DOI Number: 10.5958/0974-1283.2019.00175.0

Morphometric Analysis of Sexual Dimorphism in Foramen Magnum

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Abstract

Introduction: The establishment of human sex identity is of paramount importance in the field of forensic medicine especially when it comes to medico legal cases of disputed sex, completely decomposed or charred bodies, and decapitated cadaveric remains, exhumation of skeletonized remains where skull is recovered and referred to a forensic expert for opinion by the police, etc.

Methodology: Study sample includes 77 dry human skull bones obtained from department of forensic medicine, department of anatomy and student volunteers of T.O.M.C.H & R.C. T. The sex of the skull bone is estimated by using morphological characteristics. The anterio-posterior diameter and the transverse diameter of the foramen magnum is measured using a Vernier caliper. The results are tabulated in Microsoft Excel 2013 document and the areas of foramen magnum were calculated using the formulae derived by Routal and Teixeira. Statistical analysis for correlation between the measurements and the sex of the skull was performed using SPSS software.

Results: Majority of skulls belonged to the female sex with maximum distribution in 25 to 35 age group followed by 18 to 25 age group. The length, breadth, and the area of foramen magnum are found to be larger in males than females. However, statistically significant sex differences were observed only for the breadth and areas of the foramen magnum.

Discussion: Our findings with regard to the sexing potential of foramen magnum dimensions found a statistically significant difference for breadth of the foramen magnum but the sexual dimorphism index and logistic regression for the same does not indicate a significant difference. The present research also reports a statistically significant sex differences in the area of foramen magnum as derived by formula given by Teixeira and Radinsky which is similar to that reported in earlier studies.

Conclusion: Parameters analyzed for sexual dimorphism of foramen magnum the area of the foramen magnum proves to be a better predictor of sex compared to other features but foramen magnum alone should not be considered for sexual differentiation unless the skull is mutilated.

Keywords: *sexual dimorphism, foramen magnum, morphometric analysis*

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Introduction

The establishment of human sex identity is of paramount importance in the field of forensic medicine especially when it comes to medicolegal cases of disputed sex, completely decomposed or charred bodies, and decapitated cadaveric remains, exhumation of skeletonized remains where skull is recovered and

referred to a forensic expert for opinion by the police, etc. Sexing accuracy of the human skeleton varies for the different bones and in different population groups. Human skull is considered as one of the most reliable bones for sex differentiation[1]

The foramen magnum lies in an anteromedian position. It is oval, wider behind, with its greatest diameter being anteroposterior. It contains the lower end of the medulla oblongata, the vertebral arteries and the spinal accessory nerve. Anteriorly, the margin of the foramen magnum is slightly overlapped by the occipital condyles which project down to articulate with the superior articular facets on the lateral masses of the atlas.[2]

Skull may be shattered during high velocity impact injuries or in disruptive injuries and only fragments of bones may be available for examination. Identification of sex becomes challenging in such instances. The basal region of the occipital bone is likely to survive the physical insults than the other parts of skull owing to the abundant soft tissue cover, skull thickness in the region, and its relatively well-protected anatomical position. Thus, there is an increased possibility of recovering this part of skull even in cases of severe trauma, and studies on the occipital bone may provide useful clues in identification of significantly disrupted remains[3]explosions or violence. The basal region of the occipital bone is covered by a large volume of soft tissue and is therefore in a relatively well-protected anatomical position, and as such, classification of sex using the occipital bone may prove useful in cases of significantly disrupted remains. The aim of this paper is to evaluate manually recorded morphometric variables of the region of the foramen magnum using both discriminant function analysis and linear regression. The skulls utilised in this study were selected from the eighteenth to nineteenth century documented skeletal collection of St. Bride's Church, Fleet Street, London. Adult human skulls n = 158 (male symbol82/female symbol76

The occipital bone is frequently considered for the determination of sex in both forensics and anthropology. Qualitatively the nuchal line roughness and the prominence of external occipital protuberance are considered good indicators for determination of the sex [4]. Quantitatively many indexes have been built based on the dimensions of foramen magnum and the occipital condyles. Also many authors have described their use in determination of sex especially when the skeleton is incomplete or in case of fractures of the cranial bones[5–7]

The present research was planned to evaluate the sexing potential of foramen magnum by way of morphometric analysis using sexual dimorphism index.

Materials and Method

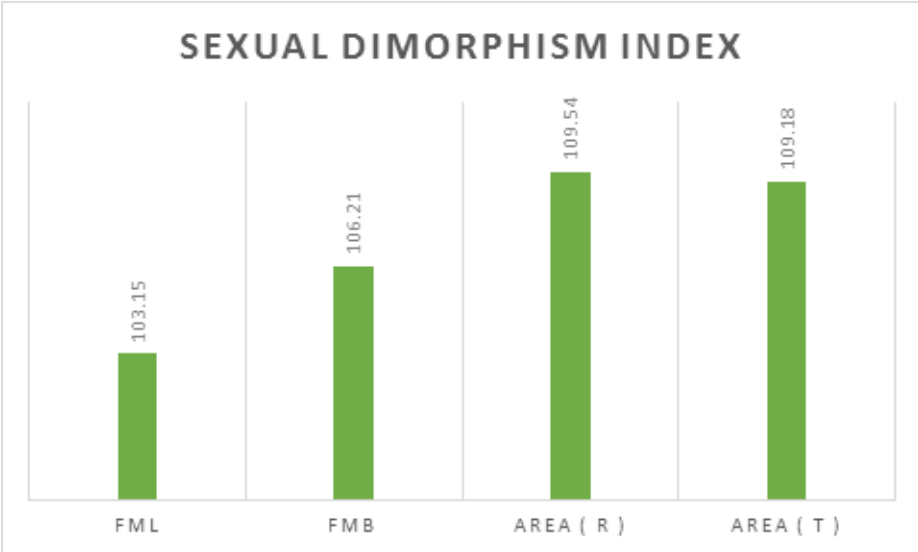
The present study was conducted in The Oxford Medical College, Hospital and Research Center (T.O.M.C.H & R.C), Bangalore (affiliated to Rajiv Gandhi University of Health Sciences). An approval was obtained from the Institutional Ethics Committee of T.O.M.C.H & R.C before conducting the study. Study sample included 77 dry human skulls preserved in the museums of Department of Forensic Medicine and Department of Anatomy in T.O.M.C.H & R.C. The sex and age of the skulls was assessed by morphological and sutural examination using data as described in literature[1] and all skulls were confirmed to be of adult age. All the samples were free from any fractures, deformity or damage.

The following dimensions of foramen magnum were measured using Vernier caliper and were graduated till the last 0.01cm.

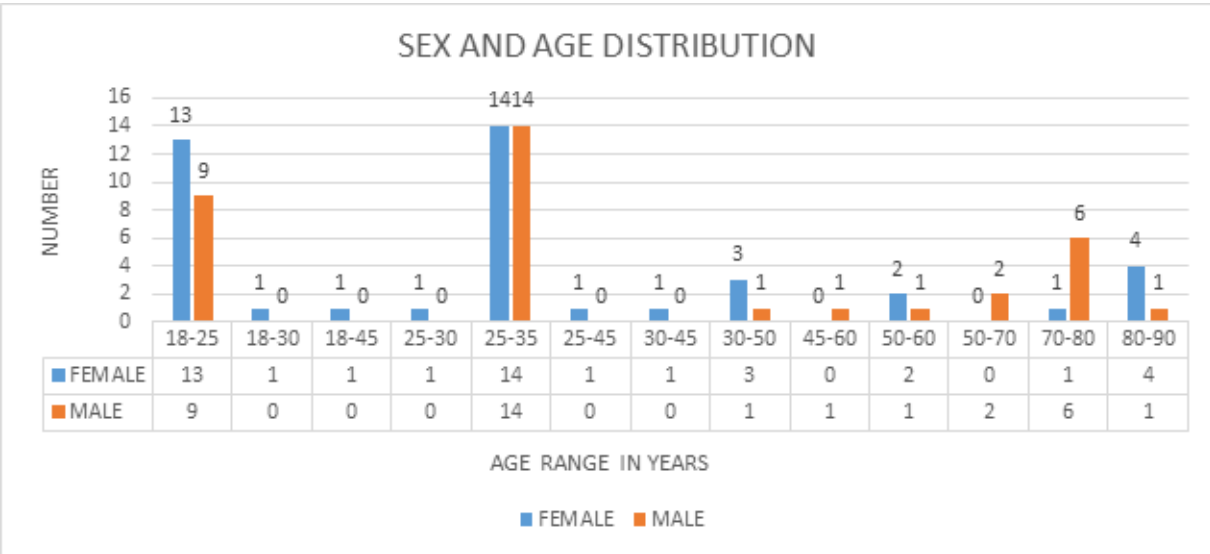
Foramen magnum length (FML): The distance between Basion and Opisthion.

Foramen magnum breadth (FMB): The distance between the lateral margins of the foramen magnum at the point of greatest lateral curvature.

The data was tabulated in M.S Office 2013 Excel sheet and was analyzed statistically using SPSS (Statistical Package for Social Sciences) version 11.0 computer software (SPSS, Inc., Chicago, IL, USA). The area of foramen magnum (A) was calculated from the length and breadth of foramen magnum utilizing the formulae derived by Routal[8] and Teixeira[6] . Male-female differences in measurements were tested using Student's t-test and statistical significance (p-value) was defined at $\alpha = 0.05$. Sexual Dimorphism Index was calculated to find the ability of each variable in sexing the skulls as; Mean Male value/ Mean Female value multiplied by 100.



GRAPH 1:



GRAPH 2:

TABLE 1: DESCRIPTIVE STATISTICS: DIMENSIONS AND AREA OF FORAMEN MAGNUM

	MALE (N=35)			**FEMALE (N=42)**				
	Mean	**S.D**	**Range**	**Mean**	**S.D**	**Range**	**t-value**	**p-value**
FML	3.368571	0.20871	2.94 - 3.8	3.265714	0.260863	2.8 - 3.92	1.883	0.064
FMB	2.826857	0.217604	2.22 - 3.34	2.661667	0.190608	2.49-2.78	3.55	0.001*
AREA (R)	7.48852	0.830576	5.81 – 9.29	6.836074	0.81971	5.32 – 8.61	3.457	0.001*
AREA (T)	7.558685	0.82607	5.92 – 9.29	6.923123	0.836323	5.43 – 8.63	3.339	0.001*

FML–Anteroposterior diameter (cm), FMB–Transverse diameter (cm), Area(R)–Area from Routal's formula, Area(T)–Area from Teixeira's formula, S.D. – Standard Deviation

Table 2: Logistic regression of breadth of foramen magnum

Variable	Gender		Odds ratio	p value
	Male(mean±SD)	Female(mean±SD)	0.013	0.002
FMB	2.901±0.217	2.721±0.191		

FMB–Transverse diameter (cm); Mean in cm; SD – Standard Deviation

Results

Graph 1 shows the values of sexual dimorphism index from which it is evident that area of the foramen magnum calculated using the formula derived by Routal and Teixeira are better predictors of sex when compared to the length and breadth of the foramen magnum. Graph 2 shows the sex and age distribution of the male and female skulls where in more number of skulls belonged to the female sex (42 female: 35 male) and the age distribution of skulls based on their osteological age showed maximum distribution in 25 to 35 age group followed by 18 to 25 age group. Table 1 shows the descriptive statistics for the length, breadth, and the area of the foramen in males and females. The length, breadth, and the area of foramen magnum are found to be larger in males than females. However, statistically significant sex differences were observed only for the breadth and areas of the foramen magnum. Table 2 shows the logistic regression of breadth of foramen magnum in which the odds ratio was found to be 0.013 which implies that for every 1 cm decrease in Foramen magnum breadth, the odds of the skull being a female is 0.013 (but since measurements are almost similar, clinically it will not be helpful).

Discussion

The first researcher who published his research on estimation of sex based on the size of foramen magnum was probably Teixeira[6]. In past, studies on estimation of sex from foramen magnum have been conducted on British[3]explosions or violence. The basal region of the occipital bone is covered by a large volume of soft tissue and is therefore in a relatively well-protected anatomical position, and as such, classification of sex using the occipital bone may prove useful in cases of significantly disrupted remains. The aim of this paper is to evaluate manually recorded morphometric variables of the region of the foramen magnum using both discriminant function analysis and linear regression. The skulls utilised in this study were selected from the eighteenth to nineteenth century documented skeletal collection of St. Bride's Church, Fleet Street, London. Adult human skulls n = 158 (male symbol82/female symbol76, Central European[9] Turkish[10,11] and Indian[8,12–14] populations using different methodologies and statistical considerations. All the previous researchers have reported a larger size of foramen magnum in males compared to that of females. Our findings in this regard are consistent with that reported in the earlier studies[6,8–14]. These studies however, have observed a varying degree of sexing accuracy from the dimensions of foramen magnum.

Our findings with regard to the sexing potential of foramen magnum dimensions found a statistically significant difference for breadth of the foramen magnum but the sexual dimorphism index and logistic regression for the same does not indicate a significant difference. Therefore, the authors are of the opinion that even though a statistically significant difference exists in the breadth of foramen magnum it is unlikely to be a good predictor in sexual dimorphism of foramen magnum. This finding is in agreement to studies reported by Gruber et al[9] and other Indian[8,12–14] studies who did not find any sexual dimorphism in the diameters of foramen magnum

The present research also reports a statistically significant sex differences in the area of foramen magnum as derived by formula given by Teixeira and Radinsky which is similar to that reported in earlier studies from different parts of the world[3,10,14]explosions or violence. The basal region of the occipital bone is covered by a large volume of soft tissue and is therefore in a relatively well-protected anatomical position, and as such, classification of sex using the occipital bone may

prove useful in cases of significantly disrupted remains. The aim of this paper is to evaluate manually recorded morphometric variables of the region of the foramen magnum using both discriminant function analysis and linear regression. The skulls utilised in this study were selected from the eighteenth to nineteenth century documented skeletal collection of St. Bride's Church, Fleet Street, London. Adult human skulls n = 158 (male symbol82/female symbol76.

Though the differences in the observations of previous researchers are attributed to the variations in the study samples, methodology, and statistical analysis employed, most of the researchers are of the opinion that the dimensions of the foramen magnum and its area are not a very reliable indicator in estimation of sex of an unknown skull and thus, these should only be used as a corroborative finding

Conclusion

This study observes that out of all the parameters analyzed for sexual dimorphism of foramen magnum the area of the foramen magnum proves to be a better predictor of sex compared to other features. Also, it is to be noted that foramen magnum alone should not be considered for sexual differentiation unless the skull is mutilated and it should always be corroborated with other findings for better accuracy of achieving sexual dimorphism.

Conflict of Interest: Nil

Source of Funding: Self

Ethical Clearance: obtained from Institutional Ethics Committee, The Oxford Medical College, Hospital and Research Center.

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