

Estimation of Cranial Capacity in 17-26 Years Old University Students

Estimación de la Capacidad Craneana en Estudiantes Universitarios entre 17 y 26 Años de Edad

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SUMMARY: It is natural that there is close relationship between cranial capacity, and the size of brain. Several studies have estimated the cranial capacity which indirectly reflects the brain volume. This study was carried out on 366 (226 male and 140 female) healthy university students aged between 17-26 years old at Mugla University, Mugla, Turkey. By using linear dimensions of the head the mean cranial capacity and SD in males and females were $1411.64 \pm 118.9 \text{ cm}^3$ and $1306.95 \pm 162.9 \text{ cm}^3$, respectively. There was a significant difference between genders ($p < 0.05$). This investigation was showed the cranial capacity is larger in males than females. We also proposed a regression formula that could be used to predict the cranial capacity.

KEY WORDS: Craniometry; Cranial capacity; Regresion formula.

INTRODUCTION

A number of accurate methods for determining the cranial capacity (CC) of the macerated skulls are available (Haack & Meihoff, 1971; Hwang *et al.*, 1995; Manjunath, 2002a,b; Golalipour *et al.*, 2005;). Some of the investigators have estimated the CC in the past which indirectly reflects the brain volume (Gault *et al.*, 1988; Wolf *et al.*, 2003; Mazonakis *et al.*, 2004). One of the most satisfactory method for measuring CC of a dry skull is measuring the amount of water poured into a balloon which introduced into the cranial cavity through the foramen magnum (Manjunath, 2002a; Acer *et al.*, 2006). Most of those available studies have been made on dry skulls using linear dimensions, packing methods or occasionally radiological methods. It is also an indirect approach to evaluate the size of the brain (Mac Kinnon, 1995; Dekaban, 1977; Manjunath, 2002a; Mazonakis *et al.*).

CC, which is in close correlation with brain volume, reflects racial characteristics and thus has been thought to be one of the commonest items in physical anthropological studies (Hwang *et al.*; Manjunath, 2002b;). A few studies have been made on living subjects (Golalipour *et al.*). This information is useful in correlating cranial capacity with other cranial measurements and in studies of primate phylogeny.

Medically, an analysis of cranial capacity exposes another aspect of growth and development and permits critical evaluation of unusually large, small or misshapen (Haack & Meihoff).

An attempt has been made in the present study to estimate the cranial capacity of living subjects using the linear dimensions of the heads in 17-26 years old healthy university students. The purpose of the study was to investigate the relation between the CC and age, body weight, body height, body mass index (BMI) in living subject.

MATERIAL AND METHOD

This study was carried out on 366 healthy 17-26 years old (226 males, 140 females) Mugla University students, at the Mugla University, Mugla, Turkey, between January and March 2006. Body height (cm) and body weight (kg) of the students were measured and BMI (kg/m^2) was calculated. BMI was calculated by dividing the weight in kilograms by the square of height in meters. BMI groups were defined using

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the World Health Organization's (WHO) classification system (Report of a WHO consultation, 2000). At each examination, measurements of height and weight were obtained by trained examiner according to a standardized protocol. Height was measured to the nearest 0.1 cm with an Iowa Height Board, and weight to the nearest 0.1 kg using a balance beam metric scale. Since soft tissue, especially the subcutaneous fat tissue's thickness might effect the measurements we used only the cases with normal BMI values. Descriptive data was given as mean and standard deviation.

In each case the following linear dimensions of the head were measured by craniometry:

- Maximum head length (Glabella-inion length: L).
- Maximum head breadth (measured between parietal eminences: W)
- Auricular height (external acoustic meatus to the highest point of the vertex: H) using an auricular head spanner.

Each measurement was taken to the nearest millimeter at least three times and the average was considered for computation. The CC was calculated using the following formula given by Williams *et al.* (1995) and Manjunath (2002b).

Males : $0.000337(L-11) (W-11) (H-11) +406.01$
 Females: $0.000400(L-11) (W-11) (H-11) +206.60$

The data for each person was recorded in a special form and then analyzed by SPSS 11.0. For comparison of the means of anthropometric measurements Student *t* test ($p>0.05$) was used for sexes.

The interaction between the linear measurements and the BMI were analyzed using Pearson correlation test and a regression formula was proposed for the prediction of CC using the age, body weight, body height and BMI value. A paired Student's *t*-test was applied in order to investigate possible statistical differences among formulae. CC was calculated for both sexes. Thus actually proved to be easy using these formulae for calculate CC.

RESULTS

Means (\pm SD) of head length, head width and auricular height in both sexes are depicted in Table I. The means (\pm SD) of cranial capacity were $1411.64 \pm 118.9 \text{ cm}^3$ (Range: 1137.33-1798.92), and of females: $1306.95 \pm 162.97 \text{ cm}^3$ (Range: 991.59-1930.5) in males, respectively. Male CC was larger than female ($p<0.05$). A positive correlation was found between CC and age, body weight, body height and BMI. Different formulae and *r*, *F*, *p* values were proposed (Table II).

Table I. Showing various parameters on 366 healthy 17-26 years old both sexes, Mugla University students, Turkey.

	N	Minimum	Maximum	Mean	Std. Deviation
Age	366	17	26	19.83	1.96
Body Weight (kg)	366	47	90	65.34	8.88
Body Height (cm)	366	155	193	174.21	8.18
BMI (kg/m ²)	366	18.42	24.82	21.43	1.61
Head length (mm)	366	152	205	182.79	8.02
Head width (mm)	366	136	170	154.62	6.50
Auricular height (mm)	366	107	168	127.94	9.74
WxHxL (cm)	366	2533.35	5275.2	3626.39	451.87
Cranial capacity (cm ³)	366	991.59	1939.50	1371.60	146.37

Table II. Linear curve estimation between cranial capacity (CC) and age, weight, height, body mass index (BMI), on 366 healthy 17-26 years old both sexes, Mugla University students, Turkey.

Parameters	Men				Women				Both sex			
	n	r	F	p	n	r	F	p	n	r	F	p
Age-CC	226	0.127	32.69	<0.000	140	0.151	24.50	0.000	366	0.160	69.14	<0.000
Body Weight-CC	226	0.129	33.11	<0.000	140	0.351	74.79	0.000	366	0.305	160.1	<0.000
Body Height-CC	226	0.074	17.96	<0.000	140	0.391	88.55	0.000	366	0.293	150.6	<0.000
WxHxL-CC	226	1.000	26619	<0.000	140	1.000	23727	0.000	366	0.990	3774	<0.000
BMI-CC	226	0.062	14.82	<0.000	140	0.050	7.25	0.000	366	0.111	45.48	<0.000

Table III. Different formulae (F1:age, F2:weight, F3:height, F4:BMI and F5: WxHxL).

	n	Men		n	Women	
		Mean± SD	Min-Max		Mean± SD	Min-Max
CC*	226	1411.64±118.9	1137-1798	140	1306.95±162.9	991-1939
F1	226	1411.63±42.4	1347-1531	140	1306.94±63.2	1217-1487
F2	226	1411.06±42.6	1320-1534	140	1306.87±96.6	1147-1603
F3	226	1411.03±32.3	1339-1489	140	1306.26±101.8	1116-1629
F4	226	1411.57±29.6	1344-1469	140	1306.94±36.4	1252-1396
F5	226	1411.67±118.8	1134-1797	140	1306.98±162.9	987-1934

*Males : 0.000337(L-11) (W-11) (H-11) +406.01, Females: 0.000400(L-11) (W-11) (H-11) +206.60

The relation between CC and age is expressed in the following regression equation:

CC=999.268+(20.46 x Age) (for male), 563.926+(38.47 x Age) (for female). There was a strong correlation between CC and age (p<0.001, r:0.160) (Fig. 1).

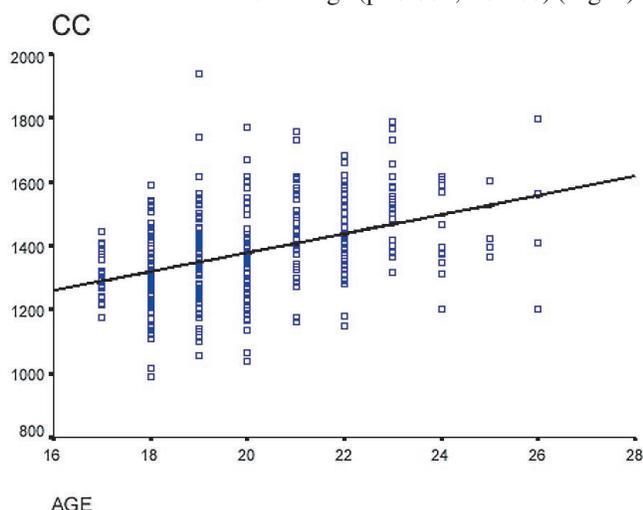


Fig. 1. Scatter plots and regression lines showing the relationship between age and CC in both sexes.

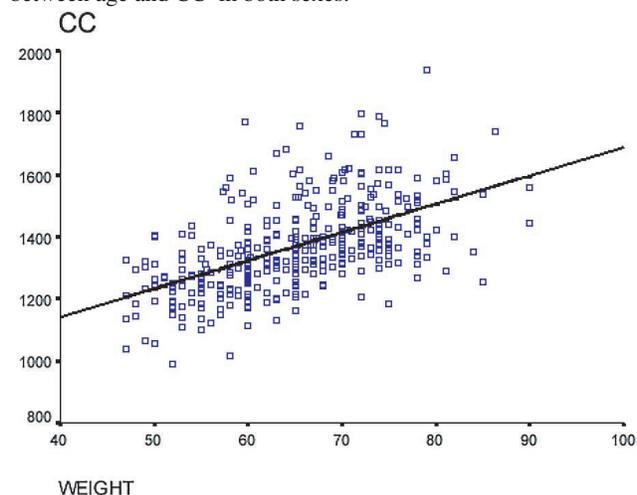


Fig. 2. Scatter plots and regression lines showing the relationship between weight and CC in both sexes.

The relation between CC and body weight is expressed in the following regression equation: CC=984.136+(6.12 x Weight) (for male), 477.362+(14.25 x Weight) (for female). There was a strong correlation between CC and body weight (p<0.001, r:0.305) (Fig. 2).

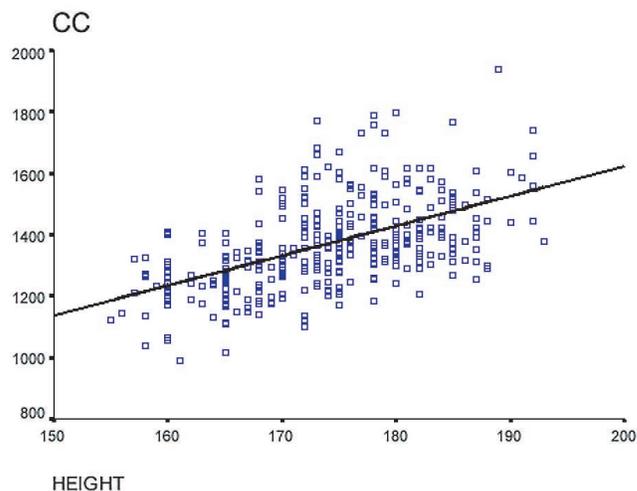


Fig. 3. Scatter plots and regression lines showing the relationship between height and CC in both sexes.

The relation between CC and body height is expressed in the following regression equation:

CC =453.439+ (5.37 x Height) (for male), -1222.6+ (15.09 x Height) (for female). There was a strong correlation between CC and body height (p<0.001, r:0.293) (Fig. 3).

The relation between CC and BMI is expressed in the following regression equation: CC=978.694+ (19.76 x BMI) (for male), 803.856+ (24.33 x BMI)(for female). There was a strong correlation between CC and BMI (p<0.001, r:0.111) (Fig. 4).

The relation between CC and WxHxL is expressed in the following regression equation: CC=320.457+ (0.2929 x WxHxL) (for male), 112.217+ (0.3455 x WxHxL)(for female). There was a strong correlation between CC and WxHxL (p<0.001, r:0.990) (Fig. 5).

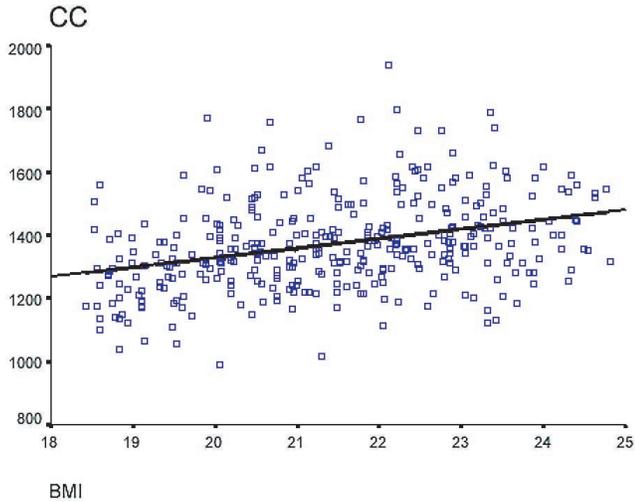


Fig. 4. Scatter plots and regression lines showing the relationship between BMI and CC in both sexes.

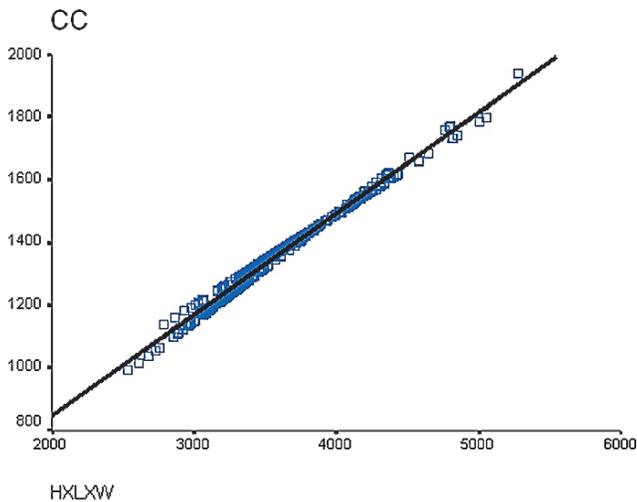


Fig. 5. Scatter plots and regression lines showing the relationship between WxHxL and cranial capacity in both sexes.

The results of CC values were compared statistically. There was no difference between CC values and age, body weight, body height, BMI formulae ($p>0.05$) (Table III).

DISCUSSION

Many of studies showed that the CC accompany increasing age from birth throughout childhood. Most growth is achieved in the first 5 years (Sgouros *et al.*, 1999; Piatt & Arguelles, 1991). At the age of 16-20 the CC reaches its peak size and it is thought that the CC does not change its size during the rest of the life (Knutson *et al.*, 2001; Wolf *et al.*).

Several investigators have estimated the CC in the past which indirectly reflects the brain volume (Gault *et al.*; Mazonakis *et al.*, 2004; Wolf *et al.*). Most of these studies have been made on the dry skulls using linear dimensions, packing methods or occasionally radiological methods (MacKinnon; Dekaban; Manjunath, 2002a; Mazonakis *et al.*).

The CC of skulls belonging to different races has been determined by several authors (Manjunath, 2002a; Hwang *et al.*; Gopalipour *et al.*). Manjunath (2002a) reported the cranial volume was $1152.813 \pm 279.16 \text{ cm}^3$ in males and $1117.82 \pm 99.09 \text{ cm}^3$ in females. According Hwang report's, the cranial volume was $1470 \pm 107 \text{ cm}^3$ in males and $1317 \pm 117 \text{ cm}^3$ in female skull. Gopalipour *et al.* reported cranial capacity of the Turkman was $1420.60 \pm 85 \text{ cm}^3$ in male and $1227.2 \pm 120 \text{ cm}^3$ in females, and in native Fars group in male and female were $1369.4 \pm 142 \text{ cm}^3$ and $1215.8 \pm 125 \text{ cm}^3$, respectively. Also, Dekaban reported cranial volume, 1548 cm^3 in males and 1425 cm^3 in females. In this study, determined average cranial capacity was $1375.67 \pm 91.17 \text{ cm}^3$ in males and $1237.32 \pm 95.12 \text{ cm}^3$ in females. The findings of this research are higher than Indian skulls and lower than Korean, supports the observation of Gopalipour *et al.*, Turkman group.

Age-related decrease in the weight of adult brains has often been noted in cross-sectional studies. Some investigators have questioned whether such decreases are due to aging, because it is known that the stature of humans, as well as the size of the head and brain, has increased during the last century. The most likely explanation is that the head size of humans, and consequently the intracranial volume, increases with age and that such changes mask the long-term trend that affects the population as a whole (Ho *et al.*, 1980).

Pearl (1905) found that at the young subject, the correlation for the following pairs of characters: brain weight and stature, brain weight and age, brain weight and skull length, brain weight and skull width.

An initial linear regression analysis examined the effect of age and BMI on normalized brain volume to determine whether the effect observed in elderly females could be observed in younger men and women (Gustafson *et al.*, 2004). Ward *et al.* (2005) indicated that to determine whether additional variables may also predict normalized brain volume, a stepwise linear regression analysis was used to examine the effects of age, BMI and gender on normalized brain volume. Ward's results showed that age and BMI together were the best predictors of normalized brain volume. In addition, BMI affects brain volume at a relatively young

age extends prior research on the harmful effects of obesity on the brain. Ward *et al.* also stated that age and BMI were each associated with decreased brain volume in 40-66 years old (54.2 ± 6.6).

Ruben *et al.* (1991) reported age was negatively correlated with brain volume between 18-80 years old 69 subject. Etsuro *et al.* (1997) reported the mean total intracranial volume for the group of normal subjects was 1472 cm^3 ; the mean for the women was 1413 cm^3 , and the mean for the men was 1551 cm^3 . Mazonakis *et al.* stated that the techniques of stereology and planimetry provided a mean intracranial cavity volume (\pm SD) of 1323.0 ± 180.7 and $1329.1 \pm 168.5 \text{ cm}^3$, respectively. Acer *et al.*, stated that the means of the intracranial volume was $1311 \pm 133 \text{ cm}^3$. The means and range

of values are comparable with earlier reports. We also found support for the cranial volume increases the correlations with age, and all effects sustained controlling for height, and weight.

In conclusion an increase of CC resulted in increase of the body height, body weight and BMI. There are satisfactory correlation between age, BMI, WxHxL and CC. Thus actually proved to be easy using these formulae for calculate CC.

It may be perhaps helpful in medico legal and anthropological examination to find the relations between cranial capacity and age, height, body weight, BMI which could also be applied for the dementia, brain atrophy and other neurodegenerative diseases in living subjects.

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RESUMEN: Es natural que exista una relación entre la capacidad craneana y el tamaño del cerebro. Numerosos estudios realizados, han estimado la capacidad craneana con lo cual han determinado indirectamente el volumen del cerebro. El estudio fue realizado en 366 individuos (226 hombres y 140 mujeres), normales, entre 17-26 de edad, pertenecientes a grupos del Mugla Universidad de Mugla, Turquía. Para la estimación de la capacidad craneana se utilizaron las dimensiones lineales de la cabeza. La media y SD de la capacidad craneana en hombres y mujeres, fue de $1411,64 \pm 118,9 \text{ cm}^3$ y $1306,95 \pm 162,9 \text{ cm}^3$, respectivamente. Las diferencias fueron estadísticamente significativas ($p < 0.05$). La investigación demostró que la capacidad craneana es mayor en los hombres que en las mujeres. También propusimos una fórmula de regresión que podría ser usada para predecir la capacidad craneana.

PALABRAS CLAVE: Craneometría; Capacidad craneana; Fórmula de regresión.

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