Original Article

MORPHOMETRIC ANALYSIS OF ENDOCRANIAL CAPACITY

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ABSTRACT

Background: Endocranial capacity is an important parameter in the study of human evolution, race and sex determination of skull. Endocranial capacity is an important parameter in the study of racial differences and in clinical practice for the study of the abnormalities of cranial size, it is one of the most important variable in the study of the human evolution. The objective of present study is to measure endocranial capacity of skulls.
Materials and Methods: 150 dry skulls and 30 CT scan images of living subjects were studied. Endocranial capacity of skulls was measured by modified Breitinger's method and CT scan imaging by planimetry method.
Results: The Mean endocranial capacity of male and female skulls were 1367.3ml and 1255.2ml respectively by modified Breitinger'smethod and by CT scan image planimetry method were 1347.1ml and 1130ml.
Conclusion: Endocranial capacity of male skulls were greater than females. The knowledge of endocranial capacities were help in neurosurgical, anthropology and forensic practice.

KEYWORDS: Skull, Sex; Endocranial capacity; Race.

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INTRODUCTION

Endocranial capacity is widely used as a proxy for actual brain size, one of the most important variable in the study of the human evolution [1], hence it is studied in fossil remains in order to draw the conclusions on the brain size of the early man [2]. Endocranial capacity is an important parameter in the study of racial differences and in clinical practice for the study of the abnormalities of cranial size (indirectly the brain size). Medically, an analysis of cranial capacity exposes another aspect of the growth and development and permits critical evaluation of unusually large, small or misshapen crania [3,4,5,6,7,9]. Cranial capacity of the female is about 11% less than male. Hence it can be used as parameter for sex determination. It can be correlated with other cranial parameters and in the studies of the primate phylogeny [10].

The endocranial capacity is a measure of the volume of the interior of the cranium of those vertebrates who have both a cranium and brain. The endocranial capacity is used as a rough indicator of the brain size (brain volume is about 150- 200cc less than endocranial capacity) and this in turn is used as a rough indicator of the potential intelligence of the organism. However, larger endocranial capacity is not always indicative of a more intelligent organism, since larger capacities are required for controlling a

large body or in some cases an adaptive feature for life in a colder environment [11]. Different authors have used different terms for endocranial capacity such as endocranial volume, cranial volume, skull volume, intracranial volume, cranial capacity and skull capacity. The endocranial capacity of modern man ranges between 1200-1800cc and with an average of 1350 to 1400 cc.17 Average endocranial capacity in female generally 10-11% less than in males, is mostly reflecting large male body mass [11,12]. The endocranial capacity in the first few months of life is on an average 900cc in males and 600cc in females. By the age of 15 years, it reaches upto 1500cc in males and 1300cc in females. By 2 years of age endocranial capacity reaches 77% (1150 cc in ma les and 1000 cc in females), and by 5 years 90% (1350 cc in males, 1200 cc in females) of the endocranial capacity observed at age of 15 years [4].

The changes in endocranial capacity that occurs with age is not linear, but there seems to be a segmental pattern.Three main periods can be distinguished each lasting for approximately 5 years (0-5, 5-10, 10-15 years), during which the growth of endocranial capacity is linear. There is rapid linear growth during first five years of life. In subsequent years, growth continues but at a slower rate, with a mild spurt starting at approximately 10 years and lasting for an additional 5 years. Throughout the childhood, males have higher endocranial capacity than females with a similar growth pattern. At the age of 16-20 years the endocranial capacity reaches its peak and it is thought that endocranial capacity does not changes its size during the rest of the life. The two factors that affect endocranial capacity are Genetic and racial/ ethnic characteristics, Environmental factors[5,7]. The present study main objectives are to measure the endocranial capacity/endocranial volume of the skulls.

Welcker developed a method by modifying the Broca's method, he suggested each new series of measurements should be preceeded by measurement is controlled by the standard skulls. Hrdlicka developed his own method by modifying Welcker's method [13]. Martin used millet seeds to measure the endocranial capacity, he advised some manipulation to fill the cranial cavity completely [14]. Breitinger E. framed definite rules to measure the endocranial capacity, this method was later critically studied and approved by Stewart T.D. , Tildesley and Datta-Majumder. Later this method was used widely by anthropologist [15,16].

In 1948 A.D. Keen made comparison between the cranial capacity results obtained by using higher media, canary seed, lentil seed and mustard seeds. He showed lighter media give larger cranial capacity than heavier media because they are subjected to packing during filling the cranial cavity. This packing is influenced by density of the medium, shape of the particles and friction between the particles [13]. In 1950 Keen standardized the Britinger's technique of cranial capacity determination. According to Keen the Brietinger's technique is a reliable and consistent method of measuring the cranial capacity. He has also discussed the calculation of cranial capacity by using various regression formulae by using linear dimensions of skull. He showed that calculated cranial 20 capacity in general are unreliable when the method is applied to individual crania; but some of the regression formulae can give good results when the mean dimensions of groups of crania were used [17].

A study was carried out on 808 normal 17-20 years old (male 398, female 410) in Turkmen and native for groups in south east of Caspian Sea border, by using linear dimensions of the head cranial capacity was estimated. The mean cranial capacity for Turkmen males was 1420.6±85ml and 1227.2 ±120ml for females. For native for group males mean cranial capacity was 1369±142ml and 12158±125ml. This investigation has shown that the cranial capacity is higher in male than female. The rapid and unprecedented expansion of brain capacity (roughly cranial capacity) in course of evolution of man from one of the apes species is due to the development of language and associated thinking process [9].

A study on Korean adult crania showed mean cranial capacity of 1470±107cc for males and 1317±117cc for females [18]. The measurement of total intracranial volume may be of clinical value. Reported evidence has suggested that the intracranial cavity remains stable even after

brain atrophy. Accurate total intracranial volume measurements may provide reliable indications of pre-morbid brain size in neurodegenerative disease. More over total intracranial volume has been extensively used as the proper correction factor for head size variability during volumetric measurement of cerebral structures [19].

A study conducted on 366 (226 males, 140 females) healthy students aged between 17-26 years old at Mugla University Turkey. In this study cranial capacity of students estimated by using linear dimensions of head. The mean cranial capacity for male was 1411.64±118.9cc and 1306.95±162.9cc for females. The study showed the cranial capacity of male is larger than females [10]. A metrical study of 84 mature male Chinese skulls conducted at University of Edinburgh, which showed mean foramen magnum length for Chinese type I skull of 35.71mm and breadth was 28.24mm, whereas Chinese type 2 crania had mean foramen magnum length of 35.21mm and breadth was 28.00 mm. [20].

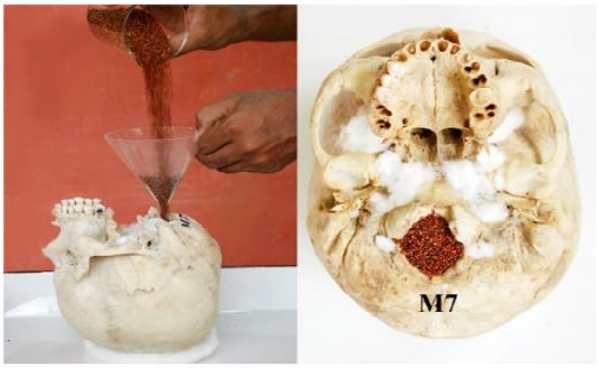
MATERIALS AND METHODS

The present study was done on dry adult human skulls and CT scan images of living subjects. 150 dry adult human skulls (100 male, 50 female) were collected form the Department of Anatomy, and Forensic Medicine, J.J.M. Medical College, Davangere (Fig No 1). Sex of each skull was determined by the classic anatomic features, the age of the skulls was determined by recording the fusion of closure of the sutures.

Fig. 1: Showing the specimens.

Measurement of Endocranial Capacity: The endocranial capacity in dry human adult skulls was measured by modified. Breitinger's method [17] (Fig. No. 2) which is a manual packing method of measuring endocranial capacity. The packing material used was millet seeds obtained from the local provision stores; they were cleaned and dried in sunlight. Size of seeds varied from 1.5-2.5mm in diameter.

Fig. 2: Measurement of endocranial capacity in skulls.



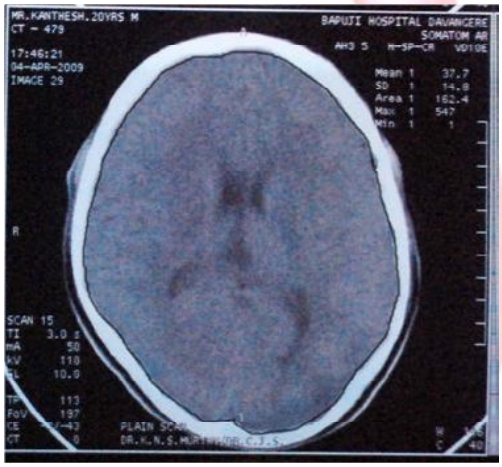
Procedure: First optic canals, supraorbital and infraorbital fissures were plugged with cotton, then all foramina in the base of the skull except the foramen magnum and small foramina less than the size of millet seed were plugged with cotton by using forceps. The skulls were placed on a cotton cushion kept at the centre of tray, with the foramen magnum upwards and its plane parallel to ground. Then funnel spout was inserted into foramen magnum, it was held upright. Millet seeds were poured into skull cavity through foramen magnum via funnel, until seeds reach the rim of the foramen magnum. Then skull was shaken with hands laid flat on it. Using small side to side forearm movements with elbow remaining pressed against the sides of the body. Rate of movements was 4 movements per second. Time of movements was 15 seconds with hands holding the frontal and occipital ends and 15 seconds with hands holding sides of the skull. By these movements seeds packed close to each other and caused lowering of seed level in the skull cavity. Once again the remaining part of cavity was filled by millet seeds and shaken as before. Wooden stick was pushed through the foramen magnum into the mass of the seeds in six different directions, that is to the right obliquely forwards, to the right obliquely side wards, to the right obliquely backwards, then same three actions done on the left side. Then remaining cavity is filled slowly by using small beaker. The final distribution of seeds made by pushing thumb in all directions through the foramen magnum, once again the remaining part of the cavity was filled up to the rim of the foramen magnum (Fig. No. 2), [18].

Seeds were poured from the completely filled skull cavity into an empty tray. The volume of these seeds measured by using measuring jar and its levelling piston.

In CT Scan Images: The computerized tomographic (CT) scan images of 30 living subjects (15 male, 15 female) were taken from the Department of Radio-Diagnosis, J.J.M. Medical College, Davangere. Age of the subjects was between 6 to 85 years. The CT scan images of the subjects with life time history of serious head trauma, neurological illness, medical or surgical illness or drug abuse/alcohol abuse were excluded from the study. All subjects were right handed. All subjects were scanned in supine position, slices were taken parallel to the orbitomeatal line, by a high resolution scanner without contrast media.

Measurement of endocranial capacity: The slices at every 10mm measured for cross sectional area by using planimetry method by using Dicom Works software. Planimetric method is based on Cavaleiri principle. In this method the inner table of the cranium is traced manually to get the cross sectional area of the slice (Fig. No. 3). The endocranial capacity was calculated by sum of the cross-sectional areas of slices multiplied by the slice thickness. Measurements were taken twice and average of two values taken as final measurement [19].

Fig. 3: Measurement of endocranial capacity in ct scan images (Planimetry method).



Statistical methods

Results were expressed as mean ± standard deviation and range. Unpaired't' test was used to compare between males and females. P value of 0.05 or less was considered for statistical significance.

RESULTS

In present study 150 dry human adult skulls (100 male, 50 female) were studied for the endocranial capacity (Table. No. 1). The endocranial capacity of the male skulls varied from 1021.6 – 1706.0 ml with a mean of 1367.3±127.8 ml while in female skulls endocranial capacity varied from 1045.3 – 1515.7 ml with a mean of 1255.2±113.3ml (Graph.No. 1). The endocranial capacity of male skulls was larger than in female. The difference between these two values was highly significant (p <0.001). CT scan images of 30 subjects (15 male, 15 female) with age between 6-85 years were analysed. The endocranial capacity of male subjects was varied between 1202.9 – 1508.3 ml with an average of 1347.1 ± 90.7 ml, whereas in female endocranial capacity was varied between 998.1 – 1349.9 cc with an average of 1130.8 ± 111.9 ml. The mean endocranial capacity of male subjects was significantly larger than in female subjects (Table. No. 1).

Graph 1: Endocranial capacity of Skulls.

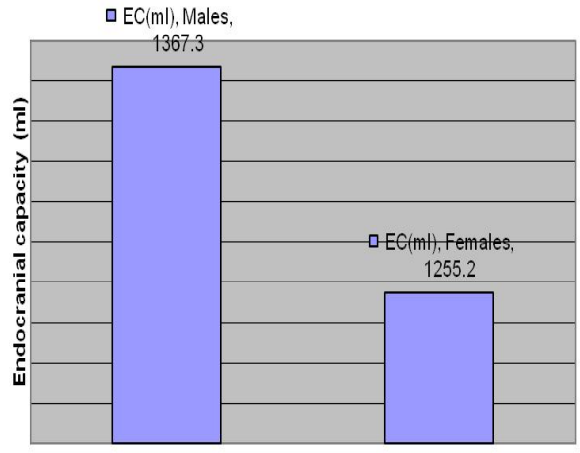


Table 1: Range, mean, standard deviation and "t" values for dimensi0ns of foramen magnum and endocranial capacity.

	PARAMETERS	MALES		FEMALES		MALE v/s FEMALES	
		RANGE	MEAN±SD	RANGE	MEAN+/-SD	t	p
Dry Skull	EC(ml)	1021.6 - 1706.0	1367.3±127.8	1045.3 – 1515.7	1255.2 + 113.3	5.41	<0.001
CT Scan	EC(ml)	1202.9 – 1508.3	1347.1± 90.7	998.1 – 1349.6	1130.8 + 111.9	5.85	<0.001

DISCUSSION

In the present study on dry human skulls, the mean endocranial capacity of male skulls was significantly higher than the female skulls (p=0.001). The mean endocranial capacity (Table No. 2) of the male skulls (1367.3ml) of the present study was similar to the observations made by Keen on skulls of cape colored population (1355.0 cc)[16], Shukla on male skulls of Indian population (Kanpur) (1371.0ml)[4] and by Ricklan on male skulls of Zulu population of South Africa[21]. The mean endocranial capacity was lower than the observations made by Hwang on Korean male skulls (1470.0ml)[18].

Table 2: Endocranial capacity of human skulls by different authors of different regions of world.

Year	Author	Region	Range	Mean
1926	Morant	English and Scottish Neolithic series	-	1533.0 cc
1934	Szombathy	Lower Austria and Moravia	-	1465.0 cc
1935	Lebzelter	Hungary	-	1390.0 cc
1946	Hooton	Modern Australian skulls	-	1294.0 cc
1954	Keen	Cape coloured population male skulls	1000-1750	1355±117.9
1962	Chaturvadi	Jaipur (India)	-	1296.6±138.8
1966	Shukl	Kanpur (India) Male skulls	1200-1457	1371.0 cc
1984	Routal	Surat (India) Gujarat	950-1520	1215±125.3
1986	Ricklan	Zulu skulls (South Africa)		
		Male	-	1373.3±107.4
		Female	-	1251±101.1
1995	Hwang	Korean skulls		
		Male	-	1470±107
		Female	-	1317±117
2009	Present study	Karnataka		
		Male	1021.6-1706.0	1367.3±127.8
		Female	1045.3-1515.7	1255.2±113.3
		Male & Female	1021.6-1706.1	1329.9±133.7

The mean endocranial capacity of the female skulls (1255.2ml) of present study correlated with observations of Ricklan on Zulu skulls (1251.2 ml)[21], whereas it was lower than the observations made by Hwang on Korean skulls (1317.0 ml)[18]. The mean endocranial capacity of present study was higher than the observations made by Keen on skulls of cape coloured population (1194.0 ml)[17]. The mean endocranial capacity of both male and female skulls (1329.5ml) was similar to the observations made by Chaturvadi on skulls of Jaipur (1296.6ml)[3] and by Hooton on modern Australian skulls (1294.0ml)[22]. The mean endocranial capacity of present study was higher than the observations made by Routal on Gujarati skulls (1215.0ml)[23].

Sameul G. Morton (1799-1851 A.D.) an American Physician is one of the first person to systematically measure skulls. In 1830-1840 A.D. he conducted a study on more than 1000 skulls from different parts of the world, in which he studied endocranial capacity and he concluded that skulls of different races will have different endocranial capacity and all races are not having one ancestor. In his book Crania Europe (1839 A.D.) he claims that mean cranial capacity of the skulls of the whites was 87 in3 (1425 cc), while skulls of the blacks was 78 in3 (1278 cc)[20]. In his another study on 144 skulls of native Americans he reported a mean cranial capacity of 82 in3 (1344cc)[24].

Paul Broca (1875 A.D.) studied skulls systematically, he used liquid (water) medium for filling cranial cavity, later he used lead shots. He framed some rules to measure endocranial capacity. He introduced funnel to fill the cranial cavity and to fill measuring jar. His method later became popular by his name [16].

Sir William Turner of Edinburgh developed a method of measuring endocranial capacity by using lead shots. This method became popular in British anthropological schools [16]. During early part of the 20th century, Tiedemann Busk, Flower used small, rounded seeds, beads shots or other similar materials for filling cranial cavity for estimation of endocranial capacity. Mustard seeds were used in Biometric schools of Karl Pearson and in most American laboratories [25].

According to a study conducted at S.M.S. Medical College, Jaipur on 150 adult skulls the endocranial capacity ranged between 1015-1670cc with a mean of 1296.6cc. Out of 80 skulls measured for endocranial capacity 72.8% belong to the microcranial group, 17.3% to the mesocranial group and 9.9% belong to megacranial group [3].

In a study of 266 male adult skulls of Kanpur showed endocranial capacity 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% were megacranial[4]. Stewart in 1954 A.D. measured cranial capacity of 1179 while male skulls and 182 white female

skulls. Their cranial capacity ranged between 1099-1782 cc and 1070-1749 cc respectively [26].

A study on 50 male and 50 female skulls of Zulu showed a mean endocranial capacity for male was 1373.3±107.4 ml and 1251.2±101.1 ml for females. The index of sexual dimorphism was 8.9% which is low when compared to other negroid population [21].

According to the study on Western Australian aboriginal crania, male endocranial capacity was 1239±92.3 cc, while female skulls had 1118±77.5 cc. 22 The sexual dimorphism was 9.7% which is slightly lower than previous published data on Australian skulls [27].

In a study of the patterns of cranial capacity evolution in Homo erectus, early Homo Sapiens and in regional subsamples of Homo erectus, it is showed an nonparametric test for trend suggested cranial capacity in both Homo erectus and early Homo sapiens may increase significantly through time. Cranial capacity in an Asian subsample of Homo erectus (comprised of Chinese and Indonesian specimens) increases significantly through time. Other sub-samples of Homo erectus (African, Chinese and Indonesian) do not appear to increase significantly through time [27]. In a study of estimation of cranial volume in dissecting room cadavers, mean cranial volume for males was 1152.813±279.16 cc and for females it was 1117.82±99.09 cc [6]. In the present study on CT scan images male subjects showed a significantly higher endocranial capacity than females.

CONCLUSION

The mean endocranial capacity of male skulls was higher than females. Endocranial capacity is widely used as a proxy for actual brain size, is 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.

Conflicts of Interests: **None**

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