with an average of 29.96 ± 0.95 as mean ± SD, and in females, it was 26.93–28.81 mm with an average of 27.74 ± 0.86 mm. The area (A) of foramen magnum in males ranged from 683.77 to 1118.56 mm² with an average of 871.46 ± 84.39 mm² as mean ± SD, and in females, it was 625.12–1005.31 mm² with an average of 803.42 ± 72 mm². All these observations are given in Table 1 and Figure 2.
The mean basio-occipital point was 0.98 mm in males and 0.83 mm in females. The mean opisthio-occipital point was 2.65 mm in males and 2.41 mm in females [Figure 3].

**DISCUSSION**

The present study shows the mean LD of the foramen magnum of male skulls to be 35.48 mm. This mean value of the present study was little higher than the observations reported by Sayee *et al.* [13] and Muralidhar *et al.* [11]. However, it was slightly lower than the observations reported by Routal *et al.* [12] on Gujarati male skulls with a mean value of 35.5 mm and 33.5 mm in females, Catalina Herrera on Spain Caucasian male skull, [14] and Suazo *et al.* on Brazilian male skulls. [15] The mean LD of the foramen magnum in female skulls of the present study was 34.15 mm. This mean value was higher with the observations reported by Sayee *et al.* [13] whose mean value was 33.50 mm in Karnataka female skulls and Watanabe *et al.* [16] reported 33.70 mm as the mean value on Japanese female skulls, but it was lower than the values reported by Catalina Herrera [14] on Spain white female skulls (34.30 mm) and Suazo *et al.* [15] on Brazilian female skulls (35.6 mm).

In the present study, the mean TD of the foramen magnum of male skulls was considerably higher than the female skulls. The mean TD of the foramen magnum of male skulls (29.96 mm) of the present study was nearly similar to the observations of Sayee *et al.* [13] on Karnataka male skulls (28.5 mm), whereas it was lower than the values reported by Catalina Herrera [14] on Spain Caucasian male skull (31.1 mm), Suazo *et al.* [15] on Brazilian male skulls (30.6 mm), and Routal *et al.* [12] on Gujarati male skulls (30.6 mm). The mean TD of the female skull (27.74 mm) in the present study was similar to the observations made by Routal*et al.* [12] on Gujarati female skull mean value of 27.11 mm and Sayee *et al.* [13] on Karnataka female skulls reported 28.0 mm as mean, but it was lower than the values reported by Catalina Herrera [14] on Spain white female skulls which was 29.60 mm, Watanabe *et al.* [16] on Japan female skulls to be 28.60 mm, and Suazo *et al.* [15] on Brazilian female skulls to be 29.50 mm as the mean value.

In the present study, the area of the foramen magnum of male skulls (871.46 mm$^2$) was remarkably larger than female skulls (803.42 mm$^2$). The mean area of the foramen magnum of males in the present study was slightly higher than the observations made by Sayee *et al.* [13] on male skulls of Karnataka (769.0 mm$^2$). On the other hand, the area was less than the observations made on Gujarati male skulls (819.0 mm$^2$) by Routal *et al.* [12], on Spain Caucasian male skull (888.4 mm$^2$) by Catalina Herrera, [14] and on Turkey male skulls (909.9 mm$^2$) by Gunay. [8] The mean area of the foramen magnum of female skulls in the present study (803.42 mm$^2$) was also higher than the observations made by Sayee *et al.* [13] on Karnataka female skulls (746.0 mm$^2$) and Routal *et al.* [12] on Gujarati female skulls (771.0 mm$^2$). It was lower in comparison with observations of Gunay [9] on Turkey female skulls (819.0 mm$^2$).

<table>
<thead>
<tr>
<th>Samples</th>
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<th>Male</th>
<th>Female</th>
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<tr>
<td></td>
<td>Range</td>
<td>Mean±SD</td>
<td>Range</td>
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<tr>
<td>Foramen magnum</td>
<td>28.34–39.26</td>
<td>35.48±0.46</td>
<td>27.56–37.15</td>
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<td>27.24–32.19</td>
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<td>683.77–1118.56</td>
<td>871.46±84.39</td>
<td>625.12–1005.31</td>
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LD: Longitudinal diameter, TD: Transverse diameter, SD: Standard deviation
Apart from the above used usual morphometric parameters, we also analyzed two specific parameters with reference to occipital condyle, the mean basio-occipital point and mean opisthio-occipital point. The mean basio-occipital point was 0.98 mm in males and 0.83 mm in females. The mean opisthio-occipital point was 2.65 mm in males and 2.41 mm in females. These measurements may also be helpful in relation to the size and dimensions of foramen magnum in cases of gender determination as there are differences in the mean values between these two osteometric of male and female.

One study reported 80% accuracy of sex determination using morphological parameters of cranium. The parameters associated with the foramen magnum such as the LD, TD, and its area have a high specificity and sensitivity for the determination of sex. The rate of accuracy was about 96% using this method. However, considering the high percentage of gender predictability by the dimensions of the foramen magnum in the present study and the studies preceding it, the foramen magnum measurements can be used to supplement other sexing evidence available so as to precisely ascertain the sex of the skull and in turn the individual itself.

**CONCLUSION**

High significant difference was observed between the two sexes. The dimension of the foramen magnum is clinically important because of the vital structures passing through it. Apart from its clinical significance, it is also useful in anthropology, forensic medicine, etc., for the determination of sex. Sex determination in missing or damaged skeletal remains is a major problem in forensic medicine. Therefore, anthropo-morphometric measurements can help us in solving this problem. Since the foramen magnum has a regular structure and is located in an area that is less prone to injury, it can be used as a helpful tool for sex determination. Nevertheless, to utilize these indicators, it is required to have local data in each country.

**REFERENCES**


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