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Correlation Between Cranial Capacity and Mental Ability among School Children in Kuala Terengganu, Malaysia

[1]*K.B. Swamy,* [1]*Ahmad Zubaidi Bin Abdul Latif,* [1]*Suwaibah Abd Hadi,*
[2]*Azmi Bin Hassan,* [1]*Norizahar bin kadarman,* [1]*Khairi Che Mat,*
[3]*Ponnusamy A\LSubramaniam and* [1]*Husbani bt Mohd Amin Rebuan*

[1]Faculty of Medicine and Health Sciences Universiti Sultan Zainal Abidin (UniSZA) Kota Campus, Jalan Sultan Mahmud 20400, Kuala Trengganu, Trengganu Darul Iman, Malaysia
[2]Centre for Community Development and Quality Of Life Faculty of Medicine and Health Sciences Universiti Sultan Zainal Abidin (UniSZA)Kota Campus, Jalan Sultan Mahmud 20400, Kuala Trengganu, Trengganu Darul Iman, Malaysia
[3]Faculty of Health Sciences. Universiti Kebangsaan Malaysia. Unit of Health Psychology, Faculty ofHealth Sciences, Jalan Raja Muda Abdul Aziz, 50300 Kuala Lumpur, Malaysia

Abstract: Intelligence quotient (IQ) is widely used to assess different aspects of mental ability. Development in mental ability initiates from conception and continues through adulthood. Various environmental factors affect IQ. The aim of this study was to assess the correlation between IQ and environmental characteristics on cranial capacity in children and adolescents in Malaysia. This cross sectional study was performed on primary and secondary school students in Kuala Terengganu, Malaysia. Students, who were aged between 6 to 16 years and did not have any mental or physical disabilities, participated in this study. Measurements including weight, height, body mass index and cephalometry were performed for each subject. The Wechsler Abbreviated Scale of Intelligence-second edition (WASI-II) questionnaire was used for each subject to evaluate the subtests of IQ. A total of 419 subjects with the mean age of 12.51 ± 2.82 years had participated in this study. Boys were taller ($p=0.04$), had higher IQ ($p=0.01$) and cranial capacity ($p<0.001$) as well as block design score ($p=0.02$) when compared with girls. There was a significant mean effect for age ($p=0.03$), gender ($p=0.04$), paternal education ($p=0.04$), family income and block design ($p=0.03$) on cranial capacity. This study revealed different patterns of brain growth, function and IQ amongst male and female subjects as well as defining the environmental factors that can affect cranial capacity and that the IQ and cranial capacity may be improved by tuning up the lifestyles and economic conditions of the families in developing countries.

Key words: Cranial Capacity · Intelligence Quotient · Adolescents · Children · Malaysia

INTRODUCTION

Intelligence quotient (IQ) is related to many longevity factors including life expectancy, fertility, maternal and infant mortality rate, daily intakes of calories, proteins and fats as well as to crime rate including murder, rape and assaults [1-3]. IQ has also been shown to be dependent to both genetic and environmental factors [4-6].

Genetic factors including race and ethnicity are suggested to be important factors in determining the IQ [4, 7]. In studies performed on monozygotic twins, IQ was found to be highly correlated to genetics [4, 8]. Furthermore, comparing the national IQ analyses revealed that the black race have lower IQ scores when compared with the East Asians (mostly Japanese and Chinese populations) and that the Indians and European whites scored in between [7, 9]. It is hypothesised that larger

Corresponding Author: Kaki Swamy, Faculty of Medicine and Health Sciences Universiti Sultan Zainal Abidin (UniSZA) Kota Campus, Jalan Sultan Mahmud 20400, Kuala Trengganu, Trengganu Darul Iman, Malaysia.
Tel: +60109243849; 60166424301, Fax: +609 627 5772.

cranial capacity can be an indicator of larger brain that ndicates more grey and white matter [6]. Therefore a bigger brain with more neuronal connections can lead to a higher IQ score [6]. It was previously shown that children of mixed Japanese and white parents have lower IQ compared with those whose both parents are Japanese while at the same time having higher IQ scores compared with children of pure white parents [7]. This finding is also prominent in the children of Japanese and black mixed parents [7]. Regarding these findings, cranial capacity serves as an important genetic indicator for the IQ and can link ethnicity and race to the IQ of a person [6].

While monozygotic twin studies revealed a high possibility of the effect of genetic background on IQ, the Flynn effect, on the other hand, reflects the importance of environmental characteristics in reaching higher IQ scores [4, 8]. The Flynn effect describes that environmental improvement can lead to increased IQ [8]. This idea was generated based on the findings of the studies in different countries that monitored changes in national IQ scores over time [1, 10, 11]. It is now believed that the Flynn effect is of no effect in the developed countries while it is still effective in determining the IQ score in underdeveloped and developing countries [1]. Although environmental changes have led to increased IQ scores in all nations, a significant difference in IQ and cranial capacity still exists between races which insist on the importance of the role of genetics in IQ.

Malaysia is one amongst the fast developing countries. Majority of the Malaysian population is of Malays while Chinese and Indians also constitute a considerable fraction of the population. Based on the above mentioned facts, it is hypothesised that the Malaysian population might have different IQ scores compared to other East Asian countries. The aim of this study was to assess the relationship between cranial capacity and IQ as well as mental ability in Malaysian students in one of the districts of Malaysia.

MATERIALS AND METHODS

Subjects: This cross sectional study was conducted in Kuala Terengganu on primary and secondary school students. Subjects were selected by stratified-random sampling. A total of 9 primary and 10 secondary schools were randomly selected and 22-24 students were randomly recruited from each school. The inclusion criteria were being registered and studying in the primary or secondary school at the time of the research data collection, being within the age range of 6 to 16 years. Subjects with prominent mental, developmental, physical disorders or any documented diseases or conditions like epilepsy, brain tumours, surgical interventions on the skull or trauma to the skull that might affect the IQ were excluded from the study. A total of 420 subjects were recruited in the study but one was excluded due to a gross congenital anomaly, leaving the final number of 419 subjects.

A written informed consent was obtained from each subject as well as parents or caregivers or school managers.

This study was approved by 1) University Sultan Zainal Abidin, (UniSZA), 2) Human Research Ethics Committee (UHREC) of UniSZA, 3) The Ministry of Education, Putra Jaya, Malaysia and 4) The State Education Department of Terengganu, Malaysia.

Procedure: All subjects were interviewed individually. The measurements for anthropometry and Cephalometry were taken separately for each subject. Demographic data including age, gender, year of study, date of birth, ethnicity, siblings, paternal education and family income were recorded for each subject. General health examination was conducted by expert medical doctors to identify any serious health problems or hidden congenital anomalies.

Measurements: Weight of the subjects was measured using the SECA Digital Weighing Scale to the nearest 0.1 kg. Subjects were weighed barefooted with their regular clothing and emptied pockets. Height was measured for each subject using the SECA 217 Stadiometer to the nearest 0.1 cm. Weight and height measurements were repeated twice and the mean of the measurements were taken for further calculations. BMI was calculated by dividing subject's weight by the square of height in meters.

Cephalometry was performed for each subject in sitting position, in relaxed condition and with the head in the anatomical position based on the method described by Hrdliécka [12]. Vernier calipers, measuring tape, ruler and spring calliper were used for Cephalometry. Measurements were performed to the nearest 1 millimetre in 3 trials. The average of the trials was used for further calculations. Maximum head length (L) was measured as the maximum length between glabella and inion using a sliding calliper. Maximum head breadth (B) was measured as the maximum length between parietal eminences. Head height (H) was measured from the external acoustic meatus to the highest point of vertex using a sliding calliper and an auricular head spanner.

Cephalic index was calculated for each subject using the Lee-Pearson's formula given below [13]. Cranial capacity in cubic centimetres (cc) was calculated based on the following equations proposed by Williams [14] and Manjunath [15].

Males: 0.000337x(L-11)x(B-11)x(H-11)+406.01cc
Females: 0.000400x(L-11)x(B-11)x(H-11)+206.60cc

Instruments: The Wechsler Abbreviated Scale of Intelligence-second edition (WASI-II) was applied by trained personnel to assess the IQ as well as its subsets [16]. This questionnaire provides two types of scores including scaled scores and composite scores. The scaled scores consist of 4 subtests comprising of block design, vocabulary, matrix reasoning and similarities while the composite scores include verbal comprehension index (VCI), perceptual reasoning index (PRI) and full scale IQ (FSIQ) [16]. WASI-II was shown to produce more consistent measurement results as well as reduced testing time compared with the previous forms of intelligent assessment questionnaires [16]. The reliability coefficients of WASI-II were previously reported to be 0.93 for children and 0.96 for adults [17].

Statistical Analysis: Analysis was performed using the statistical package for social sciences (SPSS) version 20.00 (IBM Inc, Chicago, Il, USA). Continuous variables were assessed for normality using the Kolmogrov-Smirnov test. Mean and standard deviation (SD) were used for the data since the data were normally distributed in this study. Frequency and percentage were used to describe categorical variables including gender, ethnicity and parental education and monthly income of the family. Analyses of the main effect of WASI subtests and demographic characteristics of the subjects on cranial capacity was performed using the analysis of covariance (ANCOVA) with cranial capacity as dependent variable and categorical variables with more than 2 categories, including paternal education and family income as fixed factors and the rest of variables as covariates. This analysis was performed in 2 steps: the first step with all the study variables in the model and the 2nd step after adjustment for BMI for age percentile and gender. Significance was considered as p values smaller than 0.05 and the confidence interval was considered as 95%.

RESULTS

A total of 419 subjects (203 males and 216 females) participated in this study. The mean and SD for age was 12.51 ± 2.82 years. Most of the subjects (95.2%) were Malay followed by 4.3% Chinese and 0.5% Indian. Most of the subjects' parents were educated up to primary/secondary education (n=275, 65.6%), followed by graduate/diploma (n=87, 20.8%) and post graduate (n=57, 13.6%). Consumption of breakfast before coming to school was reported by 116 males and 128 females (58.2% of study population). Most of the subjects (106 subjects 25.3%) in this study were from families with monthly income of less than 500 US dollars (USD) followed by 65 subjects (15.5%) with family income of 1500-2300 US dollars (USD), 48 subjects (11.5%) with family income of 830-1300 USD and 40 subjects (9.5%) with family income of 2300-3300 USD while 32 subjects (7.7%) reported their family income to be between 500-830 USD and 24 subjects (5.7%) reported their family income to be higher than 3300 USD. Other characteristics of the study subjects were presented in Table 1.

Males were significantly taller (p=0.04) and had larger cranial capacity (p<0.001) compared with females. Males also had higher PRI (p<0.001), block design (p=0.02) and matrix reasoning (p=0.03) scores as well as SFIQ (p=0.01) (Table 1, Figure 1).

The ANCOVA revealed that there was a significant positive main effect for BMI for age percentile and gender on cranial capacity (p<0.001 each) (Table 2). This indicates that subjects with higher IQ had higher BMI for age and were of male gender. When adjusted for BMI for age percentile, a significant positive main effect was found for age (p=0.04), paternal education (p=0.03), family monthly income (p=0.04) and block design (p=0.03) (Table 2). Indicating that higher cranial capacity was observed in subjects who were older, having parents with higher education level, live in families with higher economic status and were able to achieve higher scores in block design after adjusting data for BMI for age and gender percentile (Table 2, Figure 2).

Table 1: Descriptive statistics of the subjects

	Gender	Mean	SD	P
Age (y)	Male (n=203)	12.45	2.92	0.69
	Female (n=216)	12.56	2.72	
	Total (n=419)	12.51	2.82	
Weight (kg)	Male (n=203)	43.19	16.55	0.17
	Female (n=216)	41.13	13.76	
	Total (n=419)	42.13	15.19	
Height (cm)	Male (n=203)	148.01	17.45	0.04*
	Female (n=216)	144.94	13.15	
	Total (n=419)	146.43	15.45	
BMI (kg/m^2)	Male (n=203)	19.41	4.85	0.77
	Female (n=216)	19.27	4.85	
	Total (n=419)	19.33	4.84	
Cranial capacity (cm^3)	Male (n=203)	1282.72	125.63	<0.001**
	Female (n=216)	1173.25	158.12	
	Total (n=419)	1226.40	153.22	
Cephalic index	Male (n=203)	81.48	10.55	0.05
	Female (n=216)	79.51	10.04	
	Total (n=419)	80.47	10.32	
VCI	Male (n=203)	93.07	24.37	0.16
	Female (n=216)	89.65	14.32	
	Total (n=419)	91.33	24.54	
PRI	Male (n=203)	92.85	14.33	<0.001**
	Female (n=216)	87.18	14.73	
	Total (n=419)	89.96	14.79	
Block design	Male (n=203)	28.93	13.03	0.02*
	Female (n=216)	25.80	13.39	
	Total (n=419)	27.33	13.29	
Vocabulary	Male (n=203)	28.51	17.92	0.14
	Female (n=216)	26.13	15.05	
	Total (n=419)	27.29	16.54	
Matrix reasoning	Male (n=203)	14.60	6.27	0.03*
	Female (n=216)	13.25	6.38	
	Total (n=419)	13.90	6.36	
Similarities	Male (n=203)	20.70	9.85	0.82
	Female (n=216)	20.49	9.55	
	Total (n=419)	20.59	9.69	
Full scale IQ 4	Male (n=203)	182.30	39.20	0.01**
	Female (n=216)	172.21	41.37	
	Total (n=419)	177.14	40.59	

* Significant at α =0.05** Significant at α =0.01 BMI= body mass index

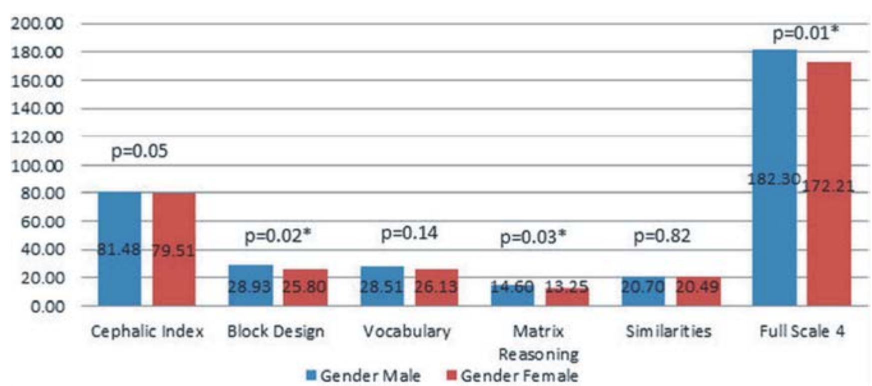

Fig 1: Comparison of cranial index and IQ parameters between genders

Table 2: Analysis of covariance (ANCOVA) results for the main effect of study parameters on cranial capacity before and after adjustment for age and BMI percentile for age.

	Unadjusted				Adjusted for BMI percentile for age			
	F	P	Partial eta square	Observed power	F	P	Partial eta square	Observed power
BMI percentile for age	18. 81	<0.001**	0.10	0.99	-			
Gender	21.83	<0.001**	0.10	0.99	-			
Age (y)	3.90	0.05	0.02	0.50	4.44	0.04*	0.02	0.56
Paternal education	0.94	0. 46	0.02	0.33	2.51	0.03*	0.05	0.78
Family monthly income	0.52	0.76	0.01	0.19	2.40	0.04*	0.05	0.76
Consuming breakfast before school	1.70	0.19	0.01	0.26	1.41	0.24	0.01	0.22
Cephalic index	3.36	0.07	0.02	0.45	2.51	0.11	0.01	0.35
VCI	1.05	0.31	0.01	0.18	0.67	0.41	0.003	0.13
PRI	0.17	0.69	0.001	0.07	0.63	0.43	0.003	0.12
Block design	0.20	0.66	0.001	0.07	4.73	0.03*	0.02	0.58
Vocabulary	0.20	0.66	0.001	0.07	0.72	0.40	0.003	0.14
Matrix reasoning	1.89	0.17	0.01	0.28	0.89	0.35	0.004	0.16
Similarities	0.48	0.49	0.002	0.11	2.35	0.13	0.01	0.33
FSIQ 4	1.21	0.27	0.01	0.19	1.21	0.27	0.01	0.20

Degree of freedom (df)=1 for all variables * Significant at α =0.05** Significant at α=0.01

VCI=verbal comprehension index, PRI=perceptual reasoning index, FSIQ= full scale intelligence quotient

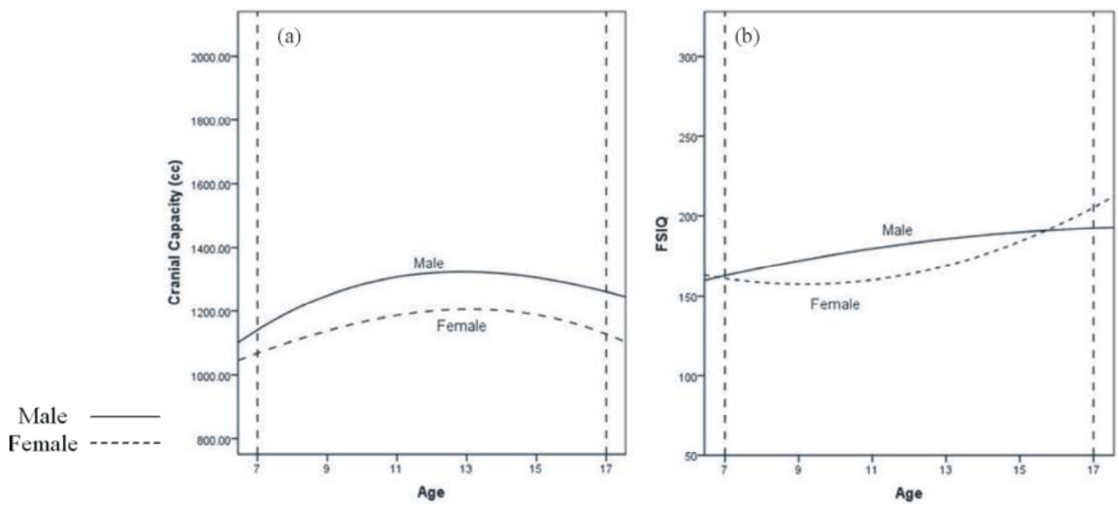

Fig. 2: Changes in cranial capacity and FSIQ as per age FSIQ= Full scale intelligence quotient

DISCUSSION

In this study male subjects had significantly larger cranial capacity when compared with female subjects. This finding is in line with the previous study performed in Malaysia [18]. It was previously shown that the difference in cranial measurements between males and females occurs from the age of 5 years among Malay ethnicity [18]. This study also revealed a significant difference between gender in terms of IQ which is in line with the findings of previous studies [19, 20]. Previously, a study on 633 Malaysians, reported that males have higher IQ compared with females [20]. In this study male subjects were also found to gain higher score in block design which is a subgroup of VCI. In a study by Lynn and Mulhern, [19], males were reported to have better abilities in VCI compared with females. It was previously shown that IQ in both genders remains equal till the age of 15 when the cranial growth peaks in boys and result in a higher IQ in boys till the end of life span [21].

This study revealed a significant main effect for gender and BMI on the cranial capacity. This finding is in line with the previous study findings indicating larger cranial capacity in older children [22-24]. The skull grows in size in line with the longitudinal growth till the age of 20 years [24]. This study revealed that although there is a positive relation between age and cranial capacity, this relation is more prominent in younger subjects (Figure 2).

The trend of increase in the cranial capacity indicates a change in size in male and female subjects who were 9-10 years old (Figure 2). On the other hand, this trend was not observed in FSIQ (Figure 2). FSIQ improved with a lower rate in male subjects compared with female subjects at the age of 9 to 10 years old. This finding might be related to the changes in environmental factors such as nutrition and lifestyle amongst Malaysian children. In a study by Noor *et al*. (2002) the intake of milk and poultry by the Malaysian population was shown to increase dramatically from the year 1995 (18 years before conducting this study) [25]. It was previously shown that environmental factors may have an effect on the brain and skull size in turn on the IQ both in the same individual as well as of the next generation [1, 10, 11]. On the other hand, the effect of environmental factors was shown to be less powerful as that of the genetic and gender related factors [6, 7]. Therefore, the observed difference between the trend of cranial capacity and FSIQ in this study might in part be related to the limited effect of environmental factors on IQ.

This study found a significant main effect for paternal education and family income on cranial capacity. This finding is also in line with the findings of the previous studies which indicate the effect of environmental factors on IQ [1, 10, 11]. Children from a higher educated and wealthier households may have better energy and food intakes which in part result in better growth and development to impart improvements in brain functions [1, 25].

This study revealed no effect for FSIQ on cranial capacity. The relationship between cranial capacity and IQ in children and adolescents varies in age due to the changes in physical and brain maturation. In a study by Giedd *et al.* [26] on magnetic resonance imaging (MRI) analysis of children and adolescents, no direct relationship was found between cranial capacity and IQ. They indicated that the maturation of different brain regions, which might not significantly affect the cranial capacity, may have different effects of the overall IQ scores [26]. Most of these changes start from the age of 10 years in girls and 15 years in boys along with the physical maturation but this trend continues till late adolescents and early adulthood [26]. Lack of relation between cephalic index and cranial capacity in this study might also indicate that there was no significant change in the overall shape of the skull (maxillofacial vs cranial dimensions) which may also include that the maturation of the brain might have not yet been completed amongst the subjects of this study. This study also revealed that the block design was the only compartment of the FSIQ that had a significant effect on cranial capacity. Based on the higher scores of block design in male subjects, this effect might have been more related to the maturation of brain in male subjects. It was previously found that boys have better VCI scores compared with girls and this finding may also indicate the difference in the process of brain maturation in boys and girls [19].

Regardless of its cross sectional design, this study was able to highlight the effect of economic growth on the Cephalometry and IQ measures of growing Malay students that can be evaluated by conducting longitudinal studies. One of the main limitations of this study was the small proportion of non-Malay ethnicity amongst the subjects that prevented the evaluation of the effect of ethnicity on FSIQ among children and adolescents. It is recommended for further researchers to conduct their research on a stratified sample of students of all common ethnicities in Malaysia in order to identify the effect of ethnicity and genetics on IQ.

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