International Journal of Medical, Medicine and Health Sciences
ISSN: 2517-9969
Vol:7, No:7, 2013

Craniometric Analysis of Foramen Magnum for Estimation of Sex

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***Abstract*—**Human skull is shown to exhibit numerous sexually dimorphic traits. Estimation of sex is a challenging task especially when a part of skull is brought for medicolegal investigation. The present research was planned to evaluate the sexing potential of the dimensions of foramen magnum in forensic identification by craniometric analysis. Length and breadth of the foramen magnum was measured using Vernier calipers and the area of foramen magnum was calculated. The length, breadth, and area of foramen magnum were found to be larger in males than females. Sexual dimorphism index was calculated to estimate the sexing potential of each variable. The study observations are suggestive of the limited utility of the craniometric analysis of foramen magnum during the examination of skull and its parts in estimation of sex.

***Keywords*—**Forensic Anthropology, Skeletal remains, Identification, Sex estimation, Foramen magnum.

I. Introduction

ESTIMATION of the sex of the skeletal remains is an essential element of any medicolegal investigation. Human skeleton shows sexually dimorphic traits, and estimation of the sex of skeletal remains is thus, based on morphological and morphometric examination. 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]. Previous studies have used different measurements on the skull to estimate its sex accurately [2]-[5].

During high impact and severe disruptive injuries, only fragments of bones may be available for examination. Estimation of sex becomes challenging when only a part of skull is brought for examination and hence, a need to derive standards for sex estimation from different regions of the skull. 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 [6]. The present research was planned to evaluate the sexing potential of the dimensions of foramen magnum in forensic identification by craniometric analysis using sexual dimorphism index.

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II. Materials and Methods

The present study was conducted at Kasturba Medical College, Mangalore (affiliated to Manipal University) in India. An approval was obtained from the Institutional Ethical Committee of Kasturba Medical College, Mangalore before conducting this study. The study sample included 118 dry skulls (69 males and 49 females). The sex of the skulls was assigned based on morphological examination of the sexually dimorphic traits described in literature [1]. The adult age of the crania was confirmed based on the closure of sphenooccipital synchondrosis and dentition. All the skulls were free from any fracture or other deformities.

The following dimensions of foramen magnum were measured using Vernier calipers graduated to the last 0.01 mm:

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 analyzed statistically using SPSS (Statistical Package for Social Sciences) version 11.0 computer software (SPSS, Inc., Chicago, IL, USA). The area of the foramen magnum (A) was calculated using the following formula derived by Radinsky [7] and Teixeria [8]. 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.

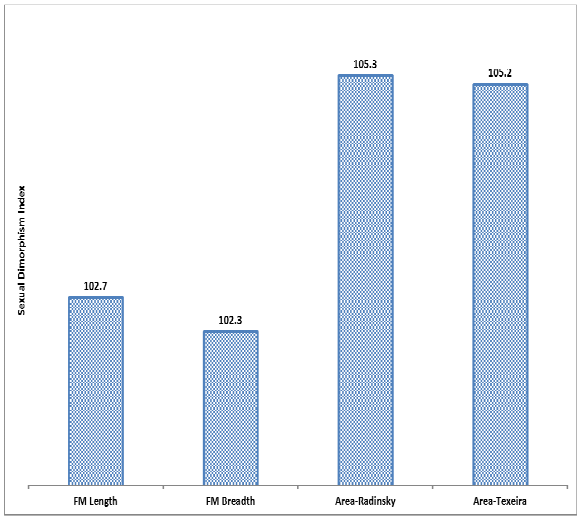

Fig. 1 Sexual Dimorphism Index of the variables included in the study

TABLE I
DESCRIPTIVE STATISTICS: DIMENSIONS, AND THE AREA OF THE FORAMEN MAGNUM

	Males (n=69)			Females (n=49)			t–value	p–value
	Mean	**S.D**	**Range**	**Mean**	**S.D**	**Range**		
FML	34.51	2.77	27.0–41.0	33.60	2.63	27.0–39.0	1.807	0.073
FMB	27.36	2.09	23.0–32.0	26.74	2.36	22.0–31.0	1.522	0.131
Area (R)	744.33	101.43	530.36–934.21	706.93	95.02	530.36–895.71	2.026	0.045*
Area (T)	755.46	103.38	531.14–962.50	717.92	94.84	531.14–908.29	2.011	0.047*

FML–Anteroposterior diameter (mm), FMB–Transverse diameter (mm), FMI–Foramen Magnum Index, Area(R)–Area from Radinsky's formula, Area(T)–Area from Teixeria's formula, S.D. – Standard Deviation

TABLE II
FREQUENCY DISTRIBUTION OF THE FORAMEN MAGNUM DIMENSIONS IN MALES AND FEMALES

	Male (n=69) N (%)	**Female (n=49) N (%)**	**Total (n=118) N (%)**
Foramen Magnum Length			
< 30	01 (25.0)	03 (75.0)	04 (100.0)
30-34	27 (51.9)	25 (48.1)	52 (100.0)
35-39	40 (65.6)	21 (34.4)	61 (100.0)
>39	01 (100.0)	00 (--)	01 (100.0)
Foramen Magnum Breadth			
<25	03 (21.4)	11 (78.6)	14 (100.0)
25-29	53 (63.9)	30 (36.1)	83 (100.0)
>29	13 (61.9)	08 (38.1)	21 (100.0)

TABLE III
FREQUENCY DISTRIBUTION OF THE AREA OF FORAMEN MAGNUM IN MALES AND FEMALES

Range	**Area–Radinsky**		**Area–Texeira**	
	Male N (%)	**Female N (%)**	**Male N (%)**	**Female N (%)**
<600	03 (04.3)	05 (10.2)	02 (02.9)	05 (10.2)
601-700	24 (34.8)	23 (46.9)	19 (27.5)	20 (40.8)
701-800	12 (17.4)	13 (26.6)	18 (26.1)	16 (32.7)
801-900	26 (37.7)	08 (16.3)	26 (37.7)	03 (06.1)
>900	04 (5.8)	00 (0.0)	04 (5.8)	05 (10.2)

III. RESULTS

Table I 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 area of the foramen magnum. Frequency distribution of the length and breadth of foramen magnum, and the area of foramen magnum among male and female skulls are shown in Tables II and III respectively. Overlapping of the male-female values is apparent for the different variables analyzed in the study. Sexual dimorphism Index calculated to find the sexing potential of foramen magnum dimensions and area is shown in

Fig. 1. It is evident that area of the foramen magnum calculated using the formula derived by Radinsky, and Texeira are better predictors of sex when compared to the length and breadth of the foramen magnum.

IV. Discussion

Teixeria was probably one of the first researchers who published his research on estimation of sex based on the size of foramen magnum in the later part of 20th century [8]. In past, studies on estimation of sex from foramen magnum have been conducted on British [6], Central European [9] Turkish [10], [11] and Indian [12]-[15] populations using different methodologies and statistical considerations. All the previous researchers have reported a larger size of foramen magnum in males than females. Our findings in this regard are consistent with that reported in the earlier studies [8]-[15]. 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 are in accordance with that reported by Gruber et al [9] who did not find any sexual dimorphism in the diameters of foramen magnum in dry skulls from Central Europe. Similarly, studies from different parts of India [12]-[15] have not found the foramen magnum measurements to be a reliable in sexing of skulls. These studies however, do not mention the details of analysis for determining the sexing accuracy of the foramen magnum measurements. A recent study from the region [15] has reported a low predictive accuracy of foramen magnum length in sex estimation based on BLR analysis while foramen magnum breadth was not found to be a useful criterion for sex estimation. Gapert et al. [6] in a study on sex estimation from foramen magnum dimensions based on discriminant function and regression analysis have likewise concluded that there is limited albeit statistically significant, expression of sexual dimorphism in the foramen magnum region. The present research reports a statistically significant sex differences in the area of foramen magnum as derived by formula given by Texeira and Radinsky. Our observations are similar to that reported in earlier studies from different parts of the world [6], [10], [15]. Though the differences in the observations of previous researchers are attributed to the variations in the study samples, methodology, and statistical analysis employed [15], 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.

V. Conclusions

The area of the foramen magnum was observed to have better accuracy in estimation of the sex of the skulls when compared to the length and breadth of the foramen magnum. The present study observes that the craniometric analysis of foramen magnum should be used only as a supportive finding in estimation of sex of fragmentary remains of skull.

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