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THE MORPHOMETRIC PARAMETERS OF FORAMEN MAGNUM USED TO DETERMINE THE BODY STATURE – A COMPUTED TOMOGRAPHIC STUDY

Sushma Mishra
PhD Scholar, Medical Anatomy, National Institute of Medical Sciences & Research
Department of Anatomy, NIMS University, Jaipur, Rajasthan

Dr. Upendra Kumar Gupta
MD Anatomy, Professor, Department of Anatomy, National Institute of Medical Sciences & Research, NIMS, Jaipur, Rajasthan

Dr. Sachin Khandori
MD Radio-diagnosis, Professor & Head, Department of Radio-diagnosis, Era's Lucknow Medical College & Hospital, Era University, Lucknow, Utter Predesh

Abstract
Foramen magnum is an important anatomical feature of human skull, but its anthropological importance is under assessed. Few studies done in the past which were tried to correlate the morphometric values of foramen magnum in the gender identification. Very few researchers tried to emphasis on the estimation of body stature through the anteroposterior and transverse dimensions of foramen magnum whereas a lot of data available in the relation of body stature and morphometry of long bones. Stature estimation is an important early step during forensic analysis of human skeletal remnants. The aim of this study was to obtain Pearson's correlation coefficient formula for estimating stature from the dimensions of foramen magnum of a North Indian population. This study includes 799 patients who were came to Radio-diagnosis OPD for CT scan imaging of Head neck region. The correlation was derived from transverse and anteroposterior dimensions of foramen magnum. The result of this study showing strong positive correlation of anteroposterior dimension of foramen magnum and body stature so the anteroposterior dimension can be used as better tool for stature estimation. This will be very helpful for the identification of the skeletal remain found in natural disasters, war fare, nuclear explosions etc.

Keywords: foramen magnum, stature, gender identification, morphometry, CT scan imaging.

Introduction

Foramen magnum is the transitional zone between cranial cavity and spinal canal. It plays an important role because of its close relation with the key structures such as brain and spinal cord, spinal accessary nerve, vertebral arteries and anterior and posterior spinal arteries. Despites of its importance, the anthropological value of foramen magnum is still under assessed compared to long bone by anatomist, anthropologist and forensic experts. The previous researchers had concluded that long bones are the better predictor of body stature. However, newer researches are being conducted to prove the efficiency of other bones of the body.

The probability of retrieving the intact long bone, particularly in the scenarios involving mass disasters, burns, or mutilated bodies, is less common. So, the requirement of the researchers to

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conduct their studies on the other bones which helps in better prediction of stature and thus increasing the possibility of identification of the unknown individuals. The earlier researchers performed the traditional methods by using measuring tapes and vernier caliper to measure the bones either in a percutaneous manner in the case of living subjects or by measuring from the bony landmarks after dissection in case of deceased subjects. However, the application of evolving Postmortem Multidetector Computed Tomography [PMCT] has helped researchers to a great extent that any part of the body can be studied in both living as well as dead subjects without mutilation in the case of dead subjects and maintaining the dignity of the dead.

Materials and methods

This cross-sectional study was conducted on the patients referred to the Radio-diagnosis outpatient department of Era's Lucknow Medical College & Hospital, for computed tomography of head and neck region. Total 799 patients were included in this study after excluding patient with deformities of skull and limbs as we measure the dimensions of foramen magnum as well as height of the subject. Maximum bones of the body altering the stature. Patient's personal details like age, sex, weight, address, clinical condition and consent were collected in a data collection proforma and consent form before collecting the data.

Technical specifications of the CT Scan Machine used: -

Tube	2 × Vectron^{TM} X-ray tubes
Detector	2 × Stellar^{Infinity} detectors with 3D anti-scatter collimator
Number of Acquired slices	384 (2 × 192) slices
Rotation time	up to 0.25 s[1]
In-plane temporal resolution	up to 66 ms[1]
Generator power	240 kW (2 × 120kW)
kV steps	70-150 kV. In steps of 10kV
Spatial resolution	0.24 mm[1]
Max. scan speed	737 mm/s[1] with Turbo Flash
Table load	up to 307mkg/676 lbs[1]
Gantry opening	78 cm

Statistical analysis

The results of the study were evaluated with the SPSS software v.23.0. The images were viewed using DICOM image viewer. The variables were measured from the reconstructed images as shown in Fig. 1

1. Stature
2. Shape of Foramen Magnum
3. Anteroposterior diameter of Foramen Magnum
4. Transverse diameter of Foramen Magnum

All the variables were measured using the electronic cursor [distance tool] available in the software and data were entered directly into a data collection proforma initially followed which was updated in Microsoft Excel 2016 Spreadsheet in Window 10.

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The stature was measured from vertex to sole of foot by using measuring tape. The anteroposterior diameter measured as the distance between opisthion (central point on the posterior margin of the foramen magnum) and basion (central point on the anterior margin of the foramen magnum).
All dimensions were measured in centimeters to the nearest 0.1mm. The obtained data were tabulated and analysed with the t test. The data on stature and dimensions of foramen magnum were obtained from CT images was expressed as mean with SD and range. The linear relationship between the stature and dimensions of foramen magnum had been explored by using Pearson's correlation analysis. Regression analysis both linear and multiple was used to establish the relationship between stature and dimensions of foramen magnum. All statistical analyses were carried out at a 5% level of significance using IBM Statistical Package for Social Sciences [SPSS] [v.23.0].

Result

The data of total 799 subjects (424 male and 375 female) were collected and analysed by using SPSS software (v.11.5) and descriptive statistics and regression equation was evolved. The age of subjects was between 18 to 94 years in which maximum subjects were between 21 to 30 years of age.

Table 1: Frequency distribution of gender of all subjects.

Gender	n = 799	In %
Male	424	53.07%
Female	375	46.93%

The Kolmogorov-Smirnov test was conducted on the both dimensions of foramen magnum to check for the normality of the population. The results reported that both were not normally distributed. Hence, the Kruskal-Wallis H test and Mann-Whitney test were performed. It was concluded that there was a significant difference in anteroposterior and transverse dimensions of foramen magnum between male and female subjects ($p<0.001$)

Table 2: Frequency distribution of AP and TD of foramen Magnum of all subjects.

AP (foramen Magnum)	n = 799	In %	TD (foramen Magnum)	n = 799	In %
≤ 2.50	3	0.38%	**≤ 2.50**	39	4.88%
2.51 - 3.00	48	6.01%	**2.51 - 2.75**	182	22.78%
3.01 - 3.50	321	40.18%	**2.76 - 3.00**	256	32.04%
3.51 - 4.00	358	44.81%	**3.01 - 3.25**	185	23.15%
4.01 - 4.50	58	7.26%	**3.26 - 3.50**	115	14.39%
4.51 - 5.00	11	1.38%	**3.51 - 3.75**	22	2.75%

Total 799 subjects were participated in this research in which 424 were males and 375 were females. The intra-observer reliability was assessed by using the test-retest method by measuring

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the height of the subject and dimensions of foramen magnum, two times by the observer and the mean values were considered for analysis. The age was mentioned in years whereas other variables were measured in centimeters (cm). The age was ranged from 18 to 94 years whereas height was varied from 141 to 179 cm. the anteroposterior diameter was 2.27 to 4.86 cm and transverse diameter was 2.04 to 3.68 cm. the mean of anteroposterior diameter was 3.54 ± 0,37 cm and mean of transverse was 2.94 ± 0.29 cm. The mean anteroposterior diameter was greater than mean transverse diameter in all subjects.

Table 3: Descriptive statistics of height and bone parameters of all as well as male and female subjects.

All subjects (n = 799)		**Male (n = 424)**		**Female (n = 375)**	
Mean ± SD	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**
45.95 ± 17.34	18-94	47.71 ± 18	18-82	43.96 ± 16.38	18-94
158.53 ± 7.35	141-179	159.4 ± 7.35	143-176	157.6 ± 7.25	141-179
3.54 ± 0.37	2.27-4.86	3.58 ± 0.37	2.27-4.86	3.5 ± 0.37	2.27-4.86
2.94 ± 0.29	2.02-3.68	2.96 ± 0.29	2.11-3.68	2.92 ± 0.3	2.04-3.68

The correlation coefficient determines the strength and the direction of a linear relationship between two variables. Pearson correlation was used to determine the association between anteroposterior and transverse dimensions of foramen magnum and stature. There was a significantly higher correlation (p = 0.00001) observed between stature and both dimensions of foramen magnum and stature. Pearson correlation coefficients of the male population were greater than the female population.

Table 5: Association of height with bone parameters of all subjects as well as male and female subjects separately by using Pearson's correlation coefficient

	Variables	**Corr (r)**	**t - test**	**P - Value**	**Significance**
All Subjects	**AP**	0.302	8.940	< 0.00001	All are highly significant
	TD	0.303	8.982	< 0.00001	
Male subjects	**AP**	0.326	7.082	< 0.00001	
	TD	0.276	5.908	< 0.00001	
Female subjects	**AP**	0.255	5.107	< 0.00001	
	TD	0.322	6.598	< 0.00001	

The accuracy of estimating the stature can be increased by the application of numerous regression equations. Thus, the researcher formulated simple as well as multiple regression equations to predict the human body stature estimation accuracy presented in Table 6 and Table 7. The results of this study showing higher stature estimation accuracy in multiple regression equations in compared to simple regression equations.

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Table 6: Simple regression equation for prediction of height from different bone length (All subjects, as well as female and male subjects separately).

Variables	Regression equation	Standard Error	R2	F-Value	P-Value
All subjects	Height = 5.981*AP + 137.36	7.01	0.091	79.92	< 0.00001
	Height = 7.67*TD + 135.96	7.01	0.092	80.68	< 0.00001
Female	Height = 5.04*AP + 139.95	7.02	0.065	25.88	< 0.00001
	Height = 7.89*TD + 134.54	6.87	0.104	43.18	< 0.00001
Male	Height = 6.44*AP + 136.32	6.95	0.106	50.16	< 0.00001
	Height = 7.13*TD + 138.25	7.07	0.076	34.9	< 0.00001

Table 7: Multiple regression equation for prediction of height (All subjects, as well as female and male subjects separately).

Variables		Regression equation	Standard Error	R2	F-Value	P-Value
Male	**AP**	Height = 133.31 + 5.09*APR + 6.25*APL	6.71	0.170	43.16	< 0.00001
	TD	Height = 139.72 + 1.246*TDR + 4.40*TDL	6.89	0.124	29.45	< 0.00001
Female	**AP**	Height = 138.43 + 1.258*APR + 7.38*APL	6.89	0.098	24.09	< 0.00001
	TD	Height = 137.42 + 3.89*TDR + 13.81*TDL	6.87	0.106	21.97	< 0.00001
All Subjects	**AP**	Height = 135.3 + 3.33*APR + 6.94*APL	6.80	0.146	68.14	< 0.00001
	TD	Height = 138.42 + 8.15*TDR + 9.29*TDL	6.93	0.112	50.04	< 0.00001

Discussion

The aim of this study was to find the stature of an individual from the morphometric parameters of foramen magnum. The result of this study would be helpful in the case where only occipital bone is found for the identification purpose of an individual. When the gender is unknown then the stature estimation is become difficult. So, the most of the authors suggested that the stature estimation should succeed the gender determination. The stature is estimated purely based on regression equations derived from the morphometric analysis of the various types of human bones. The present study established that the foramen magnum can be used for the estimation of the stature through an abandoned skull from the North Indian population. The stature can be correlated even though gender is unknown, with the help of the regression equation specific to the studied population with a minimal SEE (6.71 for AP and 6.89 for TD dimensions of foramen magnum) and higher coefficient of determination (0.170 for AP and 0.124 for TD diameters of foramen

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magnum). Karthi et al in their study on PMCT of foramen magnum on North Indian population found a minimal SEE (6.18 for FML and 6.64 for FMB) and higher coefficient of determination (0.52 for FML and 0.44 for FMB) for the regression equation specific to their population. They observed a correlation coefficient of 0.67(FMB), p<0.01and 0.72(FML), p<0.01 while this study observed 0.170 anteroposterior diameter, <0.00001 and 0.124 transverse diameter of foramen magnum, 0.00001. The variations in the findings could be due to different statistical procedures undertaken in this study. The comparative analysis of the correlation coefficient and SEE of the present study with a few other studies showed that the current study had a higher correlation, better coefficient of determination and lesser SEE in both gender with a P value <0.00001. The present study performed the measurements with the help of the DICOM Viewer software for CT images without any treatment of the bones and the electric cursor was used to measure the most exact dimensions of foramen magnum and body stature by measuring tape.

The comparative analysis of the correlation coefficient and SEE of the present study with a few other studies showed that the current study had a higher correlation, better coefficient of determination and lesser SEE in both gender with a P value <0.00001.

Table 8: Comparison of the results of current study with results of other past studies

S.No.	Author's Name, Place & Year	Variables (n=799)	Correlation Coefficient	P value		SEE	R2
Males							
1.	Karthi et al, North India (2021)	FML FMB	0.69 0.61	<0.001 <0.001		4.77 5.21	0.47 0.37
2.	Gilbe PS et al, Western India (2020)	FML FMB	0.69 0.75	- -		5.6 5.1	0.48 0.55
3.	Zhan M J et al., Chinese (2019)	FML FMB	0.15 0.34	0.035 <0.001		6.28 5.97	- -
4.	Villarreal M, American White (2015)	FML FMB	0.18 0.30	0.059 0.001		- -	- -
5.	Present study (2023)	AP TD	43.16 29.45	<0.00001 <0.00001		6.71 6.89	0.170 0.124
Females							
1.	Karthi et al, North India (2021)	FML FMB	0.62 0.60	<0.001 <0.001		6.18 6.30	0.38 0.36

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2.	Gilbe PS et al, Western India (2020)	FML FMB	0.45 0.68	- -		6.9 5.6	0.20 0.47
3.	Babu et al., South India (2014)	FML FMB	0.063 0.344	0.471 0.001		- -	- -
	Villarreal M, American White (2015)	FML FMB	0.14 0.15	0.14 0.11		- -	- -
5.	Zhan M J et al., Chinese (2019)	FML FMB	0.12 0.45	0.120 0.261		5.79 5.63	
5.	Present study (2023)	AP TD	24.09 21.97	<0.00001 <0.00001		6.89 6.87	0.98 0.106

Conclusion

Linear as well as multiple regression equations for stature estimation from anteroposterior and transverse dimensions of foramen magnum were established in this study. The correlation coefficients between stature and both dimensions of foramen magnum were highly significant and strongly correlated. The authors conclude that foramen magnum measurements in the North Indian population can be considered a reliable predictor of body stature. Thus, in scenarios where an isolated skull is retrieved, the linear as well as multiple regression equations can still assist in measuring the possible body stature of deceased.

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