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Determination of Sex by Foramen Magnum Morphometry in South Indian Population

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ABSTRACT

Background: Sex determination in mutilated and fragmentary remains is an important exercise in forensic practice. Present study was conducted to establish sex using foramen magnum morphometry on skulls from autopsied bodies. **Materials & Methods:** A total of 230 skulls (146 males and 84 females) were studied to measure antero-posterior diameter (length) and transverse diameter (breadth) of foramen magnum. Area of foramen magnum was calculated and Sectioning point analysis was performed. **Results:** Mean length, breadth and area of foramen magnum in male were 36.40 mm, 32.93 mm and 939.50 mm2 respectively, whereas the mean length, breadth and area in females were 31.62 mm, 28.32 mm and 700.5 mm respectively. Thus, measurements in males were significantly higher as compared to females. Sectioning points for length, breadth and area were 34.01 mm, 30.62 mm and 820 mm2 respectively. Sectioning Point analysis showed the accuracy of sex determination is more with area of foramen magnum followed by length and breadth of foramen magnum. **Conclusion:** The foramen magnum morphometry can be an important tool in sex differentiation.

Key words: Skull; foramen magnum; sex determination; south Indian.

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INTRODUCTION

In the field of forensic anthropology, determining gender from skeletal remains has been an age-old problem. Determination of sex forms an irreplaceable component of identification in unknown, decomposed, mutilated and skeletonized bodies. There are numerous morphological and morphometric methods to determine the sex form a skeleton. The process becomes even more complicated when fragmentary skeletal remains are the only available source as in explosions, warfare and other mass disasters like aircraft accidents[1]. In the forensic context, the anthropological analysis for sexing skeletal material provides relatively fast and reliable data as this could help to narrow down the police investigator's field of search to

approximately half the population which would otherwise be exhausting the available resources[2]. This stresses need to determine new techniques that are less economical, less time consuming and probably more accurate in the determining sex of an unknown body[3].

In determining gender from skeletal remains, the skull plays an important role, as it is probably the second best region of the skeleton, next only to pelvis for this purpose[4,5].

In the present study we chose foramen magnum, which is the central, deepest, & anatomically important part of the posterior cranial fossa of the skull to determine the gender of a person from its diameters and the area.

Studies on morphometric analysis of foramen magnum have been published previously by various researchers, but these have been on dried skulls or Computer tomography (CT) enabled studies[1,6,7,8,9,10,11,12,13]. The current study is based on skulls from cadavers brought for medicolegal autopsy as this gives an easy access to foramen magnum and can be studied with minimal requirements.

Further, as there are significant metric and morphologic biological differences among the skulls of Caucasoid, Mongoloid, and Negroid races[3], so values of the studies done on one population cannot be applied to another population in the determination of gender. Keeping these points in mind the authors have conducted present study to generate the values for the same purposes.

MATERIAL AND METHODS

This study was conducted in Department of Forensic Medicine, Kasturba Medical College, Manipal, India. Materials for the present study consisted of skulls of dead bodies of both sexes of known age, autopsied at the mortuaries attached to the Department of Forensic Medicine, Kasturba Medical College, Manipal; District Wenlock Hospital, Mangalore and Victoria Hospital, Bangalore. A total number of 230 cases, 146 male and 84 female adult skulls (above 18 years) belonging to South Indian population were studied. Skulls with fractures were excluded from the study.

Length of foramen magnum (antero-posterior diameter), breadth of foramen magnum (transverse diameter) and area of the foramen magnum were measured using an inside caliper and a vernier caliper (Fig 1). Anteroposterior diameter is the direct distance from Basion to Opisthion and the transverse diameter is the distance between the lateral margins of the foramen magnum at the point of greatest lateral curvature[14]. Inside Caliper there is an instrument used to measure the inside diameter of any hollow object. It has two prongs, which can be fixed at the desired position with the help of a fixing screw (Fig 2). These dimensions were measured after extracting the brain, and stripping of the dura adherent to the base of the skull.

Calculation of the Area of the foramen magnum

The area of the foramen magnum was calculated using the Radinsky's formula[15]. A = 1/ 4 x w x h x 22/7; where A – Area, w – Length, h – breadth

Fig. 1: Foramen magnum measurements

A-Basion, B- opisthion, C & D – transverse diameter.

The data was analyzed using SPSS (Statistical Package for Social Sciences, version 11.0) computer software and results were drawn. The significance of results was tested using student's

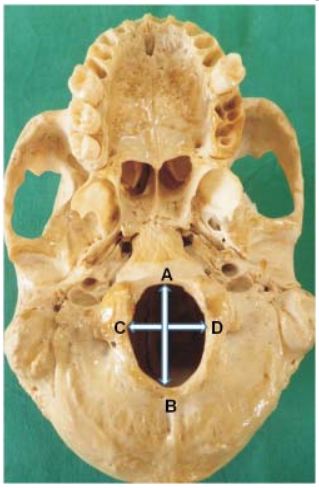

Fig. 2: Inside caliper

t-test. The p- value of less than 0.001 was considered as significant. Sectioning point analysis was performed to differentiate the sex from antero posterior, transverse diameter and area of foramen magnum. For the dimensions and area of foramen magnum, average of mean values in males and females was taken as cut off value for sex determination and termed as the 'sectioning point'. To find the accuracy of Sectioning points (SP) in sex determination, sensitivity and specificity was derived for each parameter by cross tabulation.

RESULTS

The data collected was analyzed and sectioning point (SP) and descriptive analysis was employed for determining the sensitivity and specificity of SP's for each parameter. The mean length, breadth and area of foramen magnum among the males were 36.40 mm, 32.93 mm and 939.50 mm^2 respectively. The mean length, breadth and area among the females were 31.62 mm, 28.32 mm and 700.5 mm respectively [Table 1]. The length ($p<0.001$), breadth ($p<0.001$) and area of foramen magnum ($p<0.001$) in males were significantly higher compared to females [Table 1].

Table 1: Descriptive Statistics: Measurements of the foramen magnum

	Male (n=146)				Female (n=84)			
	Min	Max	Mean	S.D	Min	Max	Mean	S.D
AP	32	49	36.40	3.27	26	36	31.62	2.05
TD	29	46	32.93	2.35	24	33	28.32	2.12
A	741.04	1769.39	939.50	146.15	418.4	904.3	700.50	86.02

AP – Anteroposterior diameter (mm), TD – Transverse diameter (mm), A – Area (mm2), Min – Minimum, Max – Maximum, S.D. – Standard Deviation, * – $p<0.001$

The SP's for length, breadth and area were 34.01 mm, 30.62 mm and 820 mm^2 respectively. The result of this analysis indicates that the SP for length has an accuracy of 82.1% in female and 95.9% in males. The SP for breadth has an accuracy of 89.3% in females and 88.4% in males. The SP for area has an accuracy of 90.5% in females and 93.8% in males [Table 2]. Based on these findings the accuracy of sex determination is more with the area of foramen magnum followed by length and breadth of foramen magnum in decreasing order.

Table 2: Accuracy of sectioning points by crosstabs analysis

	SP	Male	Female
AP	34.01 mm	95.9%	82.1%
TD	30.62 mm	88.4%	89.3%
A	820 mm^2	93.8%	90.0%

AP – Anteroposterior diameter, TD – Transverse diameter, A – Area, SP – Sectioning Point

DISCUSSION

The data from earlier studies were done on dry skull or were CT based, employing different techniques and statistical methods cannot be compared per se, as the measurements are recorded from the interior of the skull as against from the exterior of the skull in previous studies. The length of the foramen magnum in males is higher as compared to earlier studies, whereas the breadth of foramen magnum is lower compared to Gapert et al[8] and Manoel et al[9]. The breadth and area of foramen magnum are higher in the present study compared to earlier studies. The sectioning point for length of foramen magnum calculated for western population[8,9] is higher compared to the present study and other studies conducted on Indian population, whereas the sectioning point for area of foramen magnum is higher in the present study compared to other studies[6,7] [Table 3 &4].

Table 3: Comparison of foramen magnum measurements with earlier studies

	Routal et al[6]		Sayee et al[7]		Gapert et al[8]		Manoel et al[9]		Present study	
	M	F	M	F	M	F	M	F	M	F
AP	35.5	32.0	34.2	33.5	35.91	34.71	35.7	35.1	36.4	31.62
TD	29.6	27.1	28.5	28.0	30.51	29.36	30.3	29.4	32.93	28.32
A	819.0	771.0	---		783.82	730.28	---		939.50	

M – Male, F – Female, AP – Anteroposterior diameter (mm), TD – Transverse diameter (mm), A – Area (mm2)

Table 4: Comparison of Sectioning point measurements with earlier studies

SP	Routal et al[6]	Sayee et al[7]	Gapert et al[8]	Manoel et al[9]	Present study
AP	33.75	33.85	35.31	35.4	34.01
TD	28.35	28.25	29.94	29.85	30.62
A	795.0	---	757.05	---	

AP – Anteroposterior diameter (mm), TD – Transverse diameter (mm), A – Area (mm2), SP – Sectioning Point

The difference in findings of our study from the previous studies could be attributed to methodology of recording the measurements. We employed different technique of measuring foramen magnum, as the availability of sophisticated CT is a premium in our country.

Extensive search of literature did not reveal any similar studies done on cadavers and this is the first of its kind to our knowledge. The observations made in our study justifies that data compiled for a certain population cannot be employed for determining sex in another population.

We would suggest that foramen magnum is a valuable tool for sex determination and can be employed with reasonable accuracy in the South Indian population especially in circumstances where only skull fragments are available as evidentiary material. However similar studies are recommended for different and larger populations to define more accurate and reliable sectioning points for sexing foramen magnum.

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