

Original Article

## MORPHOMETRIC ANALYSIS OF FORAMEN MAGNUM

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### ABSTRACT

**Background:** Diameters of foramen magnum are important because vital structures passing through it and for sex determination of skulls. The dimensions of the foramen magnum are clinically important because vital structures passing through it may endure compression such as in cases of foramen magnum herniation, foramen magnum meningiomas and foramen magnum achondroplasia. The knowledge of foramen magnum diameters is needed to determine some malformations such as Arnold Chiari syndrome, which shows expansion of transverse diameter.

**Objectives:** To study longitudinal diameter, transverse diameter and area of foramen magnum in relation to sex.

**Methods:** 150 dry skulls and 30 CT scan images of living subjects were studied. Diameters of foramen magnum were measured by vernier calipers and its area was calculated by formula. Diameters and area of foramen were measured automatically.

**Results:** The mean longitudinal diameter of foramen magnum in male was 33.4mm and female was 33.1mm and by CT Imaging method in male was 38.5mm and female was 35.2mm. The mean transverse diameter of foramen magnum in male was 28.5mm and female was 27.3mm and by CT Imaging method in male was 29.1mm and female was 27.6mm.

**Conclusion:** longitudinal and transverse diameters and area of foramen magnum of male skulls were greater than females.

**KEYWORDS:** Skull; Sex; Anthropology; Foramen Magnum; Race.

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### INTRODUCTION

The foramen magnum is a large opening in the base of skull, it is oval, wider behind with greatest diameter being antero-posterior. It contains the lower end of the medulla oblongata, the vertebral arteries and spinal accessory nerves [1]. The dimensions of the foramen magnum are clinically important because the above mentioned vital structures passing through it may

endure compression such as in cases of foramen magnum herniation, foramen magnum meningiomas and foramen magnum achondroplasia [2]. The knowledge of foramen magnum diameters is needed to determine some malformations such as Arnold Chiari syndrome, which shows expansion of transverse diameter [3]. The dimensions of the foramen magnum are important prior to the cutting off of the foramen

magnum lesions or posterior cranial fossa lesions, because more the antero-posterior diameter, greater is the contra lateral exposure [2]. The diameters and area of the foramen magnum are greater in males than in females, hence its dimensions can be used to determine sex in the medicolegal conditions, especially in the following circumstances, such as explosions, aircraft accidents and war fare injuries [3,4].

Foramen magnum is about 3cm wide by 3.5cm anteroposteriorly [5, 6]. It is located midway between and on a level with mastoid processes. The foramen magnum is surrounded by different parts of the occipital bone, squamous part lies behind and above, basilar part in front and a condylar part on either sides [7,8]. On each side its antero-lateral margin is encroached by occipital condyles, hence the foramen magnum is narrow anteriorly. The anterior edge of the foramen magnum is slightly thickened and lies between the anterior ends of the condyles. The posterior half of the foramen magnum is thin and semicircular. Upper ends of anterior and posterior atlanto-occipital membranes are attached to the anterior and posterior margins of the foramen magnum respectively, and their lower ends are attached to the superior surface of anterior and posterior arches of the atlas respectively.[6] The foramen magnum is a wide communication between posterior cranial fossa and the vertebral canal. The narrow anterior part of the foramen magnum has apical ligament of dens, upper fasciculus of the cruciate ligament and membrana tectoria, both are attached to the upper surface of basioccipital bone in front of the foramen magnum. Its wide posterior part contains the medulla oblongata and its meninges. In subarachnoid space spinal rami of the accessory nerve and vertebral arteries, with their sympathetic plexus, ascend into the cranium; the posterior spinal arteries descend posterolateral to the brain stem, where as anterior spinal artery descends anteromedian to the brain stem. The cerebellar tonsils may project into the foramen magnum [9].

A metrical study of 84 mature male Chinese skulls conducted at University of Edinburgh, which showed mean foramen magnum length for Chinese type I skull of 35.71mm and breadth

was 28.24mm, whereas Chinese type 2 crania had mean foramen magnum length of 35.21mm and breadth was 28.00 mm[10]. The CT scan of foramen magnum of 200 children of all ages and 100 adults, showed an average foramen magnum length of 35mm in adults and that of children reached the adult size by 3-4 years of age [11]. In a presentation of Brazilian skulls, the area of foramen magnum was 673- 1195 mm<sup>2</sup> for males and 591-961mm<sup>2</sup> for females [12]. A study conducted at Govt. Medical College, Surat for dimensions of foramen magnum, study sample was composed of 141 adult skulls (104 males, 37 females) it showed following foramen magnum measurements. In males skulls anteroposterior diameter varied from 3 - 4.2 cm with an average of 3.55±0.28cm, transverse diameter was varied from 2.5-3.5cm with an average of 2.46±0.19cm, and area of foramen magnum was varied from 5.8-10.29cm<sup>2</sup> with an average of 8.19±0.94 cm<sup>2</sup>. In female skulls the anteroposterior diameter was varied from 2.8-3.5cm with an average of 3.20±0.28cm, transverse diameter was varied from 2.4- 3.2 cm with an average of 2.71±0.16cm and area of foramen magnum varied from 5.49-8.79 cm<sup>2</sup> with an average of 7.71±0.90 cm<sup>2</sup>. The study showed male skulls anteroposterior diameter, transverse diameter and area of the foramen magnum were significantly higher than female skulls [13].

In a study computerized tomographic dimensions of the foramen magnum of 63 achondroplastic individuals were compared to standards established for nonachondroplastic individuals. The size of the foramen magnum in patients with achondroplasia was small at all ages, particularly in those with serious neurological problems [14]. In an anatomic metric study of foramen magnum of 100 male and 100 female skulls of normal white people of Spain showed a mean sagittal diameter of 36.2±0.3mm and the area of foramen magnum of 888.4±13.9mm<sup>2</sup> in male skulls. In female skulls mean sagittal diameter was 34.3±0.4mm, transverse diameter of 29.6±0.3mm and the area of foramen magnum of 801±17.1 mm<sup>2</sup>. Foramen magnum dimension of male skulls were significantly higher than female skulls [14].

In a study conducted at St.John Medical College,

Bangalore on 350 skulls (175 males, 175 females) for foramen magnum dimensions showed. In male skulls antero-posterior diameter of foramen magnum was varied from 2.8-4.1 cm with a mean of  $3.42 \pm 0.24$  cm, transverse diameter was varied from 2.3-3.6 cm with a mean of  $2.85 \pm 0.23$  cm and the area of foramen magnum was varied from 5.6-11 cm<sup>2</sup> with a mean of 7.69 cm<sup>2</sup>. In female skulls antero-posterior diameter of foramen magnum was varied from 2.2-3.3 cm with a mean of  $2.8 \pm 0.22$  cm and area of the foramen magnum was varied from 5.1-10 cm<sup>2</sup> with a mean of  $7.8 \pm 0.98$  cm<sup>2</sup> [15]. The fitted nonachondroplastic foramen magnum growth curves demonstrate that the maximum growth occurs in the first 18 months and slows thereafter. Indeed, the sagittal dimension almost doubles within the first 2 years, while the transverse dimension enlarges by half the original dimension. Growth of this area is essentially complete by 5 years. The achondroplastic foramen magnum is small at birth, and during the first year it has a very severely impaired rate of growth essentially in the transverse dimension. This markedly diminished growth results not only from abnormal enchondral bone growth but also because of abnormal placement and fusion of the synchondroses [16].

In a measurement of area of foramen magnum in 219 skeletons (170 males, 39 females) of Turkey, it was observed that mean area of the foramen magnum was significantly different ( $909.91 \pm 126.02$  mm<sup>2</sup> in males,  $819.01 \pm 117.24$  mm<sup>2</sup> in females). Correlation coefficient between the area of the foramen magnum and sex was 0.27. The results confirmed that mean area of foramen magnum is lower in females than in males [13]. The present study taken up to study the longitudinal diameter, transverse diameter and the area of the foramen magnum in relation to sex.

### MATERIALS AND METHODS

150 dry adult human skulls (100 male, 50 female) were collected from the Department of Anatomy and Forensic Medicine, J.J.M. Medical College, Davangere. Sex of each skull was determined by the classic anatomic features, the age of the skulls was determined by recording the fusion of closure of the sutures.

**Measurements of the foramen magnum** (Fig. No.1): Longitudinal diameter (LD) of the foramen magnum - It is distance between basion and opisthion. Transverse diameter (TD) of the foramen magnum - It is maximum distance between two lateral margins [13]. Measurements of the foramen magnum were taken by vernier calipers to the nearest of 0.1 mm. Measurements were taken twice and average of two values was taken as final measurement. Area of the foramen magnum - It is surface area of the foramen magnum calculated by the following formula [17].

$$\text{AREA (A)} = \frac{1}{4} \times \pi \times w \times h$$

w = Width, transverse diameter

h = Height, longitudinal diameter

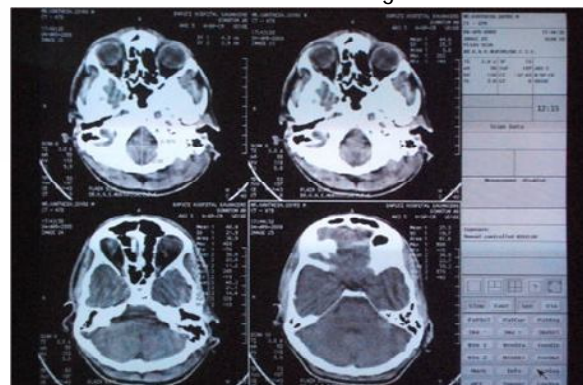
$\pi = 22/7$ , mathematical constant.

CT Image measurements of the foramen magnum - The best images of the foramen magnum was selected, longitudinal and transverse diameters of the foramen magnum were measured using tools of the software. The area of the foramen magnum was measured by planimetry method (Fig. No. 2).

**Fig 1:** Measurement of diameters of foramen magnum in skulls.



**Fig. 2:** Measurement of diameters of foramen magnum in CT scan images.





**The Statistical methods:** Results were expressed as mean ± standard deviation and range. Unpaired 't' test was used to compare between males and females. P value of 0.05 or less was considered for statistical significance.

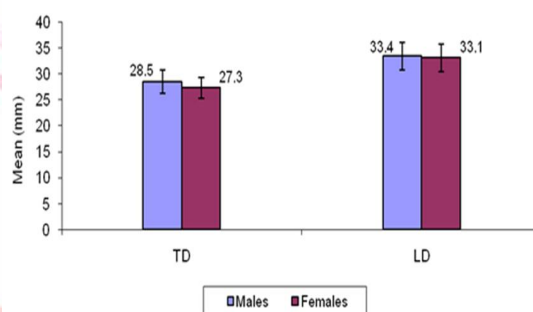
**RESULTS**

**In dry Skulls:** The longitudinal diameter of the foramen magnum in male skulls was between 26.7-39.8mm, with a mean of 33.4±2.6mm (mean ± SD), whereas in females longitudinal diameter was between 28-39.3mm with a mean of 33.1±2.7mm (Graph No. 1). The mean longitudinal diameter of male skulls was not significantly higher than in female skulls (p= 0.59). The transverse diameter of the foramen magnum in male skulls varied from 24.3 – 37.7 mm with an average of 28.5±2.2mm, while in females the transverse diameter varied from 23.6 – 33.6 mm with an average of 27.3± 2.0 mm (Graph No. 1). The mean transverse diameter of the foramen magnum of male skulls was significantly larger than in female skulls (p<0.01). The area of the foramen magnum of male skulls was between 540.8-1002.7 mm<sup>2</sup>, with an average of 748.6±97.8mm<sup>2</sup>, whereas in female skulls the area of the foramen magnum was between 557.1 – 1017.7 mm<sup>2</sup> with an average of 711.1±97.7 mm<sup>2</sup>. The area of the foramen magnum of male skull was significantly greater than in female skulls (p< 0.05).

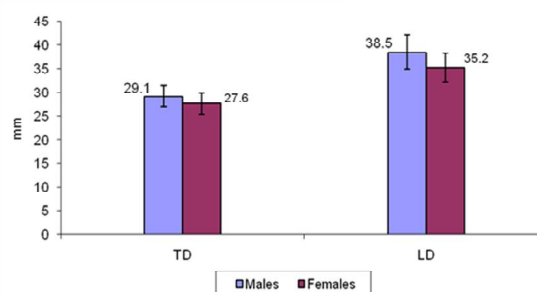
**In CT Images:** CT scan images of 30 subjects (15 male, 15 female) with age between 6-85 years were analysed (Table. No. 1). The longitudinal diameter of the foramen magnum of male subjects was varied from 32-45 mm with an average of 38.5±3.6mm, while in female it was varied from 30-39mm with an average of 35.2±3.1mm (Graph No. 2).

The longitudinal diameter of the foramen magnum of male subject was significantly large when compared to female subjects. The transverse diameter of the foramen magnum in male subject was between 25-33mm with a mean of 29.1±2.3mm, whereas in female subjects it was between 24-33mm with a mean of 27.6±2.3mm(Graph No. 2). Mean transverse diameter of the foramen magnum was not significantly greater than in female subjects. The area of the foramen magnum of male subjects was varied from 620- 1050mm<sup>2</sup> with an average of 862.0±119.0 mm<sup>2</sup>, whereas in females the area varied from 580-940mm<sup>2</sup> with an average of 758±109mm<sup>2</sup>. The area of the foramen magnum of male subjects was significantly greater than in female subjects.

**Graph 1:** Transverse Diameter & Longitudinal Diameters of foramen mangum: Skull



**Graph 2:** Transverse diameter and longitudinal diameters of foramen magnum : in CT SCAN images.



SAMPLES	PARAMETERS	MALES		FEMALES		MALE v/s FEMALES	
		RANGE	MEAN±SD	RANGE	MEAN+/-SD	t	p
SKULLS	TD(mm)	24.30 - 37.70	28.50±2.20	23.50 - 33.60	27.30 + 2.00	3.39	<0.01
	LD(mm)	26.70 - 39.80	33.40±2.60	28.00 - 39.3	33.10 + 2.70	0.54	0.59
	A(mm <sup>2</sup> )	590.80 - 1002.70	748.60±97.80	557.1 - 1017.7	711.10 + 97.7	2.21	<0.05
CT SCAN	TD(mm)	25.00 - 33.00	29.10±2.30	24.00 - 33.00	27.60 + 2.30	1.83	0.08
	LD(mm)	32.00 - 45.00	38.5 + 3.60	30.00 - 39.00	35.20 + 3.10	2.69	<0.05
	A(mm <sup>2</sup> )	620.00-1050.00	862.0 ± 112.0	580.0 - 940.0	758.0 + 109.0	2.50	<0.05

**Table No. 1:** Range, mean, standard deviation and "t" values for dimensions of foramen magnum.

## DISCUSSION

The mean longitudinal diameter of the foramen magnum of male skulls (33.4mm) of present study was similar to the observations of Sayee [15] on male skulls of Karnataka (34.2 mm), however it was lower than the observations made by Routal [13] on Gujarati male skulls (35.5 mm), Catalina Herrera [3] on Spain white male skulls and Suazo [18] on Brazilian male skulls (36.5 mm). In female skulls the mean longitudinal diameter of the foramen magnum of present study was correlated with the observations of Sayee [15] on Karnataka female skulls (33.5mm) and Wantanabe [19] on Japanese female skulls (33.7mm), but it was lower than reported by Catalina Herrera[3] on Spain white female skulls (34.3 mm) and Suazo[18] on Brazilian female skulls (35.6 mm). However the mean longitudinal diameter of the foramen magnum of female skulls of present study was higher than values reported by Routal [13] on Gujarati female skulls.

In the present study the mean transverse diameter of the foramen magnum of male skulls was significantly higher than the female skulls ( $P < 0.01$ ). The mean transverse diameter of the foramen magnum of male skulls (28.5mm) of present study was similar to the observations of Sayee [15] on Karnataka male skulls (28.5mm), whereas it was lower than the values reported by Catalina Herrera[3] on Spain white male skulls (31.1 mm), Suazo [18] on Brazilian male skulls (30.6mm) and Routal [13] on Gujarati male skulls (30.6mm). The mean transverse diameter of female skull in present study (27.3mm) was similar to the observations made by Routal [13] on Gujarati female skulls (27.1mm) and Sayee [15] on Karnataka female skulls (28.0mm), but it was lower than the values reported by Catalina Herrera[3] on Spain white female skulls (29.6mm), Watanabe [19] on Japan female skulls (28.6mm) and Suazo [18] on Brazilian female skulls (29.5mm).

In the present study the area of the foramen magnum of male skulls ( $748.6\text{mm}^2$ ) was significantly larger than female skulls ( $711.1\text{mm}^2$ ). The mean area of the foramen magnum of males in present study was similar to the observations made by Sayee[15] on male skulls of Karnataka ( $769.0\text{mm}^2$ ).

However it was lower than the observations made by Routal [13] on Gujarati male skulls ( $819.0\text{mm}^2$ ), Catalina Herrera [3] on Spain white male skulls ( $888.4\text{mm}^2$ ) and Gunay on Turkey male skulls ( $909.9\text{mm}^2$ ). The mean area of the foramen magnum of female skulls ( $711.1\text{mm}^2$ ) in present study was similar to the observations made by Sayee[15] on Karnataka female skulls ( $746.0\text{mm}^2$ ) and Routal [13] on Gujarati female skulls ( $771.0\text{mm}^2$ ). It was lower in comparison with observations of Catalina Herrera [3] on Spain white female skulls ( $801.0\text{mm}^2$ ) and Gunay on Turkey female skulls ( $819.0\text{mm}^2$ ).

In the present study on CT scan images male subjects showed a significantly higher longitudinal diameter and area of the foramen magnum. The mean longitudinal diameter of the foramen magnum in present study on CT scan images, males was 38.5mm and in females it was 35.2mm, these values were higher than the values reported by Murshed [2] on Turkey people (male 37.7mm, female 34.6mm). However the mean transverse diameter of males (29.1mm) and female (27.6mm) were lower than the values reported by Murshed[2] (male 31.6mm, female 29.6mm). Similarly the area of the foramen magnum of males ( $862\text{mm}^2$ ) and females ( $758.0\text{mm}^2$ ) were lower than the values reported by Murshed[2] (male  $931.7\text{mm}^2$ , female  $795.0\text{mm}^2$ ). The conclusion was in dry skulls - The mean transverse diameter and area of the foramen magnum of male skulls were higher than females, whereas longitudinal diameter was not significantly higher than females. In CT scan images, the longitudinal diameter and area of the foramen magnum of male subjects was higher than females, whereas transverse diameter of the foramen magnum of male was not significantly higher than females.

In a morphometric evaluation of the foramen magnum of normal adults by CT scan showed. In males sagittal diameter varied from 31-45mm with an average of  $37.2 \pm 3.43$  mm, transverse diameter varied from 27-40mm with an average of  $31.6 \pm 2.99$  mm and area of foramen magnum was varied from  $710-1266\text{mm}^2$  with an average of  $931.7 \pm 144.29\text{mm}^2$ . In females the sagittal diameter was varied from 28-42mm with an average of  $34.6 \pm 3.16$ mm transverse diameter was varied from 28-42mm with an average of

29.3±2.19mm and area of the foramen magnum was varied from 671-1006mm<sup>2</sup> with an average of 795.0±99.32mm<sup>2</sup>. In this study the sagittal diameter, transverse diameter and area of foramen magnum of males were significantly higher than females. The area of foramen magnum showed highly significant correlation for both sagittal and transverse diameters [2].

The foramen magnum meningiomas are rare and comprise 0.3-3.2% of all meningiomas. It is the most common neoplastic lesion arising at the craniocervical junction. Two-surgical approaches are routinely used to treat foramen magnum meningiomas; lateral transcondylar approach and inferior suboccipital approach with modification [20]. Metrical and nonmetrical analysis of modern female crania of northwest Kyushu area of Japan has reported foramen length between 28-42mm with mean of 33.7±2.13mm and foramen magnum breadth between 24-34mm with a mean of 28.6±1.84mm [19]. A large foramen magnum usually results from chronic increased intracranial pressure or from direct effects of an expanding process within foramen magnum like syringomyelia, Arnold Chiari malformations and also seen in children with Angelman syndrome or Rubinstein – Taybe syndrome. Asymmetry of foramen magnum occurs with cranio-vertebral anomalies or premature synostoses of one or more of occipital synchondroses. Key hole shaped foramen magnum has been described in hydrolithalus syndrome [21]. According to a study conducted on 211 (144 males, 71 females) Brazilian skulls, the mean anteroposterior diameter of the foramen magnum for males was 36.5±2.6mm and transverse diameter was 30.6±2.5mm. Mean antero-posterior diameter of the foramen magnum for female was 35.6±2.5mm and transverse diameter was 29.5±1.9mm [18].

## CONCLUSION

The mean longitudinal diameter of the foramen magnum of the male and female skulls was 33.4 mm and 33.1 mm respectively, transverse diameter was 28.5mm and 27.3mm respectively and area was 748.6mm<sup>2</sup> and 711.1mm<sup>2</sup> respectively. High significant difference was observed between sexes. The dimensions of the foramen magnum are clinically

important because vital structures passing through it. The knowledge of diameters of the foramen magnum are needed to determine radiological malformations (Arnold Chiari's syndrome) and prior to cutting off of foramen magnum or posterior cranial fossa lesions, or sex determination of skulls.

**Conflicts of Interests: None**

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