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Study of Cranial Capacity among Igbo Adolescents in Southeastern Nigeria

Ezeokoli Uzo Victory [a] and Ukoha Ukoha [b*]

[a] Dental and Maxillofacial Department, General Hospital, Onitsha, Anambra State, Nigeria.
[b] Department of Anatomy, Faculty of Basic Medical Sciences, Nnamdi Azikiwe University, Nnewi Campus, Anambra State, Nigeria.

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

This work was aimed at comparing cranial capacity and multiple intelligence in Anambra adolescents. Three hundred and eighty three subjects were enlisted in the study, comprising 228 females (59.5%), and 155 males (40.5%), with an age range of 10-19 years. Each subject filled the Russell Rowe Model (2015) of Multiple Intelligence Test for adolescents which examined them on eight different forms of Multiple Intelligence: Verbal/Linguistic, Logical/Mathematical, Bodily/Kinesthetic, Musical/Rhythmic, Visual/Spatial, Interpersonal, Intrapersonal and Naturalist intelligences. Their craniofacial parameters of head length, head with and cranial olume were measured clinically. The Cranial capacity were calculated and documented. Analysis was by SPSS version 20.0. Statistical significance was considered at $p \leq 0.05$. Verbal and intrapersonal intelligence had the highest percentage of study subjects possessing them (82.69%) and this was seen among the older adolescent age group (17-19 years), while the intelligence with the least number of individuals exhibiting them was the music/rhythmic intelligence (53.85%) also seen among the older adolescent age group of the study subjects. Cranial capacity was found to correlate positively with verbal/linguistic, logical/mathematical, interpersonal and intrapersonal intelligence, but not with musical/rhythmic, visual spatial, bodily kinesthetic and naturalistic intelligence. The prediction analysis showed an equal probability of possessing or not possessing any of the multiple intelligences (odd ratio = 1), even as the cranial capacity increased. This means that an adolescent's multiple intelligence may not be extrapolated by merely measuring his/her cranial capacity.

**Corresponding author: E-mail: drukohaukoha@yahoo.com, uzoezeokoli@gmail.com;*

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1. INTRODUCTION

Intelligence has been defined as the mental abilities necessary for adaptation to, as well as shaping and selection of, any environmental context [1]. Intelligence is a general mental capability which involves the ability to reason, think, solve both practical and abstract problems, as well as learn from experience [2]. Following the work of Thurnstone, American psychologist Howard Gardner built off the idea that there are multiple forms of intelligence. He proposed that there is no single intelligence, but rather that distinct, independent multiple intelligences exist, each representing unique skills and talents relevant to a certain category [3]. Gardner proposed the theory of multiple intelligences, which comprises: linguistic (finding the right words to express what one means), logical-mathematical (quantifying things, making hypothesis and proving them), spatial (visualizing the world in 3D), musical-rhythm (discerning sounds - their pitch, tone, rhythm and timbre), bodily-kinesthetic (coordination one's mind with one's body), interpersonal (sensing peoples' feelings and motives), intrapersonal (understanding oneself – what one feels or wants) and naturalistic (concerns with fundamental questions about life and nature). This range of intelligence helps individuals fit into particular career (or a range of careers) based on their multiple intelligence.

There have been discussions on whether the values of craniofacial indices have any relationship with intelligence, and if there are any age differences. Gould [4], while advancing the results of the research of Todd done several decades earlier [5], posited that whites had higher head circumference and cranial capacity, which he said was the reason for the perceived higher intelligence quotient of whites over blacks. This further reaffirmed the unverified assumption that cranial size was related to brain capacity, which was in turn related to intelligence. Rushton [6] and Lynn [7] have advocated that intelligence is genetically inherited, and an individual has higher intelligence quotient (representing largely the verbal/linguistic and logical/mathematical intelligence components of multiple intelligence) than another individual based solely on genetic reasons (not because of cranial size). Kamin [8] suggested that the link between head size and intelligence could be due to nutritional and social class effects (environmental, rather than genetic factors), explaining that proper data analysis only shows that any possible relations between head size and measured intelligence quotient are statistically insignificant.

Cranial capacity is a measure of the volume of the interior of the cranium of those vertebrates who have both a cranium and a brain. Cranial volume is used to approximate the size of the brain, which may also be suggestive of the intelligence of the organism [9]. In the past, several studies have been carried out to estimate the cranial capacity. Most of the studies were made on dry skull using packing methods, linear dimensions or, occasionally, radiological methods [10]. Larger capacities are observed in larger organisms and in colder environments as a feature of adaptability, and not always of superior intelligence [11]. Measured adult values are higher than teenage and school-age values, with reports that the average cranial capacity of females was 10% less than that of males [12]. It is thought that cranial capacity does not change in size during the rest of life [13]. The average cranial capacity of humans was suggested to be 1400 cm^3 (Milner, 1990), but other studies have suggested variations due to various factors such as race, environment, age, gender and hereditary factors [14,15].

2. MATERIALS AND METHODS

Subjects: The study was carried out on randomly-selected adolescents (age 10-19 years) of Anambra state origin. Anambra State is in Southeastern Nigeria and is bounded in the North by Kogi, in the East by Enugu state, in the West by Delta state, and in the South by Abia and Imo states. It comprises majorly of the Igbo tribe. The study was carried out amongst public and private secondary school students randomly selected in each Senatorial Zone of Anambra State (comprising Anambra South, Anambra Central and Anambra North Senatorial Zones).

Instruments and materials used in the research include:

1. **Calipers:** Sliding caliper (manufactured by UNICEF stainless steel Pakistan) for the measurement of cephalic length and breadth and cranial height.
2. Measuring tape (non-stretchable flexible tape which was used for the measurement of head circumference).

3. A structured questionnaire.
4. Hand sanitizer (in compliance with COVID-19 protocols).

Sample size for this research was calculated using the formular as described by Slovin in 1960, called the simplified formula for proportions. It gives the sample size 'n' as $N/1+Ne^2$ where 'N' is the population size, and *'e'* is the acceptable sample error.

The population of Anambra State is 5,527,809, with a 14.3% of adolescents aged 10-19 years (Nigerian Bureau of Statistics, 2017). Given an annual population growth of 2.21% per annum, the expected population in year 2021 was 6,016,467. This gives us an adolescent population size of 860,354.

Applying the Slovin's simplified formula for proportions, a sample size of 399.98 (approximately 400) adolescents was calculated to be used.

2.1 Data Collection

Consent to measure the children was obtained from the parents-teachers association (PTA) through the principal of each school used for the study, while adolescents up to 18 years of age gave consent by themselves.

The data collection instrument included a pre-tested interviewer-administered structured questionnaire with accompanying craniofacial measurements of head length, head width and cranial volume. The questionnaire also elicited information on demographic characteristics of each individual, factoring in the subject's biodata (name, age, sex, state of origin), with an accompanying structured multiple intelligence assessment part.

Each subject was seated comfortably on a chair with his/her head in the correct anatomical position and at the same level as the examiner's head, to rule out errors in measurement. The subject and environment were well-illuminated. Measurements were taken in the same way for each study subject and under the same conditions. All measurements were repeated two times and the mean value of the measurements adopted for further analysis. The measurements were made with a permissible error of 1mm. The measurement was performed in the daytime to eliminate discrepancies in relation to diurnal variation.

Anatomical Landmarks: Landmarks used in measuring the parameters are as shown in Fig. 1 below, and these are:

i. **Glabella (A):** the smooth part of the forehead above and between the eyebrows;
ii. **Nasion (B):** the midpoint of the frontonasal suture;
iii. Euryon (J) is the point that marks the lateral extremity of the skull on the parietal bone bilaterally.
iv. **External Occipital protuberance (S):** The raised area on the midline of the occipital bone where the posterior wall meets the base of the skull;

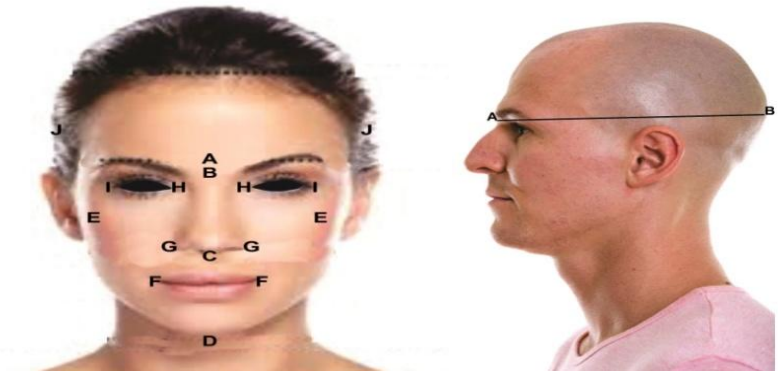

Fig. 1. Anterior and lateral view of the head showing craniofacial landmarks (*original picture from shutterstock.com*)

The Parameters that were measured are:

1. **Head length:** This was measured as the distance from the glabella to the occiput in the midline.
2. **Head width:** This was measured as the distance between the euryon bilaterally. It was measured with the use of a sliding caliper. One end of the sliding caliper was placed on the most prominent lateral part of the parietal bone, while the other end is placed on the contralateral side.
3. **Tragion:** point in the notch just above the tragus of the ear.
4. **Vertex:** the highest point of the head.
5. **Cranial height:** this is the distance between the tragion and vertex. It was measured with a sliding caliper, with one end on the tragus (anterior to the external auditory meatus) and the other end on the most superior point on the head.

The cranial capacity was calculated using the formula by William and Manjunath [16]. The formula is given as:

MALES: 0.000337(L-11)(B-11)(H-11)+406.01
FEMALES: 0.000400(L-11)(B-11)(H-11)+206.60

(Where L is head length, B is head breadth, and H is cranial height, all in millimeters).

The Multiple Intelligence profile of the subjects was evaluated using pre-tested questionnaire modified from the multiple intelligence questionnaire by Russell Rowe (2015). There were 10 statements for each of the multiple intelligence categories, making a total of 80 statements in relation to the eight intelligences proposed. Each student was required to complete the questionnaire by placing Y(YES) or N (NO) to each statement which he/she feels accurately describes him/her or otherwise. Students were scored on each of the Multiple Intelligence categories. A score of 6 or more out of 10 on a given multiple intelligence scale showed an individual's favoured multiple intelligence. Less than 6 would indicate less intelligence in that particular category.

2.2 Data Analysis

The results were presented on excel sheet and analyzed using the statistical data package for social sciences (IBM SPSS Version 20.0). Statistical analysis was with One-way ANOVA, binary logistic regression analysis and independent sample t-test. The one-way ANOVA was to compare age (which had three categories-lower, middle and older adolescents) and the cranial capacity. The binary logistic regression was for prediction analysis of multiple intelligence and cranial capacity. The independent sample t-test was to compare the averages of all the cranial and cephalic parameters between those that possess the different intelligences and those that did not.

3. RESULTS

Three hundred and eighty-three (383) subjects consisting of 228 females (59.5%) and 155 males (40.5%) were studied, as shown in Table I.

Table II shows the average values of cephalic parameters of head length (20.03cm and 19.16 for females and males respectively), head width (15.18cm and 13.61cm for females and males respectively) and cranial height (13.57cm and 12.33 respectively).

Table III shows a comparison of cranial capacity and cephalic index between the two genders. The average cranial capacity for females was 1453.41 cm^3 and 1264.25 cm^3 for males. The cephalic indexes were 76.05 for females and 71.12 for males.

Table IV compares cranial capacity and multiple intelligence. Cranial capacity was found to correlate positively with verbal intelligence, logical/mathematical intelligence, interpersonal intelligence and intrapersonal intelligence. While a negative relationship was observed between cranial and musical/rhythmic intelligence, visual/spatial intelligence, bodily/kinesthetic intelligence and naturalistic intelligence.

Table I. Gender distribution of study subjects

	Frequency	Percent
Female	228	59.5
Male	155	40.5
Total	**383**	**100.0**

Table II. Average cephalic parameters of male and female participants

	Gender	N	Mean	Std. Deviation	P value
Head Length(cm)	Female	228	20.028070	1.8042050	
	Male	154	19.157987	0.8917453	<0.001*
Head Width(cm)	Female	228	15.1790	1.36635	
	Male	154	13.6106	1.32923	< 0.001*
Cranial Height(cm)	Female	228	13.5697	1.05565	
	Male	154	12.3252	1.07540	< 0.001*

Note: Values are considered significant at P ≤ 0.05; Key: POS- Positive; NEG- Negative

Table III. Comparison of craniocephalic indexes between the genders

	Gender	N	Mean	Std. Deviation	P value
Cranial capacity(cm^3)	Female	228	1453.4098	337.31660	
	Male	155	1264.2506	160.50164	<0.001
Cephalic_Index	Female	228	76.0535	6.37919	
	Male	155	71.1238	6.99393	<0.001

Note: Values are considered significant at P ≤0.05; Key: POS- Positive; NEG- Negative

Table IV. Cranial capacity and multiple intelligence

		N	Cranial Capacity	Std. Deviation	P value
Verbal Intelligence	NEG	93	1382.8570	247.01169	
	POS	290	1453.5537	330.38504	0.058
Logical/Mathematical Intelligence	NEG	141	1433.4282	265.32996	
	POS	242	1438.1112	338.73662	0.888
Musical/Rhythmic Intelligence	NEG	143	1462.4078	336.20230	
	POS	240	1420.8832	298.57290	0.210
Visual/Spatial Intelligence	NEG	103	1470.0877	350.57035	
	POS	282	1424.4788	298.87574	0.211
Bodily/Kinesthetic Intelligence	NEG	97	1436.6082	329.47717	
	POS	286	1436.3132	308.38029	0.994
Interpersonal Intelligence	NEG	126	1412.8242	277.39548	
	POS	257	1447.9394	329.46517	0.303
Intrapersonal Intelligence	NEG	83	1406.4703	267.62278	
	POS	300	1444.9365	325.10219	0.326
Naturalistic Intelligence	**NEG**	**74**	**1457.6671**	**388.89651**	
	POS	309	1431.7211	293.70747	0.526

Note: Values are considered significant at P ≤ 0.05; Key: POS- Positive; NEG- Negative

4. DISCUSSION

Cranial capacity is a measure of the volume of the interior of the cranium (skull) of those vertebrates who have both a cranium and a brain. Cranial capacity which is in close correlation with brain volume reflects racial characteristics. This has been thought to be one of the commonest items in physical anthropological studies (Hwang et al., 1995). In the past, several studies have been carried out to estimate the cranial capacity. Most of the studies have been made on dry skull using linear dimensions, packing methods or occasionally, radiological methods. A few studies have been made on living subjects and it exists only in Iranian literature [10,16]. This arouses my interest in studying and estimating the cranial capacity in relation to multiple intelligence of my local population using living subjects.

This study showed that the average range of craniofacial parameters of Anambra adolescents is similar to those reported by other researchers

for adolescents from other parts of the country. The average cranial capacity reported in the present study are 1264.25±160 cm3 (for males) and 1453.41±337.32 cm^3 (for females). The female values are similar to that reported by Ukoha et al. [17] and Ezejindu et al., [9] who reported a mean cranial capacity of 1410±162 cm^3 for males and 1443±154 cm^3 for females, but the male values are significantly lower than that reported by him. The higher values got for females in this study when compared to that of males may be due to age differences in the sample size between females (who have a greater number of older adolescents) when compared to the male subjects. The index of sexual dimorphism becomes more significant after puberty, as people's age increase [18]. The lower male values may be because of the significant age difference in the participants since 83% of the male participants fall into the lower and middle adolescent age group, as against the females that have only about 62% in the lower and middle adolescent age group i.e a good portion of the females are in the older age group. The values in this report are also similar to the study among Iranians by Golalipour [19] which showed mean cranial capacity of 1420±85 cm^3 for males, and 1227±120 cm^3 for females. The report by Manjunath [10] for an Indian population was 1152±279 cm^3 for males and 1117±99 cm^3 for females, and this much lower than what is reported in this research. This shows racial and environmental differences as it relates to cranial capacity.

The cranial capacity of Anambra adolescents were found to have a positive correlation with their verbal intelligence (Table IV) i.e individuals who exhibit verbal intelligence have higher values of cranial capacity (which is known to correlate positively with brain size) (Vernon, 2000). This agrees with earlier studies by Umar [20], Ivanovic [21] and Rushton [6] which compared various cephalic parameters and intelligence quotient and found a positive correlation. Result of the study is in consonance with Haji et al. [22]: He found in his study a significant positive correlation between perceived verbal-linguistic, visual-spatial intelligences and academic achievement of the students. A large percentage of individuals studied exhibit verbal intelligence (over 75% of the study subjects). This may be due to the fact that these are secondary school students actively learning to improve their ability to communicate and express themselves verbally, a core component of western education. A good proportion of the students studied will be found to do well, if properly guided, in careers such as teaching, law, writing and journalism [23].

Cranial capacity showed a positive relationship with Mathematical/Logical intelligence (which is a strong component of IQ tests). This agrees with similar studies of Mukhtar [24] and Lynn [7] who reported consistently low or negative correlation of intelligence with cephalic index. Musical/Rhythmic intelligence shows a negative relationship with craniofacial parameters. This may be because of less emphasis on arts and music as students go higher in the Nigerian school curriculum, with rather higher emphasis on mathematical/logical and verbal intelligence.

Cranial capacity showed a negative correlation with Spatial/Visual intelligence. A good percentage of students (about 74%) exhibit this form of intelligence as it has a lot to do with cognition which is a major component of learning, world over. This means a good part of the student population will likely do well in careers like architecture, engineering and the arts, which are improved by spatial/visual intelligence [3]. Furthermore, this study showed that cranial capacity has a positive relationship with Bodily/Kinesthetic intelligence, negative relationship with most craniofacial parameters measured, a positive correlation with Intrapersonal intelligence and a negative relationship with naturalistic intelligence. Also, the prediction analysis predicting the multiple intelligence possessed by an individual using his/her cranial capacity showed an equal probability of possessing or not possessing either of the multiple intelligences (odd ratio = 1), even as the cranial capacity increases [25].

5. CONCLUSION

This study has been able to establish the normal range of values of craniofacial parameters for adolescents of Anambra State, Southeastern Nigeria. The cranial capacity of which was compared with their multiple intelligence, assessed the relationship between cranial capacity and various variables for determining multiple intelligence.

ETHICAL APPROVAL

Before the start of the research work, ethical approval was sought and obtained from the Ethics Committee of the Faculty of Basic Medical Sciences, Nnamdi Azikiwe University, Nnewi

Campus with serial number NAU/CHS/NC/FBMS/415.

CONSENT

As per international standard, parental written consent has been collected and preserved by the author(s).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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