ORIGINAL ARTICLE

Determination of Sexual Dimorphism from Foramen Magnum in an Eastern Indian Population

Panja WB,[1] Hansda S,[2] Chowdhuri S,[3] Saha A,[4] Das S,[5] Ghosal S.[6]

MBBS Student,[1] Assistant professor,[2,3] Associate professor,[4] Research scholar,[6]
1. Calcutta National Medical College and Hospital, Kolkata
2. Department of Anatomy, IPGMER and SSKM Hospital, Kolkata
3. Department of Forensic Medicine and Toxicology, Calcutta National Medical College, Kolkata
4. Department of Anatomy, RG KAR Medical College, Kolkata
5. Centurion University of technology and management, Odisha
6. Department of Forensic Medicine and Toxicology, Calcutta National Medical College and Hospital

Abstract:

Human identification is an important arena of forensic investigation, it includes sex determination which becomes extremely difficult in fragmented skeletal remains. Skull dimensions are measured for the purpose of sexual dimorphism which vary in different populations. In this study, we attempted to analyse the measurements from adult human skulls and employ discriminant function to predict sex accurately. A manual vernier calliper was used to measure the antero-posterior (AP) diameter and transverse diameter of foramen magnum of 88 skulls (49 males, 39 females) from the collection housed at the department of Anatomy, RG KAR medical college and Calcutta medical college. The Wilk's lambda for the model is 0.795. The discriminant function equation is, Df= 3.342× (AP diameter of foramen magnum) +0.725× (Transverse diameter of foramen magnum) -13.641(constant). The cut-off point is 0.505. So above this value 0.505, the cases are male and below it, the cases are female. On comparing the measurements, we found that antero-posterior dimensions and transverse dimensions of foramen magnum were greater in males than females. Collectively, all the results indicate that dimensions of foramen magnum can be used as a moderate indicator for sex determination in regional populations.

Keywords: Forensic science; Forensic anthropology; Sex characteristics; Discriminant analysis; Foramen magnum.

Introduction:

Identification is the determination of individuality of a person (living or dead) based on certain physical characteristics.[1] In forensic investigation human identification is an essential trait. This identification process includes sex determination which becomes extremely difficult and complex in fragmented and mutilated skeletal remains obtained from the sites of bomb explosions, mass natural disasters, exhumations and warfares.[2] In Forensic context, the process of sex determination is directly associated with the quantity and quality of bone remains. The more number of bones available, the more will be the probability for accurate sex determination results.[3] According to Krogman, sex determination from skull can be done with 90% accuracy, from pelvis with 95% accuracy, from long bones with 80% accuracy, from pelvis and skull with 98% accuracy, from complete skeleton with 100% accuracy.[1] So, skull is one of the most useful bones for accurate determination of sex.[4] In the skull inferior to the sagittal suture on the cranial base in the posterior cranial fossa, foramen magnum is located which is largely occupied by the occipital bone and it is one of the primary centers of ossification during growth and development.[5] Murshed (2003) classified foramen magnum into eight different shapes: oval, egg, round, tetragonal, pentagonal, hexagonal, irregular A, irregular B.[6]

The aim of the present study is to estimate the sexual dimorphism among East Indian population from various parameters of dry skull bones.

Materials and methods:

The study was conducted at the department of Forensic Medicine and Toxicology, Calcutta National Medical College; department of Anatomy, RG KAR Medical College and department of Anatomy, Medical college, Kolkata. The study samples comprise of 88 skulls (49 males, 39 females) which were collected from the museums housed at the above mentioned departments.

Inclusion criteria: Dry adult human skulls irrespective of sex were included in present study.

Exclusion criteria: Skulls of children, skulls with fracture, congenital deformity and other damages or loss of bone tissue from any place were excluded from present study.

Skull bones from both sexes were kept separate as the sex determination was done beforehand by forensic experts. A vernier caliper (Mitutoyo) with a least count of 0.02 mm was used for measuring the following dimensions of foramen magnum:

- Antero-posterior diameter (APD) of foramen magnum: Distance from basion to opisthotonos in the midsagittal plane.

Corresponding Author
Dr. Soumeek Chowdhuri
Email : smk.kgp@gmail.com
Mobile No.: +91 90075 80064

- Transverse diameter (TD) of foramen magnum: Maximum distance between the lateral margins of foramen magnum perpendicular to midsagittal plane.

- Foramen magnum index (FMI): It is calculated by dividing transverse diameter by antero-posterior diameter and then multiplying that value by 100.

- Foramen magnum area (FMA): It is calculated by multiplying $(\pi/4)$ with antero-posterior diameter and transverse diameter (Radinsky's formula).[7]

The data were analyzed using the SPSS (Statistical package of social sciences) software (version 29). Ethical clearance number of this study EC-CNMC/2022/32.

Table 1. Comparison of measurements in centimetre.

Sex	N=80	APD of foramen magnum	TD of foramen magnum
Males	Mean	3.56 cm	3.00 cm
	Number	49	49
	Maximum	4.07 cm	3.34 cm
	Minimum	3.05 cm	2.82 cm
	Standard deviation	0.275	0.219
Females	Mean	3.29 cm	2.84 cm
	Number	39	39
	Maximum	3.71 cm	3.24 cm
	Minimum	2.68 cm	2.62 cm
	Standard deviation	0.255	0.208

Table 2. Wilk's lambda.

Test of function (s)	Wilk's lambda	Chi-square	df	Sig.
1	0.795	19.513	2	.000

Table 3. Canonical discriminant function coefficients.

APD of foramen magnum	3.342
TD of foramen magnum	0.725
Constant	-13.641

Results:

88 skulls (n=88) were analysed for this study out of which 49 were males and 39 were females. In table 1 it has been shown that in males, mean antero-posterior diameter (APD) was 3.56 cm with a minimum value of 3.05 cm and maximum value of 4.07 cm. In males mean transverse diameter (TD) was 3.00 cm with a minimum value of 2.82 cm and maximum value of 3.34 cm. In females, mean antero-posterior diameter was 3.29 cm with a maximum value of 3.71 cm and minimum value of 2.68 cm. In females mean transverse diameter was 2.84 cm with a maximum value of 3.24 cm and minimum value of 2.62 cm. On comparing the results, we found that the antero-posterior diameter and transverse diameter of foramen magnum were greater in males than females.

Multivariate discriminant function was performed on all study variables [AP diameter, Transverse diameter of foramen magnum].The Wilk's lambda for the model is 0.795 and the p-value is 0.00 which signifies a moderate discriminating power of the model which is shown in the table 2.

Table 3 shows that the canonical discriminant function co-efficient of antero-posterior diameter of foramen magnum is 3.342 and of transverse diameter of foramen magnum is 0.725.

The discriminant function equation is: Df=3.342 ×(APD) +

Table 4. Function at group centroids.

Sex	Function
Male	0.448
Female	-0.563

Table 5. Classification results.

		Sex	Predicted group membership		Total
			Male	Female	
Original	Count	Male	35	14	49
		Female	9	30	39
	%	Male	71.4	28.6	100
		Female	23.1	76.1	100
Cross-validated	Count	Male	35	14	49
		Female	9	30	39
	%	Male	71.4	28.6	100
		Female	23.1	76.9	100
Original grouped cases that can be correctly classified			73.9%		
Cross validated cases that can be correctlyclassified			73.9%		

Table 6. Univariate discriminant function analysis.

Measurements	Constant	Co-efficient	Cut off value	Accuracy
APD of foramen magnum	-12.907	3.747	0.502	76.1 %
TD of foramen magnum	-13.641	4.659	0.371	65.9 %
Foramen magnum area (FMA)	-7.181	0.911	0.493	71.6 %

Discriminant function= (measurement x coefficient) + constant
If discriminant score> cut-off value = male
If discriminant score< cut-off value = female

0.725×(TD) -13.641(constant). Table 4 shows that the function at group centroids for males is 0.448 and for females is -0.563. The cut off point is {0.448- (-0.563)}/2=0.505. So above this value the cases are male. Below this value the cases are female.

Table 5 shows that in the present study 73.9% of original grouped cases can be correctly classified. Among the cross validated cases 73.9% can be correctly classified.

Univariate discriminant functional analysis was performed where the study samples were correctly classified according to their gender from antero-posterior diameter with 76.1% accuracy, from transverse diameter with 65.9% accuracy and from foramen magnum area with 71.6% accuracy which are shown in table 6.

Discussion:

The present study showed that the antero-posterior diameter (APD) and transverse diameter (TD) of foramen magnum are greater in males than females. This study involved the adult skull bones of eastern Indian population and values of variables obtained from this study varied with the studies conducted in recent times amongst the ethnic groups in other parts of the world. In a study conducted at Mangalore (2015), mean value of APD of males was 3.321 cm and in females was 3.099 cm, mean value of TD of males was 2.692 cm and in females was 2.545 cm, accuracy obtained from APD was 69.6% which was lower than the accuracy obtained in present study, accuracy obtained from TD was 66.4% which was slightly higher than the accuracy obtained in present study, accuracy from FMA was 70.3% which was slightly lower than accuracy of present study.[7] In a study conducted at Indore (2016), mean value of APD of males was 3.73 cm and of females was 3.395 cm, accuracy from APD here
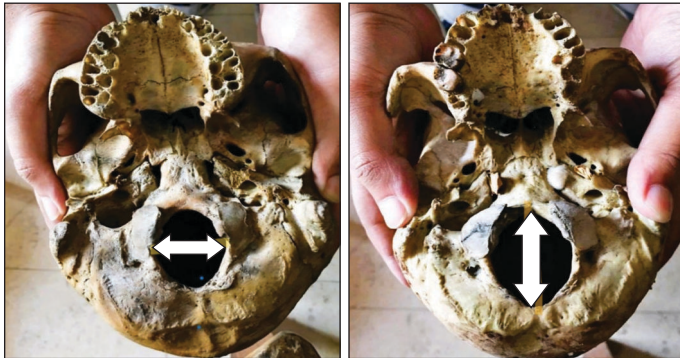
Figure 1   **Figure 2**

Figure 1. and 2. are showing the transverse diameter and antero-posterior diameter of foramen magnum marked in white arrow.

Figure 3a   **Figure 3b**

Figure 3a and 3b are showing the process of measuring the diameters of foramen magnum using vernier calipers.

was 53.9% which was much lower than the present study, mean value of TD of males was 3.71 cm and in females was 2.65 cm, accuracy obtained from TD was 65.4% which was slightly lower than the present study, accuracy from FMA was 72.1% which was greater than the accuracy obtained in present study.[9] A study conducted in Egypt [2020] showed that mean value of APD of males was 3.68 cm and of females was 3.57 cm and accuracy obtained from it was 59.5% which was much lower than the present study, mean value of TD of males was 3.15 cm and of females was 2.99 cm, accuracy obtained from TD was 64.7% which was lower than the present study, accuracy from FMA was 70.9% which was slightly lower than the present study.[10] A study was conducted in Turkey (2017) which showed that mean value of APD of males was 3.473 cm and of females was 3.299 cm and the accuracy of APD here was 69% which was lower than the accuracy obtained in the present study, mean value of TD of males was 3.047 cm and of females was 2.84 cm and the accuracy obtained from it was 66% which was similar to the present study, accuracy of FMA was 68% which was lower than the present study.[11] In the study conducted in Greece (2017), mean value of APD of males was 3.66 cm and of females 3.48 cm and the accuracy obtained was 63.6% which was much lower than the present study, mean value of TD of males was 3.24 cm and of females was 3.04 cm and the accuracy of TD was 65.6% which

was similar to the present study, accuracy from FMA was 66.9% which was lower than the present study.[12] The study which was conducted in Iraq (2014) showed that the mean value of APD of males was 3.49 cm and of females was 3.29 cm and the accuracy of APD was 69.3% which was lower than the present study, mean value of TD of males was 2.95 cm and of females 2.73 cm and the accuracy of TD was 68.2% which was greater than the accuracy obtained in the present study, mean value of FMA was 69.3% which was lower than the present study.[3] In the study conducted in Nepal (2022), mean value of APD of males was 3.48 cm and of females was 3.22 cm and the accuracy of APD was 63.2% which was much lower than the accuracy obtained in present study, mean value of TD of males was 3.01 cm and of females was 2.78 cm and accuracy of TD was 67.3% which was greater than the present study.[13] The study conducted on Bengali population (2015) showed that mean APD of foramen magnum of males was 3.402 cm and of females 3.303 cm, mean TD of males was 2.81 cm and of females 2.746 cm, but this study didn't evaluate the accuracy of sex estimation of the dimensions of foramen magnum which has been evaluated in the present study.[14]

Conclusion:

The antero-posterior dimension and transverse dimension that have been used in the present study show significant sexual dimorphism in the studied eastern Indian population. These dimensions can be used to determine the sexual dimorphism in unknown human skulls on larger multicentric studies for use in forensic practice. However, data should only be used as a supporting finding in sex estimation in case of fragmented skull bases and not recommended as sole indicators for sexing complete skulls.

Conflict of interest: The authors declare that they have no conflict of interest.

Authors contribution: W.B.P, S.H and A.S contributed in research design and original study. S.C, S.D and S.G contributed in writing the manuscript. All the authors approved the final version of the manuscript.

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