Original Article

A Cross-sectional Anthropometric Study of Cranial Capacity among Ukwuani People of South Nigeria

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Abstract

Background: **Cranial capacity is used as a measure of brain volume and has a relationship with age and gender. The purpose of this study was to provide normative data and population-, age- and gender-specific regression formulae related to cranial capacity using head dimensions among the Ukwuani people of Nigeria.**

Methods: **This study included 605 subjects grouped according to age as follows: 6–12 years, 13–19 years and ≥20 years. A cross-sectional study design using multistage sampling technique was adopted. Head length, head width, and auricular head height were measured in centimetres using a spreading caliper, and cranial capacity was calculated. The data were analysed using SPSS 20. Descriptive and inferential statistics were applied. A t-test was used to identify significant gender differences. Regression analyses were performed to derive age-, gender- and population-specific models. *P*-values < 0.05 were considered significant.**

Results: **In all the parameters, males had significantly higher values than females (P < 0.05). The mean (SD) cranial capacity values at 6–12 years, 13–19 years and ≥20 years were 1176.95 (98.35) cc, 1288.59 (113.21) cc and 1408.90 (116.44) cc, respectively.**

Conclusions: **All the parameters exhibited sexual dimorphism. Cranial capacity was found to increase with age. The models derived in this work will be relevant to population and growth studies as well as forensic anthropology.**

Keywords: *anthropometry, cephalometry, forensic anthropology, regression analysis, sex*

Introduction

Cranial capacity is the volume of the interior of the cranium of vertebrates that possess a cranium and a brain (1). Cranial volume is used to approximate the size of the brain, which is also suggestive of the intelligence of the organism (1). Larger capacities are observed in larger organisms and in colder environments as a feature of adaptability, but not always of superior intelligence (2).

Various studies estimating cranial capacity have been conducted in different populations in Nigeria (1, 3, 4, 5) and other parts of the globe (6, 7, 8). Different methods of measurement have been used to study cranial capacity in either macerated dry skulls or living subjects. Both direct (7, 9, 10) and indirect (7, 9, 11, 12, 13) methods of estimating cranial capacity have been used.

A sound understanding of cranial capacity is relevant to the study and comparison of populations with racial, geographic, ethnic and dietary differences. This knowledge is also useful for correlating cranial capacity and other cranial measurements and in studies of primate phylogeny (9, 12). It has been posited that analyses of cranial capacity, as an indicator of skull development and growth, are useful in forensic anthropology and paediatrics (9, 12, 14).

Despite the immense significance of cranial capacity, there is a paucity of similar studies regarding the Ukwuani. Therefore, this study was undertaken to provide normative data on cranial capacity; to propose population-, age- and gender-specific regression formulae; and to determine the degree of sexual dimorphism among the Ukwuani people of Southern Nigeria.

Materials and Methods

This was a cross-sectional study conducted between February and September of 2011. The study population comprised all pupils and staff members in public primary and secondary schools within the Ukwuani ethnic nation who belong to the Ukwuani ethnic group. Six hundred and five subjects participated in the study based on a multistage sampling technique. The age range of the subjects was 6 to 58 years. Six primary schools and three secondary schools within the Ukwuani Local Government Area were selected by a systematic sampling technique. Using stratified proportional allocation, subjects in each school were categorised by gender and the following age groups: 6–12 years (school age), 13–19 years (teenagers) and ≥20 years (adults), according to Eboh et al. (15). Finally, a simple random sampling technique was used to select subjects in each age category. The age of each subject was confirmed from the appropriate school register.

The lower age limit of six years was chosen based on the minimum age for first graders in public schools. The retirement age for public school teachers is sixty years (15), hence the upper limit (although no 60-year-old subjects participated). The subjects were apparently healthy and without any craniofacial deformity.

This study used primary data that were collected at the sampled schools. The Research and Ethics Committee of the College of Health Sciences of Delta State University approved the research protocol. After informed consent was obtained from the selected subjects in accordance with the revised Helsinki Declaration (16), measurements of the different parameters were performed. Maximum head length was measured in centimetres as the linear distance between the glabella and the opisthocranion (15) (Figure 1). Maximum head width was measured in centimetres as the maximum biparietal diameter (15) (Figure 2). Maximum auricular head height was measured as the distance between the external acoustic meatus and the highest point of the vertex (bregma) (Figure 3). To ensure the accuracy of auricular head height measurements, the isolated soft ear tip of the stethoscope was fitted snugly to the sharp tip of one arm of the caliper so that it lay just on the outer hollow part of the ear tip. This technique ensured that the tip of the spreading caliper fit properly into the external acoustic meatus without harming it, while the second tip made contact with the vertex of the head (Figure 3). All the measurements were performed using a spreading caliper (15) (Vintage Machinist, USA).

Cranial capacity was calculated based on the following formulae of Lee and Pearson (13): Males: 0.000337(L-11) (B-11) (HT-11) + 406.01; and Females: 0.000400(L-11) (B-11) (HT-11) + 206.60; where L, B and HT are cranial length, cranial width and cranial height, respectively.

Sexual dimorphism in cranial capacity was calculated using the following formula (7,17):

Sexual dimorphism = [(mean cranial capacity in males-mean cranial capacity in females)/mean cranial capacity in males] ×100%

The collected data were analysed using IBM SPSS 20 (Armonk, New York). Both descriptive and inferential statistics were applied. A t-test was used to determine significant differences between males and females in all the age groups. *P*-values < 0.05 were considered statistically significant.

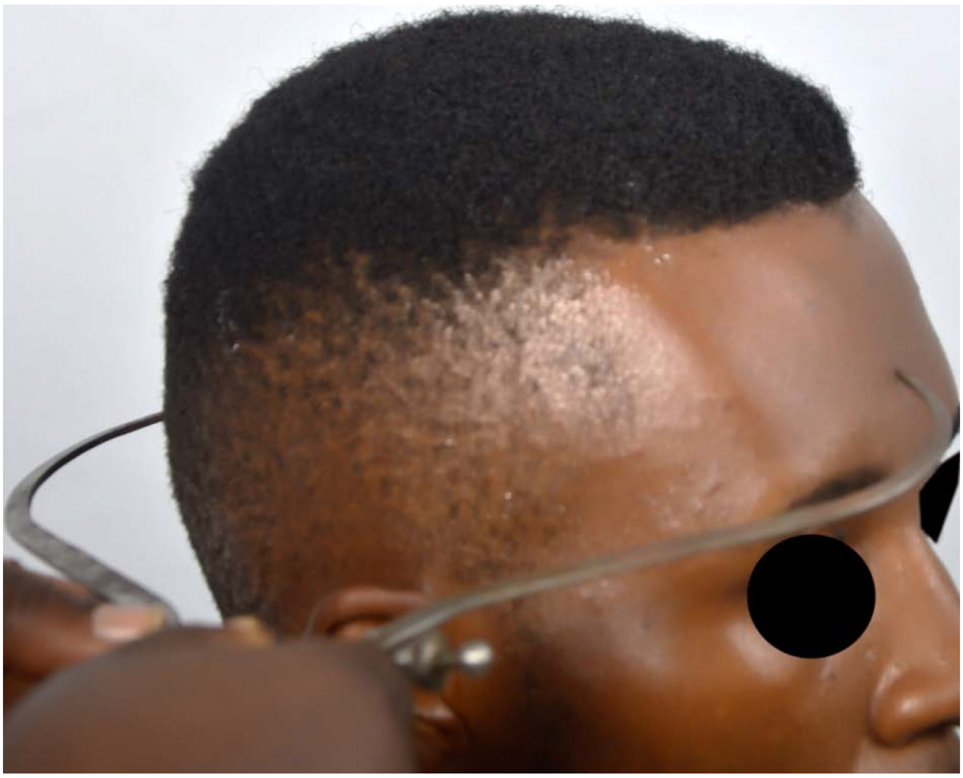

Figure 1: Measurement of head length.

Figure 2: Measurement of head width.

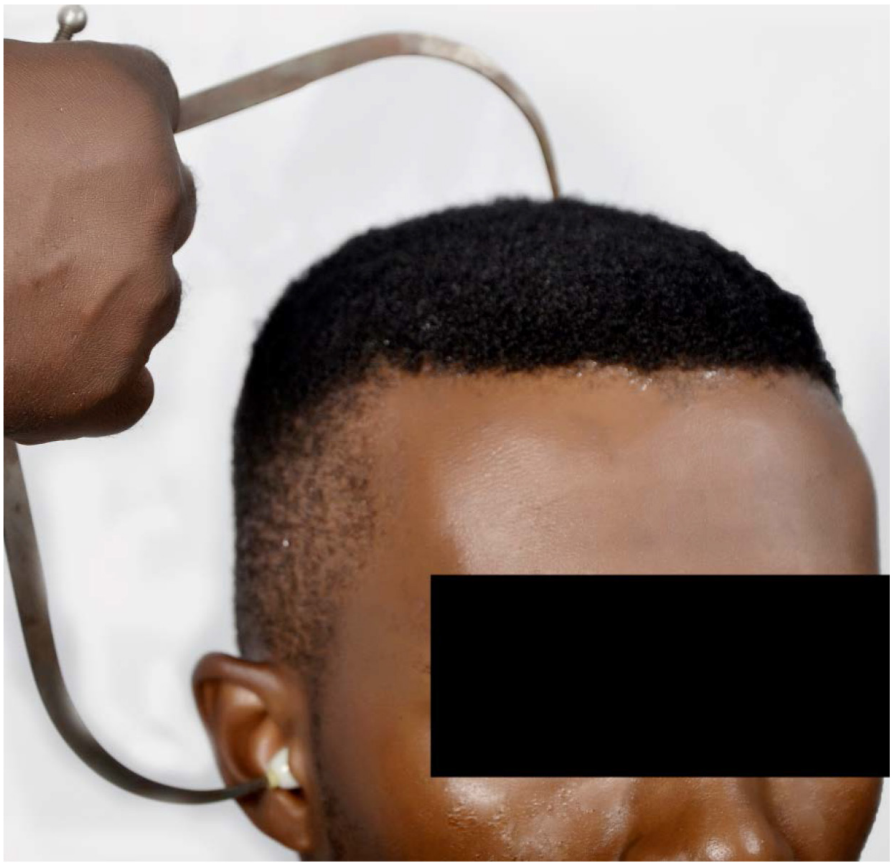

Figure 3: Measurement of auricular head height.

Results

In the present study, the mean (SD) age of subjects in the 6–12 years, 13–19 years and ≥ 20 years age groups were 10.07 (1.66) years, 15.83 (1.75) years and 31.47 (1.76) years, respectively.

Tables 1, 2 and 3 show descriptive statistics and comparisons between genders of cranial length, cranial width, cranial height and cranial capacity in subjects aged 6–12 years, 13–19 years and ≥20 years. In all the studied parameters, the mean values were significantly higher in males than females ($P < 0.05$).

The percentage sexual dimorphism in cranial capacity was 5.18%, 7.50% and 7.65% in the 6–12 years, 13–19 years and ≥20 years age groups, respectively.

Tables 4, 6 and 8 show the results of regression analyses between cranial length and cranial capacity; cranial height and cranial capacity; and cranial width and cranial capacity, respectively. There was a very strong and significant ($P < 0.05$) relationship between each of the measured parameters and cranial capacity. Consequently, regression equations were derived from the data for males, females and combined genders in each age group, as presented in Tables 5, 7 and 9, respectively.

Discussion

It has been posited that over the course of evolution, brain size and cranial space have increased (18). The average cranial capacity of humans was suggested to be 1400 cc (19), but other studies have suggested variations due to various factors (4, 5, 20–22). The present study revealed that the mean cranial capacity of the Ukwuani people varied according to age. Compared with the mean cranial capacity initially claimed for humans, the measured adult values were higher, but the teenage and school-age values were lower. This observed variation may be ascribed to gender, geographic, ancestry,

Table 1. Descriptive statistics and comparison between genders of cranial length, cranial width, cranial height and cranial capacity in 6–12 years subjects

Parameters	Gender	*n*	Min – Max	Mean (SD)	*t*	df	*P*-value
Cranial length (mm)	Male	106	163.00 – 193.00	178.35 (6.02)	4.90	213	0.001*
	Female	109	160.00 – 190.00	174.34 (5.81)			
	Combined	215	160.00 – 193.00	176.35 (6.22)	-	-	-
Cranial width (mm)	Male	106	118.00 – 143.00	131.80 (4.98)	2.17	213	0.031*
	Female	109	118.50 – 140.00	130.32 (4.98)			
	Combined	215	118.00 – 143.00	131.05 (5.03)	-	-	-
Cranial height (mm)	Male	106	124.00 – 149.00	134.65 (5.23)	4.74	213	0.001*
	Female	109	121.50 – 147.00	131.22 (5.39)			
	Combined	215	121.50 – 149.00	132.91 (5.57)	-	-	-
Cranial Capacity (cc)	Male	106	969.51 – 1489.01	1208.69 (96.20)	4.91	213	0.001*
	Female	109	989.7 – 1370.39	1146.09 (90.66)			
	Combined	215	969.51 – 1489.01	1176.95 (98.35)	-	-	-

*Significant at $P < 0.05$

Table 2. Descriptive statistics and comparison between genders of cranial length, cranial width, cranial height and cranial capacity in 13-19 years subjects

Parameters	Gender	*n*	Min – Max	Mean (SD)	*t*	df	*P*-value
Cranial length (mm)	Male	99	170.00 – 203.00	185.74 (7.19)	7.41	213	0.001*
	Female	115	161.50 – 195.00	178.95 (6.21)			
	Combined	214	161.50 – 203.00	182.09 (7.48)	-	-	-
Cranial width (mm)	Male	99	123.50 – 154.00	137.39 (5.54)	3.48	213	0.001*
	Female	115	116.00 – 150.50	134.62 (6.04)			
	Combined	214	118.00 – 143.00	135.90 (5.97)	-	-	-
Cranial height (mm)	Male	99	129.50 – 152.50	139.36 (5.20)	5.68	213	0.001*
	Female	115	123.00 – 152.00	135.47 (4.83)			
	Combined	214	121.50 – 149.00	137.27 (5.36)	-	-	-
Cranial Capacity (cc)	Male	99	1075.07 – 1636.62	1342.71(107.65)	7.23	213	0.001*
	Female	115	958.51 – 1502.95	1242.01 (96.20)			
	Combined	214	958.51 – 1636.62	1288.59 (113.21)	-	-	-

*Significant at $P < 0.05$

age, or genetic factors; even intelligence has been noted to affect cranial capacity in man (23–29).

It was previously reported that the average cranial capacity of females was 10% less than that of males (17). The results of the present study confirm this finding; males had greater cranial capacity in all the age groups considered. This study agrees with previous reports of sexual dimorphism in human cranial capacity (1, 5, 7, 9, 22).

The index of sexual dimorphism in the Ukwuani increased with greater age. During the school age, when growth is rapid, the index of sexual dimorphism was lower than in the teenage category, which was lower than in the adult category. This result is suggestive of poor sex divergence during the active growth period. The index of sexual dimorphism in adult Ukwuani is lower than in similar studies in other populations (7, 10, 22) but higher than in other studies (4, 5). However, the present study is similar to those conducted by Ali et al. (30) and Acer et al. (31). The differences in body form between males and females cannot be overemphasised. This dimorphism emphasises variations among biological populations, hence the varied results

Table 3. Descriptive statistics and comparison between genders of cranial length, cranial width, cranial height and cranial capacity in ≥20 years subjects

Parameters	Gender	*n*	Min–Max	Mean (SD)	*t*	df	*P*-value
Cranial length (mm)	Male	95	176.00 – 204.50	190.44 (5.15)	8.35	174	0.001*
	Female	81	167.00 – 197.00	183.17 (6.40)			
	Combined	176	167.00 – 204.50	187.10 (6.79)	-	-	-
Cranial width (mm)	Male	95	130.00 – 159.50	144.44 (5.02)	5.71	174	0.001*
	Female	81	128.00 – 154.00	140.05 (5.14)			
	Combined	176	128.00 – 159.50	142.42 (5.52)	-	-	-
Cranial height (mm)	Male	95	130.00 – 159.00	141.78 (5.17)	2.92	174	0.004*
	Female	81	125.00 – 155.00	139.23 (6.44)			
	Combined	176	125.00 – 158.00	140.61 (5.91)	-	-	-
Cranial Capacity (cc)	Male	95	1460.31 – 1725.20	1460.31(93)	7.21	174	0.001*
	Female	81	1129.09 – 1664.17	1348.61 (112.60)			
	Combined	176	1129.09 – 1725.20	1408.90 (116.44)	-	-	-

*Significant at $P < 0.05$

Table 4. Linear regression results for cranial length for male, female and combined data in 6-12 years, 13–19 years and ≥20 years subjects

Age group	Data	Constant	Slope	R-square	*P*-value
6-12 years	Male	−1075.16	12.81	0. 64	0.001*
	Female	−856.69	11.48	0.54	0.001*
	Combined	−1032.93	12.53	0.63	0.001*
13-19 years	Male	−867.23	11.90	0.63	0.001*
	Female	−693.46	10.82	0.49	0.001*
	Combined	−915.026	12.10	0.64	0.001*
20 years and above	Male	−545.53	10.53	0.34	0.001*
	Female	−926.83	12.42	0.50	0.001*
	Combined	−963.795	12.68	0.55	0.001*

*Significant at $p < 0.05$

Table 5. Regression equations from cranial length for male, female and combined data in 6-12 years, 13–19 years and ≥20 years subjects

Age	Gender	Regression Equation
6–12 years	Male	[a]CCm = −1075.16 + 12.81 (cranial length)
	Female	[b]CCf = -856.69 + 11.48 (cranial length)
	Combined	[c]CCc = −1032.93 + 12.53 (cranial length)
13–19 years	Male	[a]CCm = −867.23 + 11.90 (cranial length)
	Female	[b]CCf = −693.46 + 10.82 (cranial length)
	Combined	[c]CCc = −915.03 + 12.10 (cranial length)
20 years and above	Male	[a]CCm = −545.53 + 10.53 (cranial length)
	Female	[b]CCf = −926.83 + 12.42 (cranial length)
	Combined	[c]CCc = −963.80 + 12.68 (cranial length)

[a]cranial capacity for male, [b]cranial capacity for females, [c]total cranial capacity.

Table 6. Linear regression results for cranial height for male, female and combined data in 6-12 years, 13–19 years and ≥20 years subjects

Age group	Data	Constant	Slope	R-square	*P*-Value
6–12 years	Male	−906.77	15.71	0.73	0.001*
	Female	−713.35	14.17	0.71	0.001*
	Combined	−846.34	15.22	0.74	0.001*
13–19 years	Male	−844.38	15.69	0.57	0.001*
	Female	−721.21	14.49	0.53	0.001*
	Combined	−978.01	16.51	0.61	0.001*
20 years and above	Male	−621.66	14.68	0.67	0.001*
	Female	−684.32	14.60	0.70	0.001*
	Combine	−839.89	15.99	0.66	0.001*

*Significant at $P < 0.05$

Table 7. Regression equations from cranial height for male, female and combined data in 6–12 years, 13–19 years and ≥20 years subjects

Age	Gender	Regression Equation
6–12 years	Male	[a]CCm = −906.77 + 15.71 (cranial height)
	Female	[b]CCf = −713.35 + 14.17 (cranial height)
	Combined	[c]CCc = −846.34 + 15.22 (cranial height)
13–19 years	Male	[a]CCm = −844.38 + 15.69 (cranial height)
	Female	[b]CCf = −721.21 + 14.49 (cranial height)
	Combined	[c]CCc = −839.89 + 15.99 (cranial height)
20 years and above	Male	[a]CCm = −621.66 + 14.68 (cranial height)
	Female	[b]CCf = −684.32 + 14.60 (cranial height)
	Combined	[c]CCc = −839.89 + 15.99 (cranial height)

[a]cranial capacity for male, [b]cranial capacity for females, [c]total cranial capacity.

Table 8. Linear regression results for cranial width for male, female and combined data in 6–12 years, 13–19 years and ≥20 years subjects

Age group	Data	Constant	Slope	R-square	*P*-value
6–12 years	Male	−736.23	14.757	0.58	0.001*
	Female	−644.37	13.739	0.57	0.001*
	Combined	−769.20	14.857	0.58	0.001*
13–19 years	Male	−572.45	13.94	0.52	0.001*
	Female	−467.52	12.70	0.64	0.001*
	Combined	−677.36	14.67	0.58	0.001*
20 years and above	Male	−334.31	12.42	0.45	0.001*
	Female	−936.08	16.31	0.56	0.001*
	Combined	−873.76	16.03	0.58	0.001*

* Significant at $P < 0.05$

Table 9. Regression equations from cranial width for male, female and combined data in 6–12 years, 13–19 years and ≥20 years subjects

Age	Gender	Regression Equation
6–12 years	Male	[a]CCm = −736.231+ 14.757 (cranial width)
	Female	[b]CCf = −644.368 + 13.739 (cranial width)
	Combined	[c]CCc = −769.20 + 14.85 (cranial width)
13–19 years	Male	[a]CCm = −572.448 + 13.94 (cranial width)
	Female	[b]CCf = −467.519 + 12.699 (cranial width)
	Combined	[c]CCc = −677.36 + 14.47 (cranial width)
20 years and above	Male	[a]CCm = −334.308 + 12.42 (cranial width)
	Female	[b]CCf = −936.076 + 16.31 (cranial width)
	Combined	[c]CCc = −873.76 + 16.03 (cranial width)

[a]cranial capacity for male, [b]cranial capacity for females, [c] total cranial capacity.

from different studies reviewed. Knowledge of sexual dimorphism is vital in anthropology and human identification, especially when the body is in a fragmented skeletal state (7).

The effect of age on cranial capacity can be accredited to normal developmental changes observed in growth from childhood to adulthood. According to Finlay et al. (32), 'brain volume peaks around forty years of age after which declination sets in at a rate of 5% per decade'. Therefore, the larger cranial capacity observed in the subjects aged ≥20 years than that of subjects aged 6–12 years and 13–19 years is in concordance with Finlay et al. (32).

Since brain volume has been known to peak at 40 years, it is paramount that craniometric studies consider age categories when presenting standard craniometric data and their regression equations; most studies reviewed for this work were lacking in this regard. Additionally, most studies have tended to consider wide age ranges that could include both adolescents (4, 33), whose brains are still developing, and adults more than 40 years old (34), whose brain volume may have started declining.

Studies of cranial capacity that focus on 6–12 years and 13–19 years age groups are lacking in the literature reviewed over the course of the present study; therefore, the present findings will be fundamental to subsequent studies. In the adult category, the mean craniometric dimensions found in the present study are higher than in studies by Maina et al. (4), Obaje et al. (33) and Salve and Gitte (35), but they are similar to those reported by Umar et al. (36).

The mean adult cranial capacity observed in this study is larger than that reported by Odokuma et al. (5) in a study of various ethnic groups. The cranial capacity of the Ukwuani people compares favourably with those of adult Sri Lankans (7), Turkmen, Farsmans (31), Northeastern Nigerians (4) and the Ogidi people of Nigeria (1). Moreover, the values observed in this study are higher than those from a study using dissected cadavers in India (9).

The present study provides data on several cranial dimensions, cranial capacity and regression formulae with regard to the general population and gender- and age-specific categories as well as the extent of sexual dimorphism in these parameters. These data address the objective of the study.

It must be emphasised that the present study did not include subjects with a history of surgery or congenital abnormalities of the head and face. Additionally, it did not employ multiple regression analysis to derive single models that involved cranial length, width and height. It is therefore suggested that studies accounting for the aforementioned limitations be conducted to address these shortcomings.

Conclusion

In all the age groups studied, the mean dimensions of all the parameters were significantly higher in males than in females ($P < 0.05$). This study shows that age and gender are important factors in cephalometry and should be considered in the derivation of regression equations for cranial capacity. There exist strong positive correlations between cranial capacity and cranial length, cranial width, and cranial height, which make predictions of cranial capacity using regression formulae possible. Moreover, the index of sexual dimorphism increases with age.

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Conflict of Interests

None

Funds

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Authors' Contributions

Conception and design: DEE
Analysis and interpretation of the data: DEE, CEO, KAI
Drafting of the article: DEE, CEO, KAI
Critical revision of the article for important intellectual content: DEE, CEO, KAI
Final approval of the article: DEE, CEO, KAI
Provision of study materials or patients: DEE, CEO, KAI
Statistical expertise: DEE
Obtaining of funding: DEE, CEO, KAI
Administrative, technical, or logistic support: DEE
Collection and assembly of data: DEE, CEO

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