

Evaluation of Cranial Volume Determination Methods and their Corelation with Each Other in Adult Human Dried Skulls in Indian Population

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ABSTRACT

Background: Knowledge of the cranial morphometry is important from clinical and forensic point of view. Also, racial characteristics of a certain population are best described in the skull. Endocranial volume is an important parameter in the study of racial differences. Objective: The present study was thus undertaken to determine the correlation between the two methods of cranial volume determination in dried human skulls in Indian population. **Methods:** A total of 100 dried human skulls (50 male and 50 female) were included in the study. Various cephalometric parameters including cranial length, cranial breadth and cranial height in male and female skulls were recorded using sliding caliper and blunt end spreading caliper, and the two methods of determining cranial volume -1 filling method and 2 Lee and Pearson formula method were used, data obtained and statistically evaluated. **Results:** The mean and S.D. cranial volume in male, female and combined skulls came out to be 1381.54 + 131.56 cc; 1284.8 + 90.5cc ; 1333.18 + 122.87cc respectively by filling method and the mean and S.D. cranial volume in male, female and combined skulls came out to be 1450.44 + 114.46 cc ; 1316.9 + 83cc; 1383.69 + 120.24cc respectively by formula method. **Conclusion:** The results of this study highlight the racial and gender difference in terms of cranial volume. As cranial volume serves as one of the important parameter in the study of the human evolution, racial differences, in clinical practice for the study of abnormalities of cranial size and in sex determination of skulls, these dimensions will provide a baseline standard value for parameters in Indian population and will be of utmost importance to neurosurgeons, forensic experts in medico-legal cases and to the anthropologists.

Keywords: Cranial Volume, Lee Pearson formula method, Water filling method, Human dried skull, Indian Population.

INTRODUCTION

The cranial volume is a measure of the volume of the interior of the cranium of those vertebrates who have both a cranium and brain and serves as a rough indicator of the brain size. It is important in clinical practice for the study of the abnormalities of cranial size and is widely used as a representation for actual brain size and medically,^[1] an analysis of cranial volume exposes another aspect of the growth and development and permits critical evaluation of unusually large, small or misshapen crania.^[2-8] It can be used as parameter for sex determination as the cranial volume of the female is about 11% less than male. It can be correlated with other cranial parameters and in the studies of the primate phylogeny.^[9] According to

Hooton (1926), the racial characters are best defined in the skull. Cranial volume constitutes one of the most important characters for determining the racial difference. It is also an indirect approach to evaluate the size of the brain.^[10]

The cranial cavity has a volume ranging from 1300 cc to 1600 cc and occasionally beyond these limits. The volume of skull is influenced by Genetic and racial/ ethnic characteristics, Environmental factors are and the growth of the brain, the size of which beyond and certain minimal dimensions is not related to intelligence.^[4,6,11]

The first effective attempt of measuring the volume with the aid of water poured into a rubber balloon, which was lowered into the cranial cavity through the foramen magnum was made by Poll (1896).^[12] Later several authors tried measuring cranial volume by different methods. MacDonell WR (1904) determined the volume using very hard, dry mustard seed and placing them in the foramen magnum through a tin funnel.^[13] Lee and Pearson (1901) used external measurements of the skulls to calculate the cranial volume which has an added advantage as it can be used in case of living persons, as well as where skulls have been slightly

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broken or damaged.^[14] The cranial volume of skulls belonging to different races has been determined by various authors.^[10,15]

The present study was thus designed to determine the cranial volume by two different methods and correlating them with each other. This data can be used as a diagnostic tool in various cranial diseases as well as serving as a useful tool in medico-legal and anthropological case scenario in Indian population.

MATERIALS AND METHODS

Experimental design:

The present study was conducted on 100 dried human skulls (50 male and 50 female). of Indian origin, in the Department of Anatomy, S.N. Medical college, Agra.

Materials used

100 human dried skulls (50 male and 50 female), sliding calliper, blunt end spreading calliper, flexible clay material, two large beakers, water, one litre graduated cylinder – 1, two litre graduated cylinder – 1, ten ml. graduated cylinder -2 and funnel.

Exclusion criterion:

Dry human skulls showing gross deformity, asymmetry or partially broken skulls were excluded from the present study.

Ethical approval:

All procedures performed in the study involving dry human skull were in accordance with the ethical standards of the institutional research committee. The study was approved by Bioethics committee of S.N. Medical College, Agra, India.

Methodology:

All the measurements were taken with the help of sliding caliper and blunt end spreading caliper and the readings were recorded three times and the mean taken for further computation. For collecting measurements, the two arms of the instrument were held by two ends in such a manner that the curved portions remain in between middle finger and the thumb.

Measurements:

Various measurements taken were:

1. Measuring cranial volume of dry skulls

Cranial volume has been measured by two methods:

- A. **Linear measurements:** Cranial volume is calculated by using three principal dimensions of the cranium: 1) Maximum cranial length (L); 2)

Maximum cranial breadth (B); 3) Maximum cranial height (H). The following formula derived by Lee-Pearson was taken for computation of cranial volume: Males: $359.34 + 0.000365 \times L \times B \times H$ in cc . Females : $296.40 + 0.000375 \times L \times B \times H$ in cc

- B. **Packing/Filling methods:** Another method which was used for determining the cranial volume of the skull was to pack the interior of the skull with water and then measure it. In this method all the foramina and sutures of the skull were plugged with the help of clay material except the foramen magnum. We then took two large ten litre beakers with one being empty and other filled three fourth with water. After plugging all the foramina and sutures of the skull except the foramen magnum with clay material the skull was turned upside down with base of the skull and hence foramen magnum facing upwards and it was immersed in the filled beaker totally until all the intra cranial space was filled with water. The skull was then taken out in the same way as it was immersed with the base of the skull facing upward and then turned upside down again to pour all the water inside the cranial cavity into an empty beaker which was also of the same size as to accommodate the skull inside it. Next the volume of water now inside the previously empty beaker is calculated with the help of various different size graduated cylinder (ten ml to two litres).

2. **Maximum cranial length:** Measured from glabella (space between two superciliary ridges) to inion (most projecting point of the occipital bone on the base of skull).

3. **Maximum cranial breadth:** measured between two most lateral points on parietal bones.

4. **Maximum cranial height:** measured between basion (midpoint of the anterior margin of the rim of foramen magnum) and bregma (junction of coronal and sagittal sutures).

Statistical analysis:

Results were expressed as mean \pm SD and analyzed using the Statistical Package for Social Sciences (SPSS), 15th version. A comparison of the mean values and proportions between sexes was performed using the t-test and Z-test respectively.

RESULTS

The results of the present study are summarized in the tables below:

Table 1: Showing values of cranial volume by formula method and filling method

		S.S.*	Min.	Max.	Sum	Mean	S.D.**
Cranial volume (formula method)	Males	50	1192	1709	72522	1450.44	114.46
	Females	50	1144	1450	65847	1316.9	83
	Total	100	1144	1709	138369	1383.69	120.24
Cranial volume (water filling method)	Males	50	1108	1707	69077	1381.54	131.56
	Females	50	1108	1481	64241	1284.8	90.5
	Total	100	1108	1707	133318	1333.18	122.87

Cranial volume classification (El-Naijar classification):

- 1) **Microcephalic skulls:** Skulls with cranial volume less than 1350cc. commonly found in native Australians and Andaman islanders.
- 2) **Mesocephalic skulls:** Skulls with cranial volume in the range of 1350 to 1450cc. commonly found in African Negroes and Chinese.
- 3) **Megacephalic skulls:** Skulls with cranial volume more than 1450cc. commonly found in Europeans, Japanese and Eskimos.

According to the above classification our Table 01 shows that the mean cranial volume of male skulls came under Megacephalic group and that of female skulls came under Microcephalic group though the combined mean cranial volume came under Mesocephalic group.

Cranial Volume by Linear dimension /Anthropometric measurements method: In the present study, we calculated the intra cranial volume by using Lee Pearsons formula in all 50 male and 50 female skulls.

Lee Pearson formula:

For males: $359.34 + 0.000365 \times (L) \times (B) \times (H)$

For females: $296.40 + 0.000375 \times (L) \times (B) \times (H)$

The mean and S.D. cranial volume in male, female and combined skulls came out to be 1450.44 + 114.46 cc (Range: 1192 to 1709cc); 1316.9 + 83cc (Range: 1144 to 1450 cc); 1383.69 + 120.24cc

(Range: 1144 to 1709cc) respectively as shown in [Table 1].

The mean value of all the skulls (1383.69) came under Mesocephalic skull variety with following percentage distribution in male and female skulls:

Types	Male (n=50)	Female(n=50)
Microcephalic	16%	62%
Mesocephalic	34%	36%
Megacephalic	50%	02%

Cranial Volume by Packing/ Filling methods: In the present study, we calculated the intra cranial volume by using Filling water method in all 50 male and 50 female skulls.

The mean and S.D. cranial volume in male, female and combined skulls came out to be 1381.54 + 131.56 cc (Range: 1108 to 1707cc); 1284.8 +90.5cc (Range: 1108 to 1481 cc); 1333.18 + 122.87cc (Range: 1108 to 1707cc) respectively as shown in [Table 1].

The mean value of all the skulls (1333.18) came under Microcephalic skull variety with following percentage distribution in male and female skulls:

Types	Male(n=50)	Female (n=50)
Microcephalic	44%	78%
Mesocephalic	32%	20%
Megacephalic	24%	02%

Correlation of Parameters with Each Other

Table 2: Showing Correlation between two different methods of cranial volume determination in male, female and total skulls (measured in c.c.)

	S.S.*	Min.	Max.	Sum	Mean	S.D.**	r***	'p' value	Significance
Males	50	1192	1709	72522	1450.44	114.46	0.7655	<0.0001	Extremely Significant
C.V.(F)									
C.V.(W)	50	1108	1707	69077	1381.54	131.56			
Females	50	1144	1450	65847	1316.9	83	0.68	<0.0001	Extremely significant
C.V.(F)									
C.V.(W)	50	1108	1481	64241	1284.8	90.5			
Total	100	1144	1709	138369	1383.69	120.24	0.782	<0.0001	Extremely significant
C.V.(F)									
C.V.(W)	100	1108	1707	133318	1333.18	122.87			

*S.S.=Sample size ; **S.D.=Standard deviation ; ***r = correlation coefficient

The [Table 2] shows that the above two parameters correlated well with each other and there correlation is statistically proven to be extremely significant (p<0.0001) in male, female and total skull sample.

Therefore, a regression equation is calculated between these two parameters:

In males as $Y = 105.36 + 0.8798 \times$

In females as $Y = 308.60 + 0.741 \times$

And in total skulls as $Y = 227.75 + 0.7989 \times$

Where 'y' denotes cranial volume by filling method which here is the dependent variable on 'x' which denotes cranial volume by formula method which thereby is the independent variable.

- Both the methods of cranial volume determination i.e. anthropological and water filling method correlated extremely well [Table 2], thereby showing that the values by both the methods are very close to each other.

DISCUSSION

Cranial volume by formula method:

Lee Pearson formula method for determining skull volume has been used number of times in the past. Frazer J. Earnest estimated adult cranial volume using Lee Pearson formula and concluded that it varies from 1000 to 1800 cc with an average of about 1400 cc which is quite in accordance with the values of present study (1383.69 + 120.24cc).^[16] Akobus DJ Tarigan In his study of cephalometry of 57 students of medical faculty, consisting of 17 Karo Students, 27 Toba Students and 13 Mandailing students. After applying Lee-Pearson, the average cranium volume of Karo, Toba and Mandailing ethnics was 1328.3290 cc; 1344.8925 cc and 1358.0596 cc respectively which were quite similar to present study findings (1383.69 + 120.24cc).^[17]

Cranial volume was estimated in 50 dissecting room cadavers (33 males; 17 females) using linear dimensions of the head (using Lee-Pearson's formula) measured with spreading caliper by Manjunath KY. The estimated mean cranial volume was 1152.813±279.16 cc (mean ± standard deviation) in Males: 1117.82 ± 99.09 cc (mean ± standard deviation), in Females as compared to the findings of present study (1383.69 + 120.24cc).^[5]

Golalipour et al estimated cranial volume in 808 normal 17-20 years old (male 398, female 410) in Turkman and native Fars groups in South- East of Caspian Sea border (North of Iran). By using linear dimensions of the head mean and SD of cranial volume in Turkman males and females were 1420.6±85 ml and 1227.2±120 ml, respectively using Lee Pearson formula. The mean and SD of cranial volume in native Fars male and females were 1369±142ml, 1215.8±125ml, respectively, this difference was significant (P<0.05). These findings were quite similar to our present study findings (1383.69 + 120.24cc).^[8]

Gohiya et al. estimated cranial volume of 400 healthy 20-25 year old (200 male and 200 female) individuals of Madhya Pradesh state of India, by using linear dimensions of head (Lee Pearson's formula). The mean cranial volume and SD in males & females were 1380.52± 94.63 cc and 1188.75± 91.16 cc respectively. These findings were quite similar to our present study findings (1383.69 + 120.24cc) 18.^[18]

Acer N et al estimated cranial volume in 366 (226 male and 140 female) healthy university students aged between 17-26 years old at Mugla University, Mugla, Turkey. By calculating linear dimensions of

the head and using Lee Pearson formula the mean cranial volume and SD in males and females were 1411.64±118.9 cm³ and 1306.95±162.9 cm³, respectively, which was quite similar to the findings of present study (1383.69 + 120.24cc).^[9]

Cranial volume by filling method:

Previously also filling or packing method for determining skull volume has been used various number of times. According to a study conducted at S.M.S. Medical College, Jaipur on 150 adult skulls the average cranial volume value in the skulls were 1296.6 ± 13.88 cc which were quite in accordance with present study(1333.18 + 122.87cc). Out of 80 skulls measured for cranial volume 72.8% belong to the microcranial group, 17.3% to the mesocranial group and 9.9% belong to megacrannial group.^[2]

In a study of 266 male adult skulls of Kanpur showed endocranial volume varied from 1200-1475cc with a mean of 1371.0 cc, in which 50% of skulls were microcranial, 48.9% were mesocranial and only 1.1% was megacrannial.^[7] In a study on cranial cavity volume estimation on 100 cadavers at autopsy Davis PJM and Wright EA observed that the average cranial volume value in the skulls were 1366.6 ± 138.88 cc which were quite in accordance with present study(1333.18 + 122.87cc).^[19]

Another study to calculate intracranial volume (ICV) in 28 dry skulls using filling water method found the estimated mean ICV was 1,311 +/- 133 cm These findings were quite similar to our present study findings (1333.18 + 122.87cc).^[3]

Table 3: Cranial volume of human skulls by different authors of different regions of world

Year	Author	Region	Range	Mean
1926	Morant	English and Scottish Neolithic series	-	1533.00 cc
1946	Hooton	Modern Australian skulls	-	1294.00 cc
1946	Frazer J. Earnest	-	1000-1800 cc	1400 cc
1962	Chaturvedi, Harneja	Jaipur (India)	-	1296.6±13.88 cc
1966	Shukla	Kanpur (India) male skulls	1200-1457 cc	1371.00 cc
1977	Davis and Wright	-	-	1366.6±138.88 cc
1984	Routal	Surat (Gujarat, India)	950-1520 cc	1215±125.3 cc
1986	Ricklan	Zulu skulls (South Africa) Male Female	-	1373.3±107.4 cc 1251±101.1 cc
1995	Hwang	Korean skulls Male Female	-	1470±107 cc 1317±117 cc
2001	Akobus DJ Tarigan	Karo ethnic Toba ethnic Mandailing ethnic	-	1328.33 cc 1344.89 cc 1358 cc
2002	Manjunath KY	South India	Males Females	1152.8±279.16 cc 1117.8±99.09 cc
2005	Golalipour, Jahanshaei, Haidari	Iran	Males Females	1420.6±85 cc 1227.2±120 cc
2006	Acer, Sahin, Ekinci, Ergur, Basaloglu	-	-	1311±133 cc
2007	Acer, Usanmaz, Tugay and Erteki	Turkey	Males Females	1411.64±118.9 cc 1306.95±162.9 cc
2010	Gohiya, Srivastava	Madhya Pradesh (India)	Males Females	1380.52±94.63 cc 1188.75±91.16 cc
Present study	Khandelwal A., Rani P., Kulshreshtha V.	India	Males Females	1450.44±114 cc 1316.9±83 cc

CONCLUSION

The findings of the present study demonstrated the mean cranial volume as determined by Lee Pearson's formula in male skulls came under Megacephalic group and that of female skulls came under Microcephalic group though the combined mean cranial volume came under Mesocephalic group. The mean cranial volume as determined by water filling method in male skulls came under Mesocephalic group and that of female skulls came under Microcephalic group though the combined mean cranial volume came under Microcephalic group. Correlation between both the methods of cranial volume determination i.e. formula method and water filling method in male, female and combined skulls was found to be extremely significant.

Cranial measurements constitute one of the most reliable parameters for racial discrimination.^[4,20,21] To meet the objective of conclusions regarding racial and gender diversity, a number of metric and non-metric methods are used. Non-metric methods are usually not reliable owing to subjective variations while metric methods such as cranial dimensions are more reliable as they provide with actual measurement which can be statistically expressed and analysed. Hence the present study proves beneficial for forensic experts and anthropologists.

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