

## CORRELATION BETWEEN ENDOCRANIAL CAPACITY AND SIZE OF FORAMEN MAGNUM WITH SPECIAL REFERENCE TO SEX

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### ABSTRACT

**Background:** Endocranial capacity is an important parameter in the study of human evolution, race and sex determination of skull. Diameters of foramen magnum are important because vital structures passing through it may endures compression and for sex determination of skulls. Correlation between endocranial capacity and area of foramen magnum was reported in mammals. This relation in human can be used to determine sex of damaged skulls.

**Methods:** 150 dry skulls and 30 CT scan images of living subjects were studied. Endocranial capacity of skulls was measured by modified Breiteringer's method. Diameters of foramen magnum were measured by vernier calipers and its area was calculated by formula endocranial capacity of CT scan images measured by planimetry. Diameters and area of foramen were measured automatically.

**Results:** The Mean endocranial capacity of male and female skulls were 1367.3ml and 1255.2ml respectively by modified Breiteringer's method and by CT scan image planimetry method were 1347.1ml and 1130ml. 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:** Endocranial capacity, transverse diameter and area of foramen magnum of male skulls were greater than females. A significant positive correlation was observed between endocranial capacity and area of foramen magnum in male and female skulls, but highly significant positive correlation was observed when both sexes were considered together. Living subjects showed a significant positive correlation between endocranial capacity and area of foramen magnum when both sexes were considered together.

**KEYWORDS:** Skull; Sex; Endocranial capacity; Foramen magnum; Race.

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### INTRODUCTION

Endocranial capacity is widely used as a proxy for actual brain size, one of the most important variable in the study of the human evolution, hence it is studied in fossil remains in order to draw the conclusions on the brain size of the

early man [1,2]. Endocranial capacity is an important parameter in the study of racial differences and in clinical practice for the study of the abnormalities of cranial size. The diameters and area of the foramen magnum are greater in males than in females, hence its dime-

-nsions can be used to determine sex in the medico legal conditions, especially in the following circumstances, such as explosions, aircraft accidents and war fare injuries [3]. If an adequate correlation between endocranial capacity and area of the foramen magnum exists, that may help in the medicolegal or anthropological examination of a damaged or deficient skull, to find out the cranial capacity and thus the sex of the skull can be determined up to certain extent[4]. In the fast few studies that were undertaken on dimensions of the foramen magnum and endocranial capacity separately, but no study has been undertaken to examine the possible relationship between endocranial capacity and area of the foramen magnum in recent adult human crania. By considering the above mentioned importance of the foramen magnum dimensions and endocranial capacity of the human crania, this work is undertaken to study the diameters and area of the foramen magnum, endocranial capacity and to find out the correlation between the area of the foramen magnum and endocranial capacity in male skulls, female skulls and in both sexes of human skulls.

A study conducted on 366 (226 males, 140 females) healthy students aged between 17-26 years old at Mugla University Turkey. In this study cranial capacity of students estimated by using linear dimensions of head. The mean cranial capacity for male was  $1411.64 \pm 118.9$ cc and  $1306.95 \pm 162.9$ cc for females. The study showed the cranial capacity of male is larger than females[5]. 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[6].

A study conducted to know the relationship between endocranial volume and the area of the foramen magnum at Govt. Medical College, Surath. The study sample composed of 83 skulls of unknown sex, which showed the area of foramen magnum between 5.49 – 10.36 cm<sup>2</sup> with an average of  $7.7 \pm 0.9$ cm<sup>2</sup> and endocranial volume varied from 950-1520cc with a mean of  $1215 \pm 125.3$ cc. In this study the area of foramen

magnum varied more than endocranial volume and there was only partial positive correlation was observed between area of foramen magnum and endocranial volume[4].

According to a study conducted on 211 (144 males, 71 females) Brazilian skulls, the mean anteroposterior diameter of the foramen magnum for males was  $36.5 \pm 2.6$ mm and transverse diameter was  $30.6 \pm 2.5$ mm. Mean antero-posterior diameter of the foramen magnum for female was  $35.6 \pm 2.5$ mm and transverse diameter was  $29.5 \pm 1.9$ mm[7]. A study on 50 male skulls and 50 female skulls of the cape coloured population of South Africa by keen showed the length of foramen magnum varied from 30-44mm with mean of  $36.3 \pm 2.9$ mm and endocranial capacity varied form 1000-1750cc with mean of  $1355 \pm 117.9$ cc in males and in females the length of foramen magnum was 30-40mm with mean of  $34.8 \pm 2.4$ mm and endocranial capacity varied from 950-1500cc with a mean of  $1199 \pm 126.6$ cc[8].

The present study has conducted to measure the endocranial capacity/endocranial volume of the skulls. To study the longitudinal diameter, transverse diameter and the area of the foramen magnum and to understand the relation with its contents. ?To study the longitudinal diameter, transverse diameter and the area of the foramen magnum in relation to sex. To find out the correlation between endocranial capacity and the area of the foramen magnum, in male skulls, in female skulls and in both sexes of skulls or in male and female skulls separately and in both sexes of skulls.

## MATERIALS AND METHODS

The present study was done on dry adult human skulls and CT scan images of living subjects.

150 dry adult human skulls (100 male, 50 female) were collected form 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. The following measurements were recorded, longitudinal diameter, transverse diameter (TD) and area of the foramen magnum. The endocranial capacity

in dry human adult skulls was measured by modified. Breiteringer's method[9], which is a manual packing method of measuring endocranial capacity. The packing material used was millet seeds obtained from the local provision stores; they were cleaned and dried in sunlight. Size of seeds varied from 1.5-2.5mm in diameter.

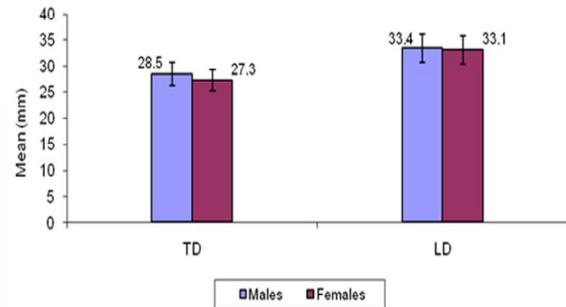
The computerized tomographic (CT) scan images of 30 living subjects (15 male, 15 female) were taken from the Department of Radio-Diagnosis, J.J.M. Medical College, Davangere. The best images of the foramen magnum was selected, longitudinal and transverse diameters of the foramen magnum were measured using tools of the software. The area of the foramen magnum was measured by planimetry method. The endocranial capacity measured by CT imaging method as slices at every 10mm measured for cross sectional area by using planimetry method by using Dicom Works software. Planimetric method is based on Cavaleiri principle. In this method the inner table of the cranium is traced manually to get the cross sectional area of the slice. The endocranial capacity was calculated by sum of the cross-sectional areas of slices multiplied by the slice thickness. Measurements were taken twice and average of two values taken as final measurement[10]. Results were expressed as mean ± standard deviation and range. Unpaired 't' test was used to compare between males and females. Correlation analysis was performed to measure the relationship between diameters and area of the foramen magnum with endocranial capacity by using Pearson's correlation coefficient. P value of 0.05 or less was considered for statistical significance.

**RESULTS**

**In dry skulls**

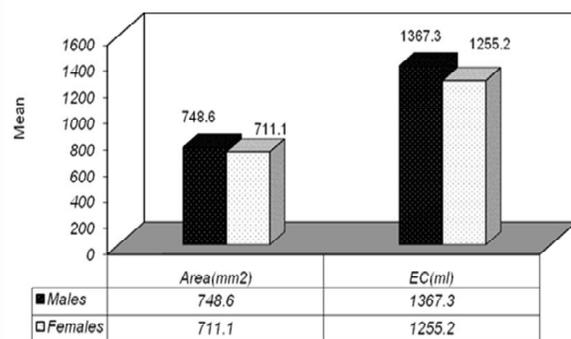
In present study 150 dry human adult skulls (100 male, 50 female) were studied for the dimensions of the foramen magnum and endocranial capacity. The longitudinal diameter of the foramen magnum in male skulls was between 26.7-39.8mm, with a mean of 33.4±2.6mm (mean ± SD), whereas in females longitudinal diameter was between 28-39.3mm with a mean of 33.1±2.7mm (Graph No. 1).

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



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>, where as in female skulls the area of the foramen magnum (it) was between 557.1 – 1017.7 mm<sup>2</sup> with an average of 711.1±97.7 mm<sup>2</sup> (Graph No. 2) . The area of the foramen magnum of male skull was significantly greater than in female skulls (p< 0.05).

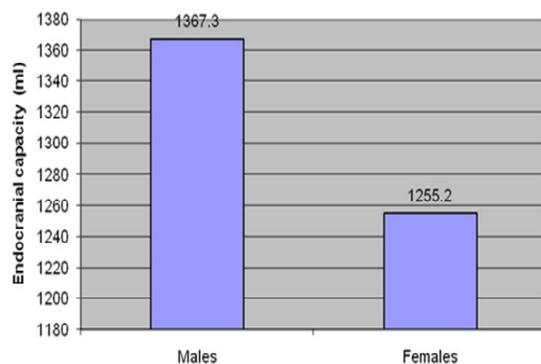
**Graph 2:** Area of foramen magnum and endocranial capacity: Skulls.



The endocranial capacity of the male skulls varied from 1021.6 – 1706.0 ml with a mean of 1367.3±127.8 ml while in female skulls endocranial capacity varied from 1045.3 – 1515.7 ml with a mean of 1255.2±113.3ml (Graph.No. 3) . The endocranial capacity of male skulls was larger than in female. The difference between these two values was highly significant (p <0.001).

The endocranial capacity of male skulls showed significant positive correlation ( $p < 0.02$ ) with mean transverse diameter of the foramen magnum, female skulls also showed significant positive correlation ( $p = 0.002$ ). The endocranial capacity of the skulls of both sexes showed highly significant positive correlation with transverse diameter of the foramen magnum ( $p = 0.001$ ). Correlation of the endocranial capacity of male skulls with mean longitudinal diameter was not significant ( $p = 0.144$ ), whereas in female skulls there was significant positive correlation ( $p = 0.028$ ). A significant positive correlation was seen between mean endocranial capacity of both sexes with mean longitudinal diameter ( $p = 0.015$ ). The mean endocranial capacity of male skulls showed significant positive correlation with mean area of the foramen magnum ( $p = 0.043$ ), even female skulls also showed significant positive correlation ( $p = 0.002$ ). The mean endocranial capacity of skulls of both sexes showed highly significant positive correlation with mean area of the foramen magnum.

**Graph 3:** Endocranial capacity: Skull.



CT scan images of 30 subjects (15 male, 15 female) with age between 6-85 years were analysed. The longitudinal diameter of the foramen magnum of male subjects was varied from 32-45 mm with an average of  $38.5 \pm 3.6$  mm, while in female it was varied from 30-39 mm with an average of  $35.2 \pm 3.1$  mm. 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 25-33 mm with a mean of  $29.1 \pm 2.3$  mm, whereas in female subjects it was between 24-33 mm with a mean of  $27.6 \pm 2.3$  mm. 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- 1050 mm<sup>2</sup> with an average of  $862.0 \pm 119.0$  mm<sup>2</sup>, whereas in females the area varied from 580-940 mm<sup>2</sup> with an average of  $758 \pm 109$  mm<sup>2</sup>.

The area of the foramen magnum of male subjects was significantly greater than in female subjects. The endocranial capacity of male subjects was varied between 1202.9 – 1508.3 ml with an average of  $1347.1 \pm 90.7$  ml, whereas in female endocranial capacity was varied between 998.1 – 1349.9 cc with an average of  $1130.8 \pm 111.9$  ml. The mean endocranial capacity of male subjects was significantly larger than in female subjects. Mean endocranial capacity of the male subjects did not show significant correlation with mean transverse diameter of the foramen magnum ( $p = 0.34$ ), in female subjects also no significant correlation ( $p = 0.16$ ) seen and in both sexes of subjects showed a significant positive correlation ( $p = 0.012$ ). Mean endocranial capacity of male subjects had no significant correlation with mean longitudinal diameter of foramen magnum ( $p = 0.48$ ), even female subject showed no significant correlation ( $p = 0.67$ ), but mean endocranial capacity of both sexes of subjects showed significant positive correlation with mean longitudinal diameter ( $p = 0.012$ ). The mean endocranial capacity of male subjects did not show significant correlation with area of the foramen magnum and female subjects also showed no significant correlation. The mean endocranial capacity of both sexes of subjects showed a significant positive correlation ( $p = 0.012$ ) with mean area of foramen magnum.

## DISCUSSION

In the present study on dry human skulls, the mean endocranial capacity of male skulls was significantly higher than the female skulls ( $p = 0.001$ ). The mean endocranial capacity of the male skulls (1367.3 ml) of the present study was similar to the observations made by Keen[10] on skulls of cape colored population (1355.0 cc), Shukla[11] on male skulls of Indian population (1371.0 ml) and by Ricklan[12] on male skulls of Zulu population of South Africa. The mean endocranial capacity was lower than the observations made by Hwang[13] on Korean

male skulls (1470.0ml). The mean endocranial capacity of the female skulls (1255.2ml) of present study correlated with observations of Ricklan[12] on Zulu skulls (1251.2 ml), whereas it was lower than the observations made by Hwang[13] on Korean skulls (1317.0 ml). The mean endocranial capacity of both male and female skulls (1329.5ml) was similar to the observations made by Chaturvadi[3] on skulls of Jaipur (1296.6ml). The mean endocranial capacity of present study was higher than the observations made by Routal[15] on Gujarati skulls(1215.0ml). In the present study a significant positive correlation was observed between endocranial capacity and transverse diameter of the foramen magnum in male skulls, even female skulls showed a significant positive correlation. Highly significant positive correlation observed between endocranial capacity and the transverse diameter of the foramen magnum, when both sexes considered together.

In the present study male skulls showed no significant correlation between endocranial capacity and the longitudinal diameter of the foramen magnum, but female skulls showed a significant positive correlation. Male and female skulls together showed a significant positive correlation between endocranial capacity and longitudinal diameter of the foramen magnum. In the present study a significant positive correlation was observed between endocranial capacity with the area of the foramen magnum in male skulls, even in female skulls also significant correlation was observed. Highly significant positive correlation was observed between endocranial capacity and the area of the foramen magnum, when both sexes of skulls considered together. Routal[4] reported a partial positive correlation between endocranial capacity and the area of the foramen magnum in his study on Gujarati skulls. Another author Sayee reported no significant correlation between endocranial capacity and the area of the foramen magnum in his study on Karnataka skulls [16].

In the present study on CT scan images male subjects showed a significantly higher longitudinal diameter and area of the foramen magnum, and endocranial capacity than females, whereas the transverse diameter of

males was not significantly higher than in females. 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 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 (male 31.6mm, female 29.6mm). Similarly the area of the foramen magnum of males (862.0mm<sup>2</sup>) and females (758.0mm<sup>2</sup>) were lower than the values reported by Murshed (male 931.7 mm<sup>2</sup>, female 795.0mm<sup>2</sup>). A significant positive correlation was observed between endocranial capacity with transverse diameter, longitudinal diameter and area of the foramen magnum when both sexes of subjects considered together, but no significant correlation was observed in males or female subjects alone [17].

## CONCLUSION

### In dry skulls

The mean endocranial capacity of male skulls was higher than females.

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.

A significant positive correlation was observed between endocranial capacity and transverse diameter of the foramen magnum in male and female skulls, but highly significant positive correlation was observed between them, when both sexes of skulls was taken into consideration.

A significant positive correlation was not observed between endocranial capacity and longitudinal diameter of the foramen magnum of male skulls, but female skulls and all skulls without sex distinction showed a significant positive correlation between them.

A significant positive correlation was observed between endocranial capacity and the area of the foramen magnum in male and female skulls, but highly significant positive correlation was observed between them when both sexes of skulls were considered together.

### In CT scan images

The longitudinal diameter and area of the foramen magnum, and endocranial capacity of male subjects was higher than females, whereas transverse diameter of the foramen magnum of male was not significantly higher than females.

A significant positive correlation between endocranial capacity with transverse diameter longitudinal diameter and area of the foramen magnum of all subjects without sex distinction, but no significant correlation was observed in male or female subjects alone.

The correlation between endocranial capacity and the area of the foramen magnum can be used in medicolegal or anthropological examination of the damaged skulls, to find the endocranial capacity and it can be used for certain extent to find sex of the skull.

**Conflicts of Interests: None**

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