

## **Sexual Dimorphism in Endocranial Capacity of Dry Human Skulls in Central India Region**

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### **ABSTRACT**

Cranial capacity is indicative of brain volume and is important for deciding racial and sexual characteristics in physical anthropological studies. It is measured both directly by filling the cranial cavity with various materials like lead shots, mustard, cast materials etc and indirectly by using derivation formulae. In the present study, volume of the cranial cavity is measured by using mustard seeds and calibrated glass cylinder. The range of cranial capacity is 1120- 1650 cc and 800-1280 cc in male and female skulls respectively. Cranial Capacity was statistically significant,  $t(258) = -16.94, p = <.001, 95\%$  confidence interval [-203.13, 160.6] it is an important measured parameter to differentiate male and female skulls. The results are useful for anatomists, medicolegal experts and anthropologists.

**KEYWORDS:** Cranial, capacity, volume, mustard, SDICC

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### **INTRODUCTION**

The neurocranium is composed of a skull vault and skull base, it surrounds and protects the brain and special sense organs of olfaction, vision, hearing and balance. [1] Endocranial capacity, which is in close correlation with brain volume, reflects racial characteristics so proves important in physical anthropological studies. [2] The capacity of the cranial cavity correlates to the size of the brain which it contained, and is most conveniently measured by filling the cavity with lead shot and measuring the contents in a graduated vessel. Skulls are classified according to their capacities by Henry Gray (1918) [3] and then by Cunningham (1951) who mentioned that there is wide range of variation in the capacity of different crania, but because of varying thickness of bone and size of sinuses, the capacity is not directly proportional to the size of skull as a whole. For purposes of classification and comparison, skulls are grouped according to their cranial capacity. [4] Microcephalic Skulls with a capacity below 1350 cc which are found in skulls of Andamanese, Veddas, Australians, Bushmen, Tasmanians. Mesocephalic Skulls with capacity range from 1350 cc to 1450 cc are found among American Indians, Chinese, and some African Negroes and megacephalic skulls are with a capacity over 1450 cc and found in Mixed Europeans and Japanese. The index of sexual dimorphism of the cranial capacity, given by the formula

(male mean female mean/ male mean) x 100 was 10.3%, which is in the middle range among several races. In a Homogenous race, the individual variability in cranial capacity would be lower than that in heterogeneous groups. [3,4]

### **OBJECTIVE**

Study was conducted to measure cranial capacity, sexual dimorphism index of cranial capacity and demarking point for identification of sex of human skull in central India region.

### **MATERIAL & METHODS**

After necessary permission from the Institutional ethics committee, the study was carried out on 260 dry human skulls in Department of Anatomy, Gandhi Medical college Bhopal from 2020-22. All available completely ossified adult dry human skulls without any apparent damage were studied from Department of Anatomy, Regional medicolegal Institute, Bhopal, and Department of Forensic Medicine and Toxicology, Gandhi Medical College, Bhopal (MP) after due permissions. The criteria to decide skull of adult age was dental examination and basi-occiput and basi-sphenoid suture fusion. The eruption of 3<sup>rd</sup> molar is between 17 to 25 years and suture at the base of skull between sphenoid and occipital bone closes around 18 years

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in males and 20 years in females. Presence of one of these in the skull is considered to be of adult male or female. Damaged or broken human skulls with visible loss of skeletal elements affecting the selected morphometric and morphological parameters are excluded from the study.

Cranial capacity is the volume of the cranial cavity measured by using mustard seeds and calibrated glass cylinder. Dry hard mustard seeds of mostly uniform size were used to fill the cranial cavity to determine the capacity. First, the orbital fissures and the major foramina of skull are plugged with cotton to rule out any possibility of escape of seeds. Then a glass funnel is placed in the foramen magnum and mustard seeds are poured to fill the cavity nearly half and then vigorous shaking is done. It will settle down the mustard seeds into the frontal part of the skull and then the cavity is filled up with more seeds up to the rim of the foramen magnum while intermittently shaking the skull and pressing the seeds gently with the thumb at the foramen magnum. The seeds move away in all directions and more seeds are poured to fill up the skull which is shaken and tapped again. The process is repeated on until the entire cavity is filled up with the seeds and there is practically no more area left to be poured. After the process, the seeds were poured from the skull into a glass jar and from there through a glass funnel into the calibrated glass cylinders of 1000 CC capacity each. The process of shaking and taping then went on with the cylinders as it was with the skulls and the volume was then recorded from the measuring cylinder. [5]

**Sexual dimorphism index of cranial capacity (SDICC)** – It is the ratio between the mean cranial capacity of male skulls minus mean cranial capacity of female skulls to mean cranial capacity of male skulls.

$$\text{SDICC} = \frac{\text{Male mean cranial capacity} - \text{Female mean cranial Capacity}}{\text{Male Mean Capacity}} \times 100$$

Identification point is calculated as above or below the maximum or minimum value of particular parameter for skull of opposite sex. Calculated range was derived as mean  $\pm$  3SD and demarking point is above or below the maximum or minimum value of calculated range of skull of opposite sex. Paired t test applied for significance.

## RESULTS

In the present study, the range of cranial capacity is 1120-1650 cc and 800-1280 cc in male and female skulls respectively. The calculated range for cranial capacity is 1022.45- 1556.28 cc and 860.4-1354.59 cc respectively for skulls in male and female groups which is calculated by mean  $\pm$  3 SD. The results of the descriptive statistics show that the female group has lower values for the dependent variable, Cranial Capacity ( $M = 1,107.5$ ,  $SD = 82.71$ ) than the male group ( $M = 1,289.36$ ,  $SD = 89.29$ ). Frequency distribution

chart shows that highest frequency of observed values for cranial capacity is in between 1200 to 1400 cc for male skulls and 1000 – 1200 cc for female skulls. It indicates that there is clear divergence of observed values for cranial capacity between male and female groups with minimum overlapping between 1150- 1250 cc range.

Table – 1– Cranial Capacity

Cranial Capacity	Female	Male
Frequency	120	140
%	46.15%	53.85%
Mean	1,107.5	1,289.36
Std. Deviation	82.71	89.29
Variance	6,840.76	7,972.84
Minimum	800	1,120
Maximum	1,280	1,650
Range	480	530
95% Confidence interval of Mean	1,092.7; 1,122.3	1,274.57; 1,304.16
Mean $\pm$ Std.	1,107.5 $\pm$ 82.71	1,289.36 $\pm$ 89.29
Range	800-1280	1120-1650
Identification Point	<1120	>1280
Calculated Range	860.4-1354.59	1022.45-1556.28
Demarking Point (D.P.)	<1022.45	>1354
No. of skulls beyond DP	21	26
% of identified Skull	8.08%	10%

Table above showing the range, mean, standard deviation, identification point,

demarking point, number and percentage of male and female skulls beyond the demarking point which is mean  $\pm$  3SD, indicates 99.7% accuracy in differentiation of sex of skull for a particular parameter. 21 (8.08%) female and 26 (10%) male skulls are identified by demarking point. A **two-tailed t-test for independent samples** (equal variances assumed) showed that the difference between skulls of female and male groups with respect to the dependent variable Cranial Capacity was **statistically significant**,  $t(258) = -16.94$ ,  $p = <.001$ , **95% confidence interval [-203.13, -160.6]**.

A multiple linear regression analysis was performed to derive formula and examine the influence of the variables Maximum Cranial Length, Maximum Cranial breadth and Cranial Height on the variable Cranial Capacity. The regression model showed that the variables Maximum Cranial Length, Maximum Cranial breadth and Cranial Height explained 54.41% of the variance from the variable Cranial Capacity. An ANOVA was used to test whether this value was significantly different from zero. Using the present sample, it was found that the effect was significantly different from zero,  $F=101.84$ ,  $p = <.001$ ,  $R^2 = 0.54$ .

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The following regression model is obtained:

$$\text{Cranial Capacity} = -986.54 + 66.59 * \text{Maximum Cranial Length} + 34.39 * \text{Maximum Cranial breadth} + 43.37 * \text{Cranial Height}$$

Sexual dimorphism index of cranial capacity calculated in the present study was 14.1. It implies the ability to differentiate male and female skulls based solely on the cranial capacity as individual parameter.

### DISCUSSION

In present study on 260 skulls, the cranial capacity of male skulls was  $1289.36 \pm 89.29$  C.C. (range 1120 -1650 C.C.) and those of female skulls was  $1107.5 \pm 82.71$  C.C. (range 800-1280 C.C.). In the present study the bisexual variation in cranial capacity of male and female skulls is highly significant as the 't' test value was -16.94 ( $p < 0.001$ ). Cranial capacity has been measured without differentiating male and female by some researchers. In the present study the mean cranial capacity of both sexes taken together is 1205.43 cc and

the skulls could be grouped as microcranial (cranial capacity  $< 1350$  cc). Classifying on the basis of cranial capacity of skulls individually a large number of skulls (78.57% male and 100% female skulls) were microcranial; 16.5% male and none of female skull were mesocranial (cranial capacity between 1350 – 1450 cc) while 5% male skulls were megacranial (cranial capacity  $> 1450$ cc), while none of the female skull was megacranial.

Cranial capacity indicates the brain volume indirectly and has been measured by different methods in various studies. Direct measurement by filling the cranial capacity with lead shots, mustard seeds, etc and then pouring out into measuring flask is considered most accurate method. Calculation of cranial capacity from length, breadth and height of cranium is also done using various formulae. In the present study, the cranial capacity was measured by mustard seed method and the mean capacity in male skulls was 1289.36 cc and in female skulls was 1107.5 cc.

**Table – 2**– Comparison of present study with various studies for Cranial Capacity

S. No.	Researcher	No. of skull	Male			Female		
			Range	Mean	S.D.	Range	Mean	S.D.
1.	Tildesley (1957) [6]	M-107 F-75		1376.94	7.92		1233.14	8.70
2.	Ricklan & Tobias (1986)	M-50 F-50	1165 - 1653	1373.3	107.4	1032- 1428	1251	101.1
3.	Simmons et al (1942)	M-179 F- 142	1090- 1782			1070- 1749		
4.	Dekaban A & Lieberman (1977) [7]	M-15 F -13		1540			1425	
5.	Hrdlicka (1928) [8]	M-7 F-6		1360			1182	
6.	Harper et al (1984) [9]	M-23 F-4	1298- 1751	1497		1175- 1588	1164.46	
7.	Routal, Pal, Bhagwat (1986) [10]	370 Gujrati skulls	1030- 1620	1252				
8.	Chaturvedi, [11] Harneja (1962)	80		1296.6				
9.	Young II et al (1995) [12]			1470	107		1317	117
10.	Manjunath KY (2002) [13]	M-33, F-17	1017- 1415.98	1152.81	94.16	975.14- 1298.64	1117.82	99.09
11.	Usnawz et al (2007)			1411	118		1306	162
12.	Gohiya et al (2010)[14]			1380	94		1188	75
13.	Maina et al (2011) [15]			1424	137		1331	201
14.	Murali et al (2012) [16]			1302	108		1179	97
15.	Nzotta et al (2014)			1636	109		1632	149

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16.	Sadakat et al (2014)[17]			1260	75		1164	89
17.	K.Sangeetha et al (2018) [18]			1275	124		1213	138
<b>18.</b>	<b>Present Study</b>	<b>M-140 F-120</b>	<b>1120-1650</b>	<b>1289.36</b>	<b>89.29</b>	<b>800-1280</b>	<b>1107.5</b>	<b>82.71</b>

Comparison of results with other Indian studies shows that cranial capacity measured in the present study correlates with the cranial capacity measured by other workers on Indian skulls. Observations of our study are comparable to K. Sangeetha et al (south Indian skulls, 2018), Sadakat et al (north Indian skulls, 2014), Murali et al (central India, 2012), Gohiya et al (central India, 2010), Chaturvedi and Harneja (1962), Routal and Bhagavat (1986). Our observations fall on lower side to the observations of Nzotta et al, Maina et al, Usanwz et al, Young H et al, harper et al, Dekaban A, Liebermann. And higher to the observation of Manjunath and Pal, Bhagavat, Routal. Observations of Shukla (Indian skulls, 1966), Thomas et.al (Indian skulls, 1980), Routal, Pal and Bhagwat (Indian skulls, 1984) are comparable to our study. The cranial capacity reported by Manjunath (south Indian skulls, 2002) using Lee Pearson formula and Spheroid formula is less for male skulls than the present study.

Among foreign studies, cranial capacity measured by Mackinnon (England, 1955) and Hooton (modern Australian skulls, 1946) also correlated with the present study. Tildesley (1957) measured the cranial capacity by direct measurements and by Negro formula and their findings were slightly higher than the present study. Cranial capacity measurement by Ricklan and Tobias (studied on Zulu Negro skulls, 1986), Todd (1923), Kitson (east African Negro skulls, 1931), Hrdlicka (west African Negro skulls, 1928), Trevor (Gabon Negro skulls, 1949), and L. Isserlis (Negro skulls, 1914) were higher than the present study. Cranial capacity measured by MacDonell (English skulls, 1904), G.M. Morant (Tibetan skulls, 1923), YoungII et.al (Korean skulls, 1995), Morant (Korean skulls, 1968), Anatole and Lieberman (European skulls, 1977) and Shima (Korean skulls, 1934) has been reported to be more than the present study. Anatole and Lieberman (1977) measured cranial capacity by direct method as well as by Pearson formula and spheroid formula and reported cranial capacity to be more than the present study.

Harper et al (Australia, 1984) measured cranial capacity by P.O.P. cast method and found cranial capacity to be more than the present study. The fresh brain volume measured by them correlates with the present study. Simmons (white skulls, 1942) measured cranial capacity of 1360 skulls, the range of capacity of male skulls coincides with the present study, but the range of female cranial capacity is more than in the present study.

## CONCLUSION

The present study concludes that male cranial capacity is higher than female and cranial capacity measurements of dry human skulls is reliable indicator in determining the sex of unknown skull in central India Region. After a detailed study and comparison of the present study with the earlier researchers, it can be concluded that the demarking point and identification point help in identification of the sex of the skull with higher accuracy than non metric morphological methods. The demarking point of cranial capacity is valid and reliable measured indicator and Sexual dimorphic index of cranial capacity (SDICC) is statistically significant for the determination of sex of skull. Hence, measured indicator of cranial capacity can be used for the anatomical and medicolegal purposes where unidentified skull is available for forensic examination.

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