

Estimation of Cranial Capacity and Growth Indicators in Elementary School Children

Estimación de Capacidad Craneal e Indicadores de Crecimiento en Niños de Educación Primaria

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SUMMARY: Cranial capacity (CC) can be used to estimate the brain volume and is correlated to the growth and development in children. Anthropometry is a useful method to obtain data of estimated cranial capacity and other growth indicators including body weight (BW) and body height (BH). Neuromuscular reflex test (NMRT) is a method to observe children's neuromuscular function. The aim of this study is to elucidate and to understand correlation between estimated CC, BW, BH, body mass index (BMI) and neuromuscular function in elementary school children in East Java, Indonesia age 7-14 years old. The anthropometric study was carried out in 153 boys and 145 girls from 3 elementary schools in East Java age 7-14 years old to measure BH and BW to calculate the BMI by WHO formula. Other data taken including NMRT and maximum head length, maximum head breadth between parietal eminence, and head height from vertex to tragus; last three are to calculate the estimated CC using formula of Manjunath (2002a). Correlations between CC, BW, BH, BMI and NMRT were analyzed with Microsoft Excel. For comparison of cranial capacity means between boys and girls, two-tailed t test was done ($p>0.05$). In boys, a positive correlation was found between the CC and: BMI ($r=0.38$), BW ($r=0.4$), BH ($r=0.3$); whilst no obvious correlation was observed between the CC and NMRT ($r=0.07$). In girls, a positive correlation was found between the CC and: BMI ($r=0.33$), BW ($r=0.45$), BH ($r=0.48$); whilst negative correlation was observed between the CC and NMRT ($r=-0.05$). Results indicate there is a strong linear correlation between CC and BMI, and BW, and BH in both boys and girls. No obvious correlations were found between CC and NMRT in boys and girls.

KEY WORDS: Craniometry; Morphology; Human development.

INTRODUCTION

Estimated cranial capacity can be obtained either from the cadaver or human (Wolf *et al.*, 2003). Several methods to estimate the cranial capacity were reported in previous literatures, including by imaging i.e. magnetic resonance imaging (MRI), computed tomography (CT) scan and by craniometry (Acer *et al.*, 2007). Whilst others reported that the volume of water filled in the balloon inside of a skull is a reliable standard procedure to estimate cranial capacity in the cadaver (Dekaban, 1977; MacKinnon *et al.*, 1955).

Although previous research reported that cranial capacity can be a good indicator for brain volume and intellectual potency, others showed that these are more to correlate to the actual microarchitecture of the brain and cellular and biomolecular functions i.e. integrating neurons, glials, neurotransmitters and the receptors as the synaps

skeleton (Witelson *et al.*, 2006). It has been reported that the physiological ratio between neurons and glials, spatiotemporal expressions of these cells and the synaps skeleton have more impact on determining cognitive and intellectual capacity (Johnson, 1991; Witelson *et al.*).

Limited data are available on the estimated cranial capacity of the school children. Furthermore, reports on its correlation to other growth and development indicators including body mass index (BMI), body weight, body height and to the neuromuscular function are scarce. These data is unquestionably has an important value to understand to detect any pathology on children's head growth and shape, to elucidate the state of children growth and development, to early identify any potential problems and to help deciding the policy to solve these.

MATERIAL AND METHOD

One hundred fifty-three boys and 145 girls age 7-14 years old from Pacar Keling Elementary School, Tenggor Elementary School and Doho Agung Elementary School of 2 different cities, Surabaya and Gresik in East Java, Indonesia were involved in the current research. The ethical clearance to conduct the research is from the Committee of Medical Research Ethics, Faculty of Medicine, Universitas Airlangga, Surabaya, Indonesia (ethical clearance No.055/EC/KEPK/FKUA/2011). The parents and teachers of these students were satisfactorily consented and signed both the form of informed consent and consent of information thus current research to be done.

Age was calculated from child’s birthday. Body weight (kg) was measured using digital balance (Camry, China), and body height (cm) was measured by the anthropometry to calculate the body mass index or BMI (kg/m²) was then calculated and plotted against the World Health Organization (WHO) classification system (Report of a WHO consultation, 2000).

The craniometry was done to obtain the maximum head length (L in mm, glabella-inion length), the maximum head breadth (W in mm, measured between parietal eminences) and the height between the highest point of vertex and the external acoustic meatus (H in mm). These measurements (WxHxL, in cm) were used to calculate the estimation of cranial capacity (CC, in cm³) using the formula of Manjunath (2000a).

The formula is different for boy and girl as noted below:

Boys: $0.000337(L-11)(W-11)(H-11) + 406.01$
 Girls: $0.000400(L-11)(W-11)(H-11) + 206.60$

Neuromuscular reflex test (NMRT) was done by measuring the length of the ruler (cm) that was successfully

stopped by a dominant thumb against the wall in a straight line in front of a standing child. Each measurement was repeated at least three times and the average of two closest results were considered for computation.

All measurements were conducted by well trained examiners according to a standardized protocol. All data were recorded and the interaction between the CC and other variables (BMI, NMRT, Body weight (BW), Body height (BH)) were analyzed by plotting at the XY scatter graphs and regression lines showed using Microsoft Excel 2007 to obtain the degree of correlation between these two variables. Differences between cranial capacity means in boys and girls were analyzed using student t-test (p<0.05).

RESULTS

Various parameters were shown for both sexes at Tables I and II below. Means (± SD) of the cranial capacity of boys is 1248.32±155.19 (range: 884.70-1537.81), and of girls is 1160.72±148.21 (range: 878.22-1593.48). Boys CC was larger significantly to girls (p<0.000).

In boys, a positive correlation was found between the CC and BMI (r=0.38), between CC and body weight (r=0.4), between CC and body height (r=0.3); whilst no obvious correlation was observed between the CC and NMRT (r=0.07). In girls, a positive correlation was found between the CC and BMI (r=0.33), between CC and body weight (r=0.45), between CC and body height (r=0.48); whilst negative correlation was observed between the CC and NMRT (r=-0.05). The XY scatter graphs and regression lines of CC and BMI for boys and for girls, of CC and body weight for boys and for girls, of CC and body height for boys and for girls, of CC and NMRT for boys and for girls were depicted at Figures 1A and B to 4A and B, respectively.

Table I. Various parameters on 153 boys 7-14 years old.

Boys	BMI (kg/m ²)	Body Weight (kg)	Body Height (cm)	NMRT (cm)	W (cm)	L (cm)	H (cm)	Cranial Capacity (cm ³)
Mean	17.03	28.02	127.28	39.92	145.19	166.01	132.14	1255.75
SD	3.70	8.42	8.09	19.93	9.84	7.20	12.37	118.69
Minimum	12.49	15.90	103.80	10.00	116.00	147.00	78.00	884.70
Maximum	34.36	55.10	156.60	83.45	167.00	187.00	172.00	1537.81

Table II. Various parameters on 145 girls 7-14 years old.

Girls	BMI (kg/m ²)	Body Weight (kg)	Body Height (cm)	NMRT (cm)	W (cm)	L (cm)	H (cm)	Cranial Capacity (cm ³)
Mean	16.86	27.44	126.31	41.47	142.50	162.30	130.52	1160.72
SD	3.54	8.83	8.97	16.39	10.41	6.92	11.23	148.21
Minimum	11.90	16.20	106.10	7.00	110.00	143.00	103.00	878.22
Maximum	32.81	65.70	151.30	73.85	161.00	182.00	162.00	1593.48

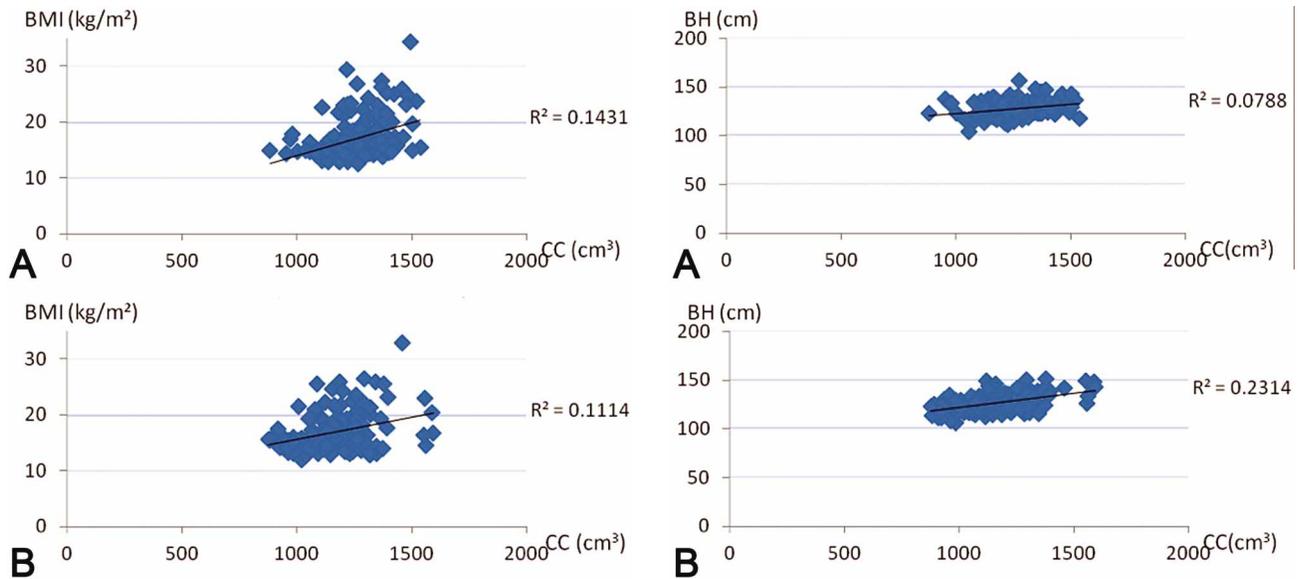


Fig. 1. A) Cranial capacity and BMI in girls, and B) in boys. The XY scatter graphs and regression lines of CC and BMI for boys (r=0.38) and for girls (r=0.33), respectively. Positive correlations were observed between CC and BMI in both boys and girls.

Fig. 3. A) Cranial capacity and height in girls, and B) in boys. The XY scatter graphs and regression lines of CC and body height (TB) for boys (r=0.3), and for girls (r=0.48), respectively. Positive correlations were observed between CC and TB in both boys and girls.

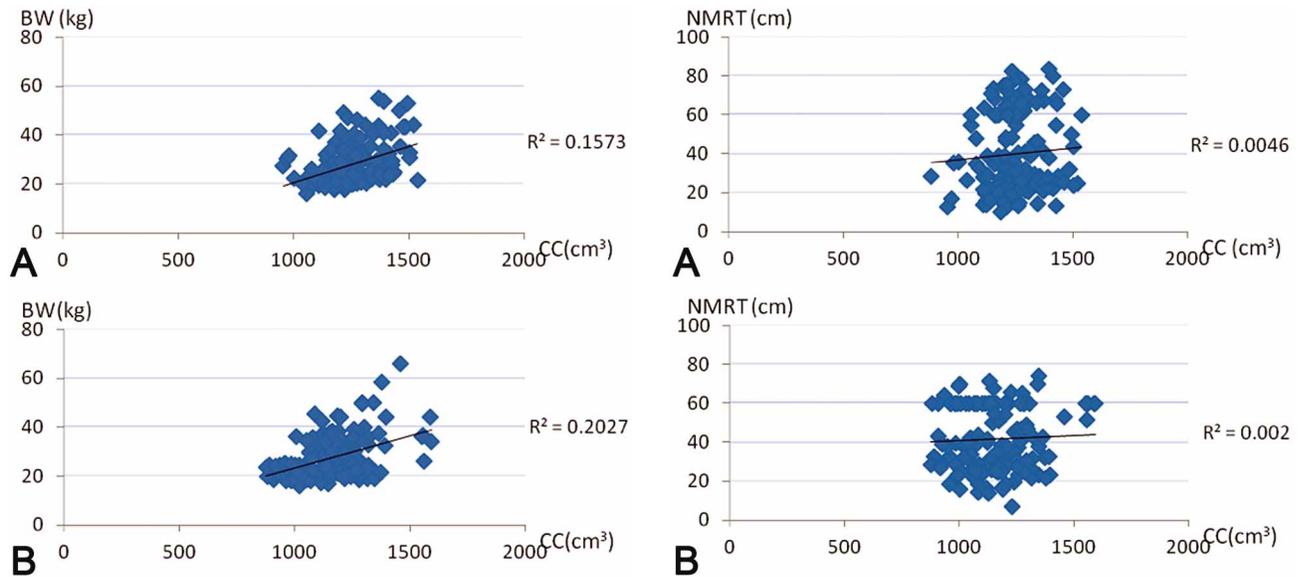


Fig. 2. A) Cranial capacity and body weight in girls, and B) in boys. The XY scatter graphs and regression lines of CC and body weight (BW) for boys (r=0.4), and for girls (r=0.45), respectively. Positive correlations were observed between CC and BW in both boys and girls.

Fig. 4. A) Cranial capacity and NMRT in girls, and B) in boys. The XY scatter graphs and regression lines of CC and NMRT for boys (r=0.07), and for girls (r=-0.05), respectively. No obvious correlations were observed between CC and NMRT in both boys and girls.

DISCUSSION

Cranial capacity of various races and ages have been reported previously. These used measurements whether from cadaver or living human (Acer *et al.*; Manjunath, 2002b; Sgouros *et al.*, 1999; Wolf *et al.*). Several factors may affect the cranial capacity including growth and development and body maturation (Acer *et al.*; Manjunath, 2002b).

Dekaban reported that the cranial volume of 7 days to 29 years old in males is 1548 cm³, whilst in females is 1425 cm³. In the current research, boys cranial capacity mean was significantly larger than girls (1248.32±155.19 cm³, range: 884.70-1537.81 cm³; girls is 1160.72±148.21 cm³, range: 878.22-1593.48 cm³, respectively). These are smaller when compared to previous studies conducted in adults. In Acer *et al.*, study on Turkey's University students, the males cranial capacity mean is 1375.67±91.17 cm³ whilst in females is 1237.32±95.12 cm³. Whilst Hwang *et al.* (1995), reported that the adult Korean's cranial volume mean in male skull is 1470±107 cm³, and in females is 1317±117 cm³.

In boys and girls, cranial capacity is larger as maturation occurred. This is nicely observed in previous study by Sgouros *et al.* The growth of skull is closely correlated to the volume of cranium, especially in children under 5 years old, whereas the relatively stagnant volume is reached at age 16-20 years old (Piatt & Arguelles, 1991; Sgouros *et al.*).

In the current research, cranial capacity is strongly correlated to BMI, body weight and body height, either in boys or in girls. These are similar to what Acer *et al.*, observed in Turkey's University students, although there are differences in race and age.

Cranial capacity is one of the indicators to estimate brain volume (Gault *et al.*, 1988; Wolf *et al.*). It was reported that the BMI is a prominent variable on the brain volume's growth (Ward *et al.*, 2005). However, correlation between brain volume and cranial capacity and BMI in the current study has yet elucidated. Additional methods including brain imaging will be beneficial and is a limitation in the current study. In previous study, brain volume could be estimated by CT scan of the head (Gault *et al.*; Pearl, 1995; Mazonakis *et al.*, 2004).

It was reported that there is a close correlation between the CT scan results with the intellectual levels in human (Witelson *et al.*). However, the potential intelligence might be more determined by the quality of the brain's

component and other factors such as the growth environment. In the current study, the neuromuscular function was tested by doing the NMRT test. Interestingly, weak correlations were observed between the NMRT and the cranial capacity in boys and in girls. It is too premature to conclude that there is no correlation between these two parameters; bigger sample size might change the results. Other factors also may affect these results including fatigue and other stress sources, as this study was done lastly.

From this study, a preliminary data on school children's cranial capacity, NMRT, BMI, body weight and body height were obtained. Although no macroscopic head and body morphology anomaly was found, data from current study are vital for the authority, parents and teachers to grasp the idea on the current general health state of the children and to decide preventive methods of morbidity related to the abnormal growth and development in later life including type 2 diabetes mellitus.

CONCLUSIONS

The larger the cranial capacity of the school children, the bigger the body weight, the body height and thus, the BMI. No obvious correlation between the cranial capacity and the neuromuscular functions was observed, although careful interpretation is called.

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RESUMEN: La capacidad craneal (CC) se puede utilizar para estimar el volumen del cerebro y correlacionarlo con el crecimiento y desarrollo de los niños. La antropometría es un método útil para obtener datos de la capacidad craneal estimada y otros indicadores de crecimiento, incluyendo el peso corporal (PC) y la altura del cuerpo (AC). La prueba del reflejo neuromuscular

(PRNM) es un método para observar la función neuromuscular de los niños. El objetivo de este trabajo fue estudiar la correlación entre CC estimada, PC, AC, índice de masa corporal (IMC) y la función neuromuscular en niños de educación primaria entre 7 y 14 años de edad, en el Este de Java, Indonesia. El estudio antropométrico se realizó en 153 niños y 145 niñas de 3 escuelas primarias de Java Oriental para medir PC, AC y calcular el IMC por la fórmula OMS. Con el objetivo de calcular CC utilizando la fórmula de Manjunath (2002a), se registraron datos incluyendo el PRNM y longitud de la cabeza, el ancho máximo de la cabeza entre las eminencias parietales, como también la altura de la cabeza al vértice al tragus. Las correlaciones entre la CC, PC, AC, IMC y PRNM se analizaron con Microsoft Excel. Para la comparación de la capacidad craneal entre niños y niñas, se realizó la prueba t de dos colas ($p > 0,05$). En los niños encontramos una correlación positiva entre la CC y el IMC ($r = 0,38$), PC ($r = 0,4$), AC ($r = 0,3$); mientras que no se observó ninguna correlación obvia entre la CC y PRNM ($r = 0,07$). En las niñas se observó una correlación positiva entre la CC y el IMC ($r = 0,33$), PC ($r = 0,45$) y AC ($r = 0,48$); mientras que se observó una correlación negativa entre la CC y PRNM ($r = -0,05$). Los resultados indican que hay una fuerte correlación lineal entre CC e IMC, y entre PC y AC en los niños y niñas. No se encontraron correlaciones evidentes entre CC y PRNM en niños y niñas.

PALABRAS CLAVE: Craneometría; Morfología; Desarrollo humano.

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