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COMPUTEDTOMOGRAPHICBASEDMEASUREMENTSOFFORAMEN MAGNUM DIMENSIONS IN DETERMINATION OFGENDER AND AGE IN KASHMIRI POPULATION

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ABSTRACT

Background: Foramen magnum (FM) is the largest foramen in the skull. Through foramen magnum cranial cavity communicates with the vertebral canal.Foramen magnum region in different ethnic populations has significant differences between the sexes in their populations. The metric examinations show significantly higher values on male skull bases than on female skull bases. Sexual dimorphism is one of the major areas of interest to anatomists, anthropologists, skeletal biologists, forensic scientists and other specialists.

Objectives: To assess computed tomographic based measurements of foramen magnum dimensions in determination of gender and age in Kashmiri population.

Methods: A total of 252 (119 males and 133 females) CT skull images ofadult population with individuals age range above skeletal immaturity (age above 20 years) wasdone. Analysis of CT images was done on a PACS workstation monitor along with an experienced radiologist. 3D multi-planar reformation on CT console was done with reformation lines oriented along the lower most points of basion and opisthion (sagittal plane) and the mid-point of cervical spinal canal at C1/C2 level (coronal plane) to get the maximum cross-sectional area of foramen magnum.

Results: The mean anteroposterior diameter among males was3.66$\pm$0.43cmwhile among females it was 3.55$\pm$0.39cm with 95% confidence interval [-0.008 to 0.211]. The association was statistically significant with [p=0.03] and t-value 2.12. The mean transverse diameter was 3.45$\pm$0.59cm among males and 3.43$\pm$0.65cmamong femaleswith 95%confidence interval [-0.134 to-0.174]. The association was found statistically insignificant with [p=0.79] and t-value 0.25. The mean A.P, transverse, circumference,areaamong>40yearswas3.69$\pm$0.58cm,3.47$\pm$0.65cm,8.04$\pm$3.04cmand30.91$\pm$3.71cm^{2}respectively. Tetragonal, irregular and rounded shape was observed in (12.3%), (8.3%), and (4.8%) cases respectively. Pentagonal and diamond shape was found in 1.6% and 0.4% respectively.

Conclusion: Data collected in present investigation could serve as database for the quantitative description of dimensions of foramen magnum during normal growth and development considering sex and ethnic related variations.

Keywords: Foramenmagnum, sexualdimorphism,anthropologists,skeletal biologists.

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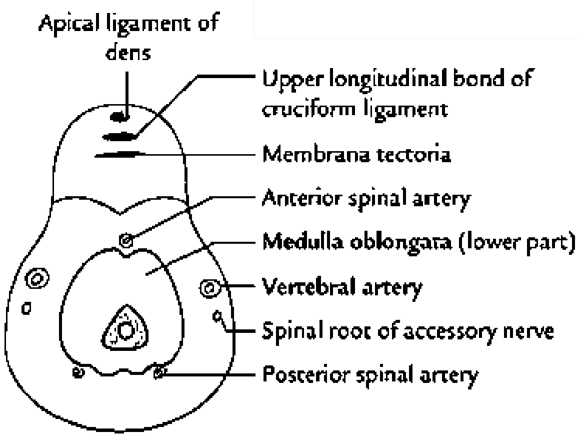
INTRODUCTION

Foramen magnum (FM) is the largest foramen in the skull. Through foramen magnum cranial cavity communicates with the vertebral canal. Itcontains the lower end of the medulla oblongata, meninges, vertebral arteries, and the spinal accessory nerve.[1]Foramen magnum lies in anteromedian position. It is oval wider behind, with its greatest diameter being anteroposterior. Anteriorly, its margin is slightly overlapped by the occipital condyles which project down to articulate with the superior articular facets on lateralmassesofatlas.[1]Themainfeaturesoftheexternalsurfacearetheexternaloccipital protuberance (EOP), the superior and inferior nuchal lines (SNL and INL) andthe external occipital crest (EOC).[2]The EOPis located midway between the posterior margin of the foramen magnum (FM) and the superior angle of the occipital bone and is the siteof attachment for ligamentum nuchae. Features visible on the internal surface are the internal occipital protuberance (IOP), the internal occipital crest (IOC), and a number of grooves. A wide depression marks the site of the COS. The IOC is a prominent ridge running inferiorly and anteriorly from the IOP to the posterior margin of the FM and divides in the lower part. The falx cerebelli attaches here and the occipital venous sinus is located in the attached margin of the falx.[2]

The alar ligaments, attached to tubercles on medial side of condyles divide foramen magnum into two compartments. (i) The smaller anterior compartment which transmits apical ligament, superior band of cruciate ligament, and the membrane tectoria.
(ii) The larger posterior compartment transmitsthe inferior part of medulla oblongatawith its associated meninges, the left and right ascending vertebral arteries, the anterior and posterior descending spinal arteries, spinal root of cranial nerve XI, the sympathetic nervous plexus around vertebral arteries from the inferior cervical ganglion.



StructurespassingthroughForamenMagnum

Other structures located in the posterior compartment are the veins that connectthe plexus of medulla oblongata with vertebral plexus. The inferior partof cerebellar tonsil may also project on either side of the medulla oblongata. The anterior and posterior margins of foramen magnum provide attachment to anterior and posterior atlanto-occipital membrane respectively.[2,3,4]Identification of human skeletal remains is of major importance in medicolegal situations such as criminal cases, mass disasters and human right abuse investigations. One of the major biological indicators of identity is the gender of an individual.[5,6]Fragmented or dispersed remains lead to an incomplete assessment resultingininconclusivegenderevaluation.[7,8]Itisthereforeimportanttodevelop

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methods for fragmented and incomplete skeletal remains. Morphometric methods rather thanmorphologicalmethodsofgenderdeterminationusingradiologicaltechniqueassume importance in mass nature disasters, explosions, exhumations and warfare where fragmentation is common.[9]

Sexual dimorphism is one of the major areas of interest to anatomists, anthropologists, skeletal biologists, forensic scientists and other specialists.

Forensic science: the determination of gender in severely compromised human remains for the purpose of identifying the deceased.[8]

Archaeological sciences: the determination of gender in skeletal remains for accurate mortality and morbidity rates of cemetery population.[10,11]

Medicalsciences:thegenderdifferenceindiseaseoccurrenceandmorbidity.

Developmental research: normal and abnormal development and growth with regards to sexual dimorphism,

Primatology and palaenthropology: to identify gender in the fossil record and apply models of observed behaviour in extinct primates to anthropoid group.[12]

Previous studies have examined the foramen magnum region in different ethnic populations and found significant differences between the sexes in their populations[13-18]. The metric examinations show significantly higher values on male skull bases than on female skull bases. The degree of expression of sexual dimorphism led to different classification methods for the different populations. Holland TD (1986)[19]achieved 71–90% correct predictions by using the multiple linear regression analysis within the Terry Collection.Routalet al.(1984)[20]areoftencitedwith100%correctpredictions.Suazo etal.(2009)wereableto correctly classify66.5% oftheirBrazilianpopulationwithlinear discriminant analysis[21]. The results of Gapert et al. (2009)[13]for a British population showed a maximum correct classification of 69.7–70.7% by using multivariate functions and 70–76% using linear regression equations. In recent years, studies have been published that used computed tomography (CT) data for the occipital region measurements. Uthman et al. (2012) evaluated an Iraqi population and used regression analysis with 81.8% correct sex prediction[15]. Edwards et al. (2013) used CT data of a Swiss population to develop discriminant functions with a predictive accuracy of 66%. Theirregression analysis ledto 66.8%correct classifications[16]. Franklin et al. (2013)used 3D image reconstruction for their investigations in a West Australian population. Their discriminant functions led to estimates with up to90% correct predictions. However, they did not limit their investigations solely to the foramen magnum region, butused measuring ranges on the entire skull[17].

Cranial analyses, whether morphognostic or morphometric have played an important role in examining age at death[22-28]biodistance, cranial variation and geographical relations[29-36], cranial development[37-40]and gender.[41-48]Foramen magnumhas been seen to exhibit difference between males and females but this difference is population specific as demonstrated by studies in Iraq[49], Brazil[50], Poland.[51]This has also been seen in India in diverse geographical locations as in Uttar pardesh[52], Gujarat[53], Chandigarh[54], and Madhya Pradesh.[55]The dimensions of foramen magnum are affectedby social, environmental and genetic factors.

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Fetuses at 9 weeks gestation have an ossification center around the hypoglossal canal in each exoccipital part and a single median ossification center in the basioccipital cartilage[56]. At 12 weeks gestation, a pair of ossification centers in the supraoccipital cartilage fuse together to form the supraoccipital bone. Rostral to the supraoccipital bone, the second pair of ossification centers in the membranous portion fuse to form the interparietal bone The intraparietal portion ossifies intramembranous while the rest of the occipital bone ossifies endochondrally utilizing cartilage as a precursor[57]. The supraoccipital and interparietal bones then fuse midline, but at this point in development are still separated laterally by the mendosal suture. At 14 weeks, ossification of the basioccipital occurs and advances laterally into the ventral portion of the condylars, while concurrently the ventral portions advance intothedorsalportions.Also,duringthe14th week, the fusion of the supraoccipital and interparietal bones progress almost to completion. The full union of these segments does not occur until between 2 and 4 years of age[56]. By the 16th week of fetal development, all intramembranous ossification centers are generally fused forming a lattice of trabeculae overlaying the external surface of the occipital squama[58]The exoccipitals remain separated from both the basioccipital and the supraoccipital segments by synchondroses and does not fuse until between 2 and 4 years of age[56].

AIMSANDOBJECTIVES

1. To measure and evaluate dimensions of foramen magnum among males and females of Kashmiri population and to establish its role in sexual dimorphism using computed tomography.
2. To measure and evaluate sagittal diameter, transverse diameter, area and circumference of foramen magnum among males and females in different age group.
3. To observe the most common shape of foramen magnum among the studied population.

MATERIALANDMETHODS

This observational cross-sectional study was carried out in the Postgraduate Department of Anatomy in collaboration with Postgraduate Department of Radio-diagnosis and Imaging, Govt. Medical College Srinagar. A total of 252 (119 males and 133 females) CT skull images, of adult population with individuals age range above skeletal immaturity (age above 20 years) done for various reasons were taken from the Department of Radiodiagnosis and Imaging, GMC Srinagar. The present study was done under ethical clearance vide order no. 165/ETH/GMC.

The scans were obtained from 16 slice spiral CT unit (Siemens Somotam Sensation, Germany).On theCTworkstation after retrieval ofdatafrom picturearchiving and communication system (PACS) multi-planar coronal, sagittal and axial reconstructions were performed. Reconstruction parameters had slice thickness 1.5 mm, recon increment 1.0 mm, field of view (FOV) 223 × 223 mm, window: osteo and kernelas H70s sharp FR (Head 70 smooth sharp Fast Reconstruction). Analysis of CT images was done on a PACS workstation monitor along with an experienced radiologist. 3D multi-planar reformation on CT console was done with reformation lines oriented along the lower most points of basion and opisthion (sagittal plane) and the mid-point ofcervical spinal canal at C1/C2 level (coronal plane) to get the maximum cross-sectional area of foramen magnum. Reformatted axial image of the foramen magnum showing the

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greatest sagittal diameter was selected. Free ROI (Region of interest) technique using electronic calliper tool was used to select the inner bony margin of the foramen magnum. Five parameters pertaining to dimensions of foramen magnum were measured separately. The shape of foramen magnum was also observed.

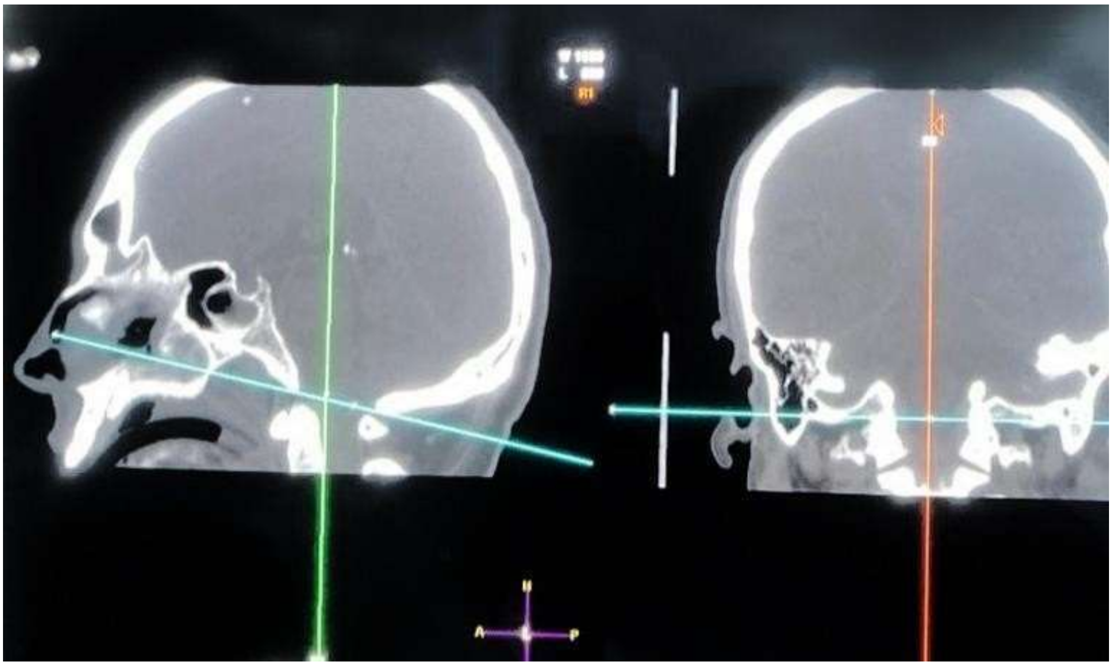

Image showing 3D multiplanar reformation on CT console with reformation lines oriented along lower most points of basion and opisthion (sagittal plane) and the mid-point of cervical spinal canal at C1/C2level(coronal plane) toget themaximumcross-sectional area offoramenmagnum

The following anatomical landmarks were used in determiningvarious parameters: Antero-posterior diameter/Maximum length of the foramen magnum (LFM) was measured from the midpoint of the anterior margin of the FM to the midpoint of the posterior margin of the FM along the principle axis of foramen magnum in mid- sagittal plane. Transverse diameter/Maximum width of the foramen magnum (WFM) was measured between the lateral margins of the FM at the point of greatest lateral curvature and recorded as the widest transverse diameter of the foramen magnum perpendicular to mid sagittal plane.

- Circumference of foramen magnum which is Perimeter of foramen magnum obtained by tracing the entire border of foramen magnum.
- Areaofforamenmagnumwasautomaticallyobtainedbytracingbonymargins using area tool
- Variation in shape of foramen magnum was noted by visual examinations of theimages.

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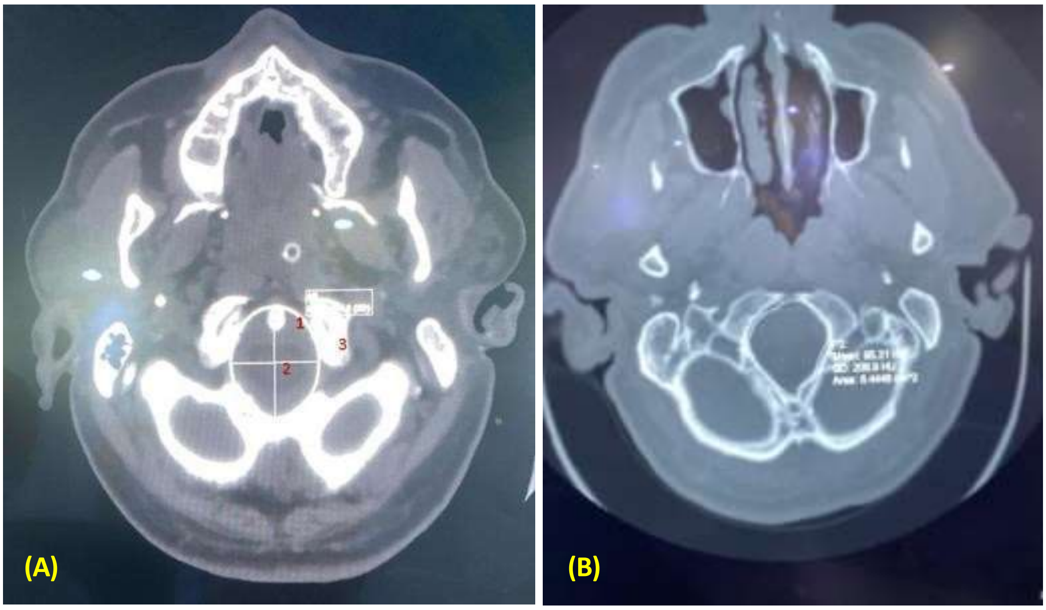

(A) Figureshowing1anteroposterior diameter2.transversediameter3.circumference
(B) Imageshowingareaofforamenmagnum

Inclusioncriteria:

- AdultKashmiripatientsaged20yearsandabove.

Exclusioncriteria:

- Individualswithagelessthan20years(skeletalimmaturity), Previous
- surgery involving occipital bone,
- Traumacausingfractures aroundforamenmagnum,
- Basilar invagination, Chiari malformation, achondroplasia and other skeletal dysplasia involving skull base.

Staistical Analysis: The recorded data was compiled and entered in a spreadsheet (Microsoft Excel) and then exported to data editor of SPSS Version 20.0 (SPSS Inc., Chicago, Illinois, USA). Statistical software SPSS (version 20.0) and Microsoft Excel were used to carry out the statistical analysis of data. Continuous variableswereexpressed as Mean±Standard deviation and categorical variables were summarized as percentages. Student’s independent t-test was employed for comparison of various parameters based on age and gender. Graphically the data was presented by bar and pie diagrams. P-value of less than 0.05 was considered statistically significant. All P-values were two tailed.

RESULTS

This observational cross-sectional study was carried out in the Post-Graduate Department of Anatomy and Post-Graduate Department of Radio-diagnosis and Imaging at Government Medical College, Srinagar. A total of 252 (119 malesand 133 females)CT skull images, of adult population (age above 20 years) done for various reasons were taken from the Department of Radiodiagnosis and Imaging, GMC Srinagar. The mean anteroposterior diameter among males was 3.66±0.43cm while among females it was 3.55±0.39cm with 95% confidence interval [-0.008 to 0.211]. The association was statistically significant with [p=0.03] and t-value 2.12. The mean transverse diameter was 3.45±0.59cmamongmalesand3.43±0.65cmamongfemaleswith95%confidence

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interval [-0.134 to-0.174]. The association was found statistically insignificant with [p=0.79] and t-value 0.25.

Themeancircumferenceamongmaleswas8.26±3.06whileinfemalesitwas 8.16±3.09 95% confidence interval [-0.664 to 0.864]. The association was statistically insignificant with [p=0.798] and t-value 0.25. The mean area among males was 30.50±3.45cm^{2}whileamongfemalesitwas31.30±2.53cm^{2}95%confidenceinterval[-1.545 to 0.054]. The association was statistically significant [p=0.03] and t- value2.13. In thepresentstudythemeananteroposterior,transverse,circumferenceandareaamong <40yearswerefoundtobe3.60±0.44cm,3.38±0.58cm,8.38±3.10cmand30.10±4.12cm^{2}respectively. The mean A.P, transverse, circumference, area among >40years was 3.69±0.58cm, 3.47±0.65cm, 8.04±3.04cm and 30.91±3.71cm^{2}respectively. Mostcommon shape observed was hexagonal accounting for (46%) followed by (26.7%) participantshavingoval shapecharacteristic.Tetragonal,irregularand roundedshapewas observed in (12.3%), (8.3%), and (4.8%) cases respectively. Pentagonal and diamond shape was found in 1.6% and 0.4% respectively.

Table1:Dimensionsofvariousparameters offoramenmagnum amongmalesandfemalesonCT scan

		Antero-posterior diameter	Transverse diameter	Circumference	Area
foramen magnumamong malesonCT scan	Mean	3.66cm	3.45cm	8.26cm	30.50cm^2
	S.D	0.43cm	0.59cm	3.06cm	3.45cm^2
	S.E	0.03cm	0.05cm	0.28cm	0.31 cm^2
foramen magnumamong Females on CT scan	Mean	3.55cm	3.43cm	8.16cm	31.30cm^2
	S.D	0.39cm	0.65cm	3.09cm	2.53 cm^2
	S.E	0.03cm	0.05cm	0.26cm	0.21 cm^2

Table2:Comparison ofvariousparametersaspergender

Parameter	Male [n=119]		Female [n=133]		P-value	95% confidence Intervalof difference	t-value
	Mean	SD	Mean	SD			
Anteroposterior diameter	3.66	0.43	3.55	0.39	0.03	-0.01to 0.21	2.12
Transverse diameter	3.45	0.59	3.43	0.65	0.79	-0.13to 0.17	0.25
Circumference	8.26	3.06	8.16	3.09	0.80	-0.66to 0.86	0.25
Area	30.50	3.45	31.30	2.53	0.03	-1.54to 0.05	2.13

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Table3:DimensionsofparametersofForamenMagnumin patients aged ≤40 and >40 years (n=101)					
		Antero-posterior diameter	Transverse diameter	Circumference	Area
Foramen Magnumin patientsaged ≤40years	Mean	3.60	3.38	8.38	30.10
	S.D	0.44	0.58	3.10	4.12
	S.E	0.04	0.05	0.30	0.40
Foramen Magnumin patientsaged >40years	Mean	3.69	3.47	8.04	30.91
	S.D	0.58	0.65	3.04	3.71
	S.E	0.04	0.05	0.24	0.02

Table4:Comparison ofvarious parameters asperage							
Parameter	≤40Years [n=101]		>40Years [n=151]		P-value	95% confidence Intervalof difference	t - Value
	Mean	SD	Mean	SD			
Anteroposterior diameter	3.60	0.44	3.69	0.58	0.18	-0.22to 0.04	1.32
Transverse diameter	3.38	0.58	3.47	0.65	0.26	0.08 to 0.24	1.12
Circumference	8.38	3.10	8.04	3.04	0.38	-0.43to 1.11	0.86
Area	30.10	4.12	30.91	3.71	0.11	-1.97to 0.17	1.62

DISCUSSION

The present study explored the dimensions of various parameters of foramen magnum like anteroposterior diameter, transverse diameter, circumference and area among males and females and in different age groups. The most common shape of foramen magnum was also observed

CTfindingsonthebasisofdimensionsofforamenmagnumamongmales andfemales: In the present study, the mean value of anteroposterior diameter, transverse diameter, circumference, and area among males and females was 3.66±0.43cm, 3.45±0.59cm, 8.26±3.06cm,30.50±3.45cm^{2}and3.55±0.39cm,3.43±0.65cm,8.16±3.09cm, 31.30±2.53cm^{2}respectively as shown in table 2 and table 3. The values were higher in males as compared to females. Among all four parameters, p value was found statistically significant (p=0.03) in anteroposterior diameter and area while p value (p=0.79) was found statistically insignificant in transverse diameter and circumference. The results of this study are in agreement with the study by Raiker NA et al (2016)[59]who found values for all the four parameters higher in males than in females with significant p value (p<0.05)forallthefourparametersi.e.,anteroposteriordiameter,transversediameter,

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circumferenceandarea,highlightingsexualdimorphisminFMdimensions.However,

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unlike our study they used submentovertex radiograph and found circumference as the best indicator for sex determination followed by area, transverse diameter and anteroposterior diameter while in our study anteroposterior diameter and area was found to be the best indicator. Kumar A et al., (2019)[60], Gargi V et al., (2018)[61],Jaitley M et al., (2016)[62]and Tambawala SS (2016)[63]conducted CT based studies similar to our study on thevariousparametersof foramenmagnumwheretheyfoundsignificantpvalue(p<0.05) among these parameters showing sexual dimorphism in foramen magnum dimensions, wherein they also concluded that the area is best parameter for gender determination. CT study conducted by Erdil FH et al (2010)[64]calculated anteroposterior diameter between opisthion and basion and transverse diameter as the maximum width. They found a significant positive corelation between the values of transverse and anteroposterior diameters of FM measurements (r=0.63; p<0.05). The comparison of the difference between anteroposterior and transverse diameter values in male and femalesubjects shows statistically significant in terms of size. In male subjects, anteroposterior and transverse diameter were longer than in females.

On comparison of all the four parameters in present study slight variation was found in dimensions of foramen magnum among males and females. The mean anteroposterior diameter among males was 3.66±0.43cm while among females it was 3.55±0.39cm with 95% confidence interval (-0.008 to 0.211). The association was statistically significant with p=0.03 and t-value 2.12 as shown in table 4 similar results were found by El-Atta A et al (2020)[65]who found significant p value = 0.002 with mean anteroposterior diameter 3.68±0.33cm in males and 3.57±0.33cm in females respectively. The mean transverse diameter was 3.45±0.59cm among males and 3.43±0.65cm among females with 95%confidence interval [-0.134 to -0.174]. The association was found statistically insignificant with p=0.79 and t-value 0.25 as shown in table 4 however, studies conducted by Taib AA et al (2021)[66]found p value significant (p=0.002) in transverse diameter among males 3.24±0.31cm and 3.07±0.32cm respectively.

The mean circumference among males was 8.26±3.06cm while in females it was 8.16±3.09cm 95% confidence interval [-0.664 to 0.84]. The association was statistically insignificant with p=0.798 and t-value 0.25 as shown in table 4 unlike present study p value was statistically significant p<0.001 in the study conducted by Uthman etal (2012)[49]who found mean circumference in males 9.26±0.65cm and 9.93±6.2cm in females respectively. The mean area among males was 30.5±3.45cm^{2}while among females it was 31.3±2.53cm^{2}95%confidence interval [-1.545 to 0.054]. The association was statistically significant p=0.03 and t-value 2.13 however Wani H A et al (2019)[67]found p value insignificant p=0.78 with mean area in males 80.6±9.84cm^{2}and 8.78±9.84cm^{2}in females respectively.

CT Findings of dimensions on the basis of age: In the present study, dimensions of various parameters in two age groups <_40 years and >40years were compared. The mean anteroposterior diameter, transverse diameter, circumference andarea were foundtobe3.60±0.44cm,3.38±0.58cm,8.38±3.10cm,30.10±4.12cm^{2}and3.69±0.58cm, 3.47±0.65cm, 8.04±3.04cm, 30.91±3.71cm^{2}respectively. There were no significant differences foundin dimensions offoramenmagnum in any ofthefourparametersamong the age groups which corresponds to the study conducted by Gapert R et al (2013)[68]who compared dimensions of various parameters of FM among <50 years and >50 years. The statistical analyses showed no significant age effect on any of the variables suggestingthat separation by age isnotnecessary for the developmentof sex determining methods.

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Similarly, Samara Osama A et al (2017)[69]performed there CT study to evaluate anteroposterior diameter, and transverse diameter among males and females and thevalues of these parameters in different age group (age range 19-95 years with mean age57 years). They found a statistically significant mean difference betweenthe anteroposterior and transverse diameters (p <0.001). Additionally, a strong positive linear correlation was found between the two variables (r=0.52, p<0.001). There was no statistically significant difference in age between males and females (p=0.2). A weak negative linear correlation was found between participants age and the anteroposterior diameter (r=-0.15, p=0.02) as well as participants age and the transverse diameter (r=- 0.14, p=0.03). The findings of present study are similar to Hosseini A et al (2021)[70]who conducted their study among 15-50 years individuals. A.P, Transverse diameter and area were measured. All of the parameters of FM (length, width, area, and FM index), were larger in men than women.The highest accuracy for sex determination was FM width. The morphometric analysis of foramen magnum was found useful for gender determination but could not be found suitable for age determination.

CT findings on the basis of shape: In the present study, most common shape observed was hexagonal accounting for (46%) followed by (26.7%) participants having oval shape characteristic. Tetragonal, irregular and rounded shape was observed in (12.3%), (8.3%), and (4.8%) cases respectively. Only (1.6%) and (0.4%) had either pentagonal or diamond shape characteristics. Similar observation was made by Taibb AA et al (2019)[66], Khalid Aljarrah et al (2021)[71], Zaidi and Dayal (1998)[72]who reported that the hexagonal type is the most common type. On the other hand, Ganapathy A et al (2014)[73], Agakani K et al (2016)[74],Sharmaetal(2015)[75],revealedthatovaltypeisthemost common. MurshedKA et al (2003)[76]found out that the most common type was round type. The tetragonal type was reportedto be the most common type by Sindel et al (1989)[77]. The difference in most common type of shape of FM could be attributed to different ethnic groups studied. The variations in shapes of FM are important in various neurological interpretations as in case of oval type, surgeons during operative procedures may find difficulty in exploring the anterior portion of FM.

CONCLUSION

Data collected in present investigation could serve as database for the quantitative description of dimensions of foramen magnum during normal growth and development considering sex and ethnic related variations. The findings of the present study allow for quantification of the foramen magnum features of Kashmiri adult population and provide parameters for preoperative planning and can also be used for identification in medico-legal cases.

REFERENCES

1) Gray'sAnatomy.Theanatomicalbasisofclinicalpractice39th edition(2005).
2) PoddarSandBhagatA(HandbookofOsteology.Patna:ScientificBookCompany (1987).
3) WarfelJH.TheHead,Neck,andTrunk.5th ed.Philadelphia:LeaandFebiger(1985).
4) McMinnRMHLast'sAnatomy.9thedition.Edinburgh:ChurchillLivingstone(1994).
5) Stewart TD. Sex determination of the skeleton by guess and by measurement. American Journal of Physical Anthropology 1954; 12(3): 385-392.
6) StewartTD.Essentials ofForensic Anthropology– EspeciallyasDevelopedinthe United States. Springfield, Il: Charles C. Thomas (1979).

7) Kelley MA. Sex determination with fragmented skeletal remains. Journal of Forensic Sciences 1979; 24(1): 154-158.
8) Scheuer L. Application of osteology to forensic medicine. Clinical Anatomy 2002; 15: 297-12.
9) Divella G, Campobasso, Dragon M, Introna F Jr. Skeletal sex determination by scapula measurements Boll Soc Ital Biol 1994; 70: 299-305.
10) Hamilton ME Sexual Dimorphism in Skeletal Samples. In: Hall, RL (ed) Sexual Dimorphism in Homo Sapiens – A Question of Size. New York:Praeger Publishers1982; pp 107-163.
11) Walker PL. Greater sciatic notch morphology: Sex, age, and population differences. American Journal of Physical Anthropology 2005; 127: 385-391.
12) Kranz GS. The fossil record of sex. In: Hall, RL (ed) Sexual Dimorphism in Homo Sapiens – A Question of Size. New York: Praeger Publishers, 1982; pp85-105.
13) Gapert R, Black S, Last J, Sex determination from the foramen magnum: discriminant function analysis in an eighteenth and nineteenth century British sample, Int J Legal Med 2009; 123: 25-33.
14) Gapert R, Black S, Last J, Sex determination from the Occipital Condyle: discriminant function analysis in an eighteenth and nineteenth century British sample. Am. J. Phys. Anthropol. 2009; 138: 384-94.
15) Uthman AT, Al-Rawi NH and Al-Timimi JF, Evaluation of foramen magnum in gender determination using helical CT scanning. Dentomaxillofac. Radiol. 2012; 41: 197–202.
16) Edwards K, Viner MD, Schweitzer W, Thali MJ, Sex determination from the foramen magnum, J. Forens. Radiol. Imag. 2013; 1(4): 186–92.
17) Franklin D, Cardini A, Flavel A, Kuliukas A, Estimation of sex from cranial measurements in a Western Australian population. Forens. Sci. Int. 2013; 229: 158.e1–158.e8.
18) Westcott DJ, Moore-Jansen PH, Metric variation in the human occipital bone: forensic anthropological applications. J. Forens. Sci. 2001; 5(46): 1159–63.
19) Holland TD, Sex determination of fragmentary crania by analysis of the cranial base.Am. J. Phys. Anthropol. 1986; 70: 203–208.
20) Routal RR,Pal GP,Bhagwat SS,Tamankar BP,Metrical studies withsexual dimorphism in foramen magnum of human crania. J. Anat. Soc. India 1984; 2(33): 85–89.
21) Suazo Galdames IC, Perez Russo P, Zavando Matamala DA & Smith RL, Sexual dimorphism in the foramen magnum dimensions. Int. J. Morphol. 2009; 27(1): 21-23.
22) Genovés S. Estimation of age and mortality. In: Brothwell D, Higgs E (eds) Science in Archaeology – A Survey of Progress and Research. 2ndrevised edition. London: Thames and Hudson, 1969b; pp 440-52.
23) Novotný V, İşcan MY, Loth SR. Morphologic and osteometric assessment of age, sex, and race from the skull. In: İşcan MY, Helmer RP (eds) Forensic Analysis of the Skull. Craniofacial Analysis, Reconstruction, and Identification. New York: Wiley- Liss, Inc., 1993; pp 71-88.
24) Hershkovitz I, Latimer B, Dutour O, Jellema LM, Wish-Baratz S, Rothschild C, Rothschild BM. The elusive petroexoccipital articulation. American Journal of Physical Anthropology 1997; 103: 365-73.
25) Rösing FW and Kvaal SI. Dental age in adults – A review of estimation methods. In: Alt KW, Rösing FW, Teschler-Nicola M (eds) Dental Anthropology. Fundamentals, Limits and Prospects. Wien New York: Springer Verlag, pp 443-468 (1998).
26) Howells WW. Who’s who in skulls. Ethnic identification of crania from measurements. Volume 82. Papers of the Peabody Museum of Archaeology and Ethnology. Cambridge Massachusetts: Harvard University (1995).
27) İşcan MY and Steyn M. Craniometric determination of population affinity in South Africans. International Journal of Legal Medicine 1999; 112: 91-97.
28) Kimmerle EH, Jantz RL, Konigsberg LW. Skeletal estimation and identification in American and East European populations. Journal of Forensic Sciences 2008a; 53(3): 524-532.

ISSN:0975-3583,0976-2833 VOL15,ISSUE07,2024

29) Howells WW. Cranial variation in man. A study by multivariate analysis of patterns of differences among recent human populations. Volume 67. Papers of thePeabody Museum of Archaeology and Ethnology. Cambridge Massachusetts: Harvard University (1973).
30) Droessler J. Craniometry and Biological Distance. Evanston Il: Centre for American Archeology at Northwestern University (1981).
31) Howells WW. Skull shapes and the map. Craniometric analyses in the dispersion of modern Homo. Volume 79. Papers of the Peabody Museum of Archaeology and Ethnology. Cambridge Massachusetts: Harvard University (1989).
32) Sendemir E, Savci G, Cimen A. Evaluation of foramen magnum dimensions. Acta Anatomica Nipponica 1994; 69: 50-52.
33) Lahr MM. The Evolution of Modern Human Diversity – A Study of Cranial Variation. Cambridge: Cambridge University Press (1996).
34) Slavec ZZ. NewMethodofIdentifying FamilyRelatedSkulls.Wien NewYork:Springer (2004).
35) Franklin D, Freedman L, Milne N. Three-dimensional technology for linear morphological studies: a re-examination of cranial variation in four southern African indigenous populations. Homo – Journal of Comparative Human Biology 2005b; 56: 17-34.
36) Smith HF. Which cranial regions reflect molecular distances reliably in humans? Evidence from three-dimensional morphology. American Journal of Human Biology 2009; 21(1): 36-47.
37) Aiello L, Dean C. An Introduction to Human Evolutionary Anatomy. London: Academic Press (1990).
38) Liebermann DE. Ontogeny, homology and phylogeny in the hominid craniofacial skeleton: the problem of the browridge. In: O’Higgins P, Cohn M (eds) Development, Growth and Evolution (2000).
39) Liebermann DE, Osbjorn MP, Mowbray KM. Basicranial influence on overall cranial shape. Journal of Human Evolution 2000a; 38: 291-15.
40) LiebermannDE,RossCF,Ravosa MJ.Theprimate cranial base: Ontogeny,function,and integration. Yearbook of Physical Anthropology 200b; 43: 117-69.
41) Keen JA. A study of the differences between male and female skulls. American Journalof Physical Anthropology. 1950 Mar;8(1):65-80.
42) Pons J. The sexual diagnosis of isolated bones of the skeleton. Human Biology 1955; 27: 12-21.
43) Ceballos JL and Rentschler EH. Roentgen diagnosis of sex based on adult skull characteristics. Radiology 1958; 70: 55-61.
44) Demoulin F. Importance of certain cranial measurements (in particular the sagittal length of the mastoid) in the sexual naming of skulls. Bulletins and Memoirs of the Anthropological Society of Paris 1972; 9(3): 259-64.
45) Baughan B and DemirjianA. Sexual dimorphism inthe growth ofthecranium. American Journal of Physical Anthropology 1978; 49: 383-90.
46) Catalina-Herrera CJ. Study of the anatomic metric values of the foramen magnum and its relation to sex. Acta Anatomica 1987; 130: 344-47.
47) Lestrel PE, Cesar Jr RM, Takahashi O, Kanazawa E. Sexual dimorphism in the Japanese cranial base: A Fourier-wavelet representation. American Journal of Physical Anthropology 2005; 128: 608-22.
48) Rogers TL. Determining the sex of human remains through cranial morphology. Journal of Forensic Sciences 2005; 50(3): 493-500.
49) Uthman AT, Al-Rawi NH, Al-Timimi JF. Evaluation of foramen magnum in gender determination using helical CT scanning. Dentomaxillofac Radiol 2012; 41: 197-202.
50) Suazo GIC, Russo PP, Zavando MD, Smith RL. Sexual dimorphism in the foramen magnum dimensions. Int J Morphol 2009; 27: 21-3.

ISSN:0975-3583,0976-2833 VOL15,ISSUE07,2024

51) Burdan F, Szumiło J, Walocha J, Klepacz L, Madej B, Dworzański W, et al. Morphology of the foramen magnum in young Eastern European adults. Folia Morphol (Warsz) 2012;71:205-16.
52) Yadav Y, Goswami P. A study of length and width of foramen magnum in north India.Int J Sci Res 2014;3:371-2.
53) Patel R, Mehta CD. Morphometric study of ForamenMagnum atthe base of human skull in South Gujarat. IOSR JDMS 2014; 13: 23-5.
54) Singh G, Talwar I. Morphometric analysis of foramen magnum in human skull for sexdetermination. Human Biol Rev 2013;2:29-41.
55) Kanodia G, Parihar V, Yadav YR, Bhatele PR, Sharma D. Morphometric analysis of posterior fossa and Foramen magnum. J Neurosci Rural Pract 2012;3:261-6.
56) Shapiro R, Robinson F. Embryogenesis of the human occipital bone. Am J Roentgenol. 1976; 126(5):1063-8.
57) Jin SW, Sim KB, Kim SD. Development and Growth of the Normal Cranial Vault: An Embryologic Review. J Korean Neurosurg Soc. 2016; 59(3):192-6.
58) Matsumura G, England MA, Uchiumi T, Kodama G. The fusion of ossification centres in thecartilaginousandmembranouspartsoftheoccipitalsquamainhumanfetuses. J Anat. 1994;185 (Pt 2): 295-300.
59) Raikar NA, Meundi MA, David CM, Rao MD, Jogigowda SC. Sexual dimorphism in foramen magnum dimensions in the South Indian population: A digital submentovertex radiographic study. J Forensic Dent Sci 2016;8:180-1.
60) KumarA,PotdarP,SinghK,Dhakar JS.ComparativeStudyofForamenMagnuminDry Cadaveric Skull and 3D CT Images. SSR Inst. Int J Life Sci 2019; 5(5): 2372-78.
61) Gargi V, Prakash SM, Malik S, Nagaraju K, Goel S, Gupta S. Sexual dimorphism of foramen magnum between two different groups of Indian population: A cross-sectional cone-beam computed tomography study. J Forensic Sci Med 2018; 4: 150-5.
62) Jaitley M, Phulambrikar T, Kode M, Gupta A, Singh SK. Foramen magnum as a tool for sexual dimorphism: A cone beam computed tomography study. Indian J Dent Res 2016;27:458-62.
63) Tambawala SS, Karjodkar FR, Sansare K, Prakash N, Dora AC. Sexual dimorphism of foramen magnum using cone beam computed tomography. J Forensic Leg Med 2016;44:29-34.
64) Erdil FH, Sabancigullari V, Çimen M, Isik O. Morphometric analysis of the foramen magnum by computed tomography. Erciyes Med J 2010;32:167-70.
65) Abo El-Atta, HM, Abdel-Rahman RH, El-Hawary G. et al. Sexual dimorphism offoramen magnum: An Egyptian study. Egypt J Forensic Sci 2020; 10: 1.
66) Taib AA, Greiw ASH, Leias AE, Ambarak OO, Abdalla MA. Morphometric evaluationof foramen magnum by using computerized tomographic images. Int J Clin Skills 2019;13:273-7.
67) Wani HA, Feroz I, Dar SM, Parry AH, Gojwari TA, etal. Sexual dimorphism of foramen magnum: a NCCT based study. Int J Clin Trials 2019;6(2):52-5.
68) Gapert R, Black S, Last J. Test of age related variation in the craniometry of the adult human foramen magnum region: implications for sex determination methods. ForensicSci Med Pathol 2013; 9(4): 478-88.
69) Samara OA, Amarin JZ, Badran DH, Al-Khayat OW, Suradi HH, Shatarat AT, Hadidi MT. Morphometric Analysis of the Foramen Magnum. Int. J. Morphol., 2017; 35(4): 1270-75.
70) HosseiniA, SoleimannejadM,JavadiA, KazemifarA,DarabiS,Pourkeramat S.Sex and age determination by measurement of foramen magnum dimensions on computer tomography scanning study in the Iranian population. J Craniofac Surg. 2021; 32(7): e604-e607.
71) Aljarrah K, Packirisamy V, Al Anazi N, Nayak SB. Morphometric analysis of foramen magnumand occipitalcondyle usingCTimages for sex determinationin a SaudiArabian population. Morphologie. 2021: S1286-0115(21)00192-2.

ISSN:0975-3583,0976-2833 VOL15,ISSUE07,2024

72) Zaidi SH and Dayal SS. Variations in the shape of the foramen magnum in Indian skulls. Anat Anz Jena 1998;167(4):338-40.
73) Ganapathy A, Sadeesh T, Rao S. Morphometric analysis of foramen magnum in adult human skulls and CT images. Int J Cur Res Rev 2014; 6(20): 11-15.
74) Aghakhani K, Kazemzadeh N, Ghafurian F, Soltani B, Soltani S. Gender determination usingdiagnosticvaluesofforamenmagnum.IntJMedToxicolForensicMed2016;6(1): 29-35.
75) Sharma S, Sharma AK, Modi BS, Arshad M. Morphometric evolution of foramen magnum and variation in its shape and size: A study on Human dried skull. Int J Anat Res. 2015; 3(3):1399-03.
76) Murshed KA, Cicekcibasi AE, Tuncer I. Morphometric evaluation of the foramen magnum and variations in its shape: A study on computerised tomographic images of normal adults. Turk J Med Sci 2003; 33(5): 301-06.
77) Sindel M, Ozkan O, Ucar Y, et al. Foramen magnum anatomic varyasyonlari. Akd U Tip Fak Dergisi. 1989;6: 97-1.