

Comparative correlation analysis of cranial capacity

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ABSTRACT

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The objectives of this study were to apply craniometric method in assessing skull capacity, determining the distribution of the known skull dimensions (length, width and height) and determining the cranial capacity separately by gender in the total sample and to examine the correlation between the results of cranial capacity in relation to gender and age. The materials used for this study were samples of 120 macerated and degreased skulls, 60 male and 60 female, with a average age of 57.97 years (\pm SD 18.45). The operating method was the craniometric method. The results showed that gender affects the value of cranial capacity, which was higher in males, whereas the effect of age was not proven statistically significant. The capacity of the skull had highly positive statistic correlation with the width, height and length of the particular. Male's skulls were on average longer, higher and wider than the female's skulls. Male's skulls were on average of larger capacity than the female's skull. Skull age as a factor had no effect on the value of cranial capacity. The skull length was the most dominant factor in determining the cranial capacity.

Keywords:

Cranial capacity
Cranioimetry
Height of the skull
Length of the skull
Skull
Width of the skull

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1. Introduction

There are many authors that are engaged in studying human skull, its structure, configuration, relationship between neurocranium and viscerocranium, presence of symmetry and asymmetry of the skull and their correlation with encephalon (Bubić, 1974; Eshel and Abboud, 1997; Sarač-Hadžihalilović and Dilberović, 2004; Sarač-Hadžihalilović and Dilberović, 2006). Cranial capacity presents particular part (chapter) of this large research. Appearance of its particular parts depends on appearance and configuration of the skull in general. Value of cranial capacity depends on the value of the length, width and height of the skull. The value of the cranial capacity varies from a person to a person, and is one of the indicators

of gender dimorphism and racial backgrounds (Buretić-Tomljanović et al., 2004; Alves et al., 2011; Manoharrao-Salve et al., 2011). In regard to many authors worldwide that have studied the value of cranial capacity in various nations, they have contributed to the anthropology development (Richard, 1993; Marinescu et al., 2014). In this publication, we show that demographic characteristics of the skull, which are reflected in the value of its cranial capacity among the other things, should be interpreted carefully, especially when it comes to comparative observing and concluding. Therefore, it is essential to explore correlation of cranial capacity with the skull length, width, height and gender.

2. Material and methods

The study was conducted on a sample of 120 macerated and digressed skulls, with the average age of 57.97 years (\pm SD 18.45). Out of the total sample, 60 skulls (50%) belonged to the males, with an average age of 56 years (\pm SD 16), and 60 remaining skulls (50%) belonged to the females, with an average age of 59 years (\pm SD 20) (Fig. 1).

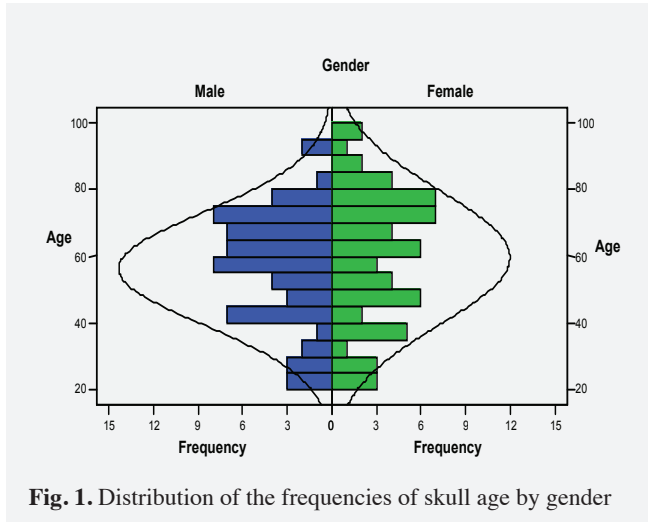


Fig. 1. Distribution of the frequencies of skull age by gender

Female skulls belong in average to slightly older women, with an average age of 59 years (\pm 20), unlike the male skulls which belong to persons with an average age of 56 years (\pm 16).

Craniometrical method was applied in estimating the capacity of the skull. Craniometrical method relies on the measurement of: (a) length, (b) width, and (c) the height of the skull, and on knowledge of empirical constant (gender-specific). Cranial capacity is determined by the patterns:

$$V(\text{♀♀}) = 0,000375 \times a \times b \times c + 296,40;$$

$$V(\text{♂♂}) = 0,000365 \times a \times b \times c + 359,34;$$

(Pearson (Hadžiselimović et al., 2009).

Before the measuring, the skull is placed in the position of "the Frankfurt horizontal", i.e. we put the line that connects the upper edge of the external acoustic meatus-PORION and the bottom edge of the left orbit-ORBITALE in the horizontal position, length of the head is measured by cephalometer in Fig. 2. It represents the maximum sagittal distance between

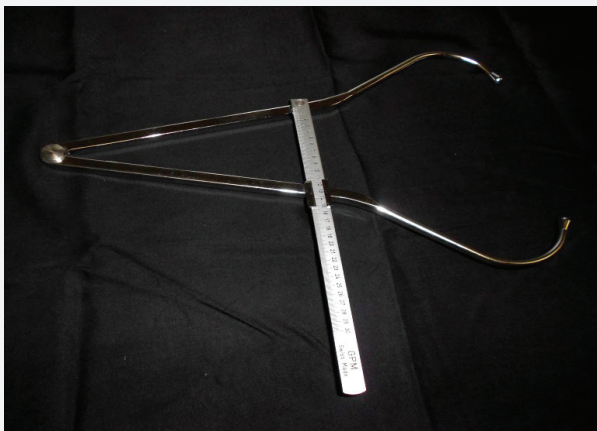


Fig. 2. Cephalometer

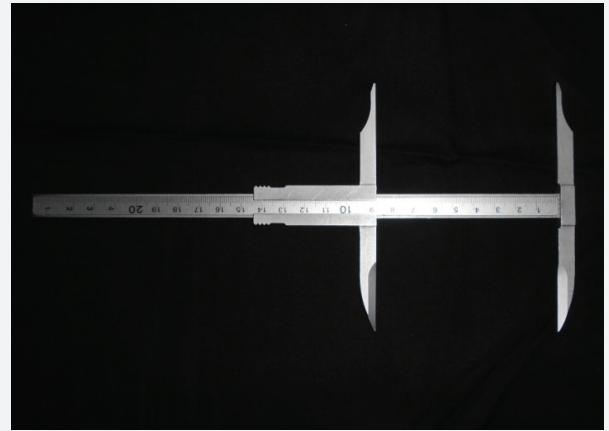


Fig. 3. Sliding divider-Schubler

anthropometric points: Glabella and opisthion. Width of the head is measured by cephalometer in Fig. 2. It presents the maximum sagittal distance between the right and left porion (mid-point on the top edge of external acoustic meatus). Height is measured by placing a ruler, long enough to cuts perpendicular external acoustic meatus, at the vertex, and then a sliding divider determines the range between that point and the ear hole as in Fig. 3.

Cephalometer is a measuring instrument that looks as its scale is on the horizontal bar which connects the two tines. It has a range of 30 centimetres and is divided in to millimetres. It is calibrated to 0.1 cm. Cephalometer is used for measuring smaller length and width, such as measuring of the head. Reading is done on the line which coincides with the inner edge of the bar (Hadžiselimović et al., 2009).

Sliding divider-Schubler is a measuring instrument that occurs in several different structures. For example, a sliding divider by Martin has a range of up to 20 cm, and the variant with nonius of up to 15 cm. In both cases a scale is calibrated to 0.1 cm. It is used to measure the smaller ranges, and the endings of its tines are slightly sharper. It is read on the line that coincides with the inner edge of the tine divider (Hadžiselimović et al., 2009).

Statistic methods

For statistical analysis of the data obtained software package SPSS for Windows (version 19.0, SPSS Inc., Chicago, Illinois, USA) and Microsoft Excel (versions 11th Microsoft Corporation, Redmond, WA, USA) were used.

Descriptive statistics is expressed as minimum and maximum values, arithmetic mean, standard deviation, standard error, frequencies and percentages. Difference between the mean values of the parameters between the two groups was tested by t-test. Normality of distribution of continuous variables was tested by using the Kolmogorov-Smirnov test. Test of correlation (Pearson's coefficient-r) was used to determine the strength and direction of the connections between the studied parameters.

For a strong correlation ($r > 0.75$) linear regression equation was constructed. The level of statistical significance was respected (statistic significance was ($p < 0.05$) with CI (confidence interval) 95%).

The following parameters were analysed:

1. Gender and age structure of the sample
2. Demographic characteristics of the skull by gender
3. Correlation of cranial capacity with the length, width, height, age and gender of examined skulls in the total sample and by gender structure.

3. Results

Results were elaborated in details, documented and presented in absolute numbers, relative numbers, statistical values using statistical indicators and presented in a simple and understandable tables and graphs.

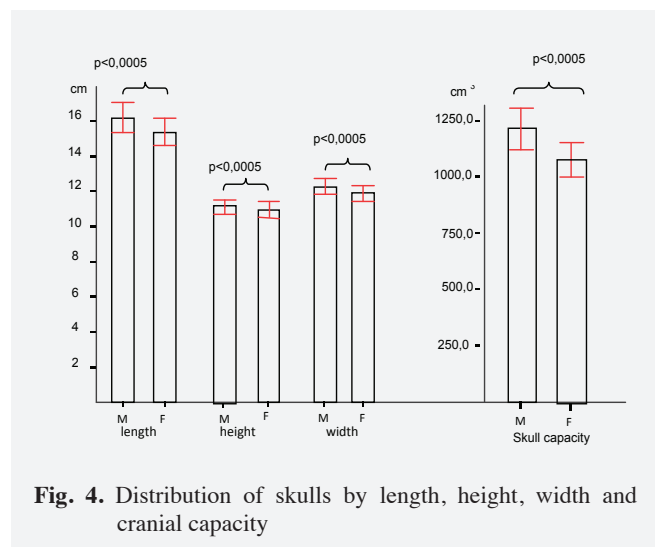


Fig. 4. Distribution of skulls by length, height, width and cranial capacity

Male skulls are on average longer [16.23 cm (± 0.87)], than the female skulls [15.44 cm (± 0.78)], that difference in length was statistically significant. Male skulls were on average

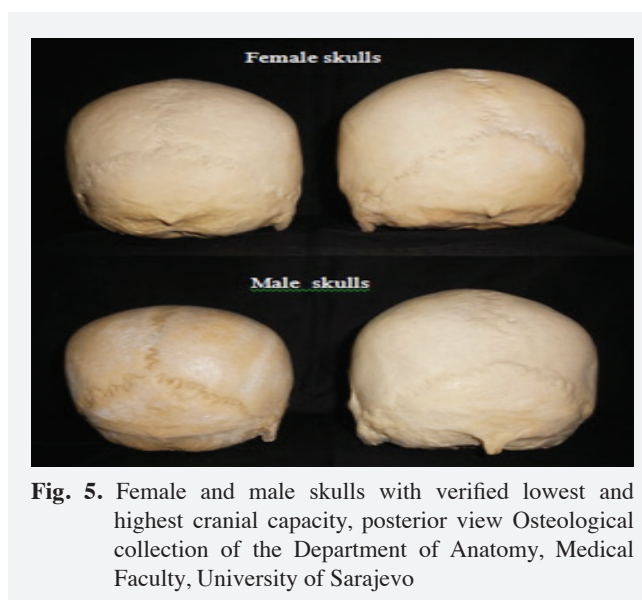


Fig. 5. Female and male skulls with verified lowest and highest cranial capacity, posterior view Osteological collection of the Department of Anatomy, Medical Faculty, University of Sarajevo

higher [11.36 cm (± 0.52)], than the female skulls [11.13 cm (± 0.50)]. The height difference was statistically significant. Male skulls were on average wider [12.73 cm (± 0.52)], than the female skulls [12.25 cm (± 0.56)]. Difference in the width was statistically significant. Male skulls were on average with larger cranial capacity [1217.92 cm³ (± 91.82)] than female skulls [1088.17 cm³ (± 77.94)]. Difference between the cranial capacities was statistically significant.

The cranial capacity was highly correlated (Pearson Correlation) with the length, width and height of the skull ($p < 0.0005$) in both genders.

Age was not correlated with the cranial capacity regardless to gender ($p > 0.05$).

Table 1. Correlations of cranial capacity with a skull length, width, height, age and gender

Gender			Cranial capacity	Length	Width	Height	Age
Male	Capacity	Pearson Correlation	1	0.839(**)	0.650(**)	0.748(**)	0.121
		P		<0.0005	<0.0005	<0.0005	0.358
	Length	Pearson Correlation	0.839(**)	1	0.344(**)	0.454(**)	0.126
		P	<0.0005		0.007	<0.0005	0.337
	Width	Pearson Correlation	0.650(**)	0.344(**)	1	0.222	-0.007
		P	<0.0005	0.007		0.088	0.955
Height	Pearson Correlation	0.748(**)	0.454(**)	0.222	1	0.132	
	P	<0.0005	<0.0005	0.088		0.315	
Age	Pearson Correlation	0.121	0.126	-0.007	0.132	1	
	P	0.358	0.337	0.955	0.315		
Female	Capacity	Pearson Correlation	1	0.755(**)	0.599(**)	0.739(**)	-0.085
		P		<0.0005	<0.0005	<0.0005	0.516
	Length	Pearson Correlation	0.755(**)	1	0.132	0.420(**)	0.063
		P	<0.0005		0.314	0.001	0.634
	Width	Pearson Correlation	0.599(**)	0.132	1	0.147	-0.066
		P	<0.0005	0.314		0.262	0.615
	Height	Pearson Correlation	0.739(**)	0.420(**)	0.147	1	-0.202
		P	<0.0005	0.001	0.262		0.121
	Age	N	60	60	60	60	60
		Pearson Correlation	-0.085	0.063	-0.066	-0.202	1
	P	0.516	0.634	0.615	0.121		

** Correlation is significant at the 0.01 level (2-tailed)

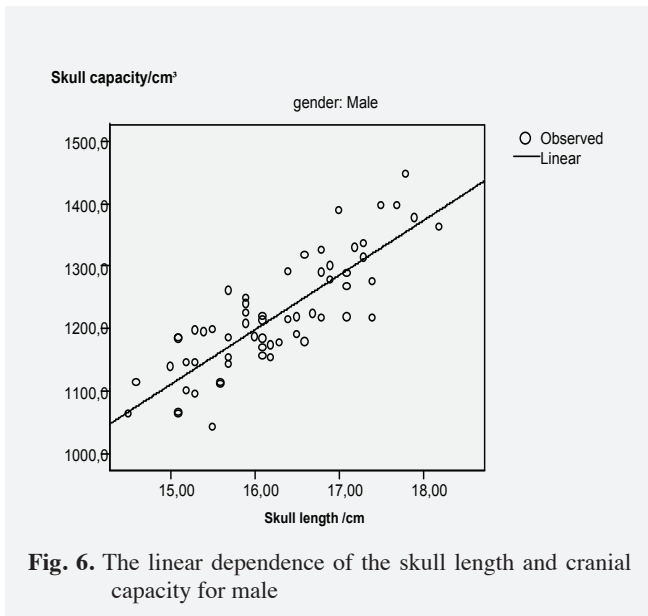


Fig. 6. The linear dependence of the skull length and cranial capacity for male

Linear regression equation for cranial capacity in relation to the skull length for the male would be:

$$\text{Capacity } \sigma = -204.781 + 87.65 \times \text{skull length}$$

Linear regression equation for cranial capacity in relation to the skull length for the female, would be:

$$\text{Capacity } \varphi = -72.427 + 75.144 \times \text{skull length.}$$

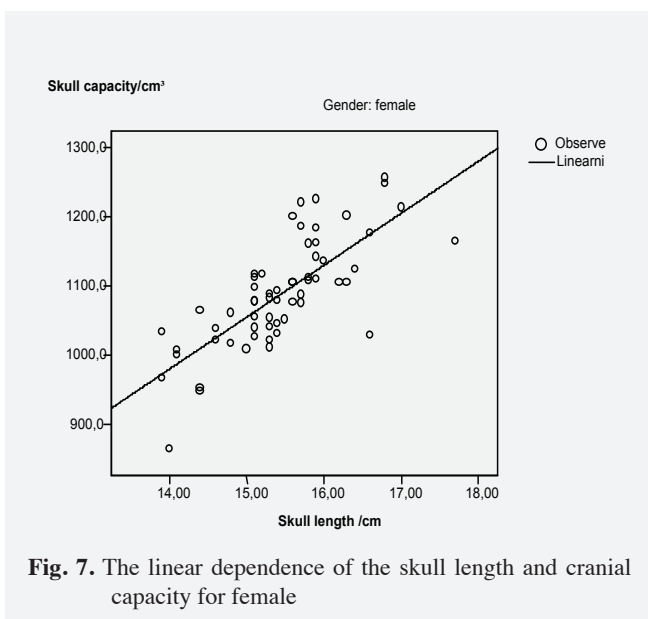


Fig. 7. The linear dependence of the skull length and cranial capacity for female

4. Discussion

Many authors of different profiles dealt with studying of human skulls, and conducted researches on its component parts (Bubić, 1974; Topić et al., 1976; George, 1987; Özdemir et al., 2012). Numerous classifications had been created, which were eventually affirmed or rejected. In literature, many factors have been suggested to influence the formation of the skull. The main subject of those factors is the shape of the skull during its growth and development (Krpmotić-Nemanić et al., 1977; Russo et al., 2011). We distinguish general and local factors. General factors include: Heredity, constitution, hormones and vitamins. Local factors include:

dentition, the prominence of the head muscles, prominence of the eye, ear and sinus cavities, and maxillo-mandibular apparatus as well as blood vessels within the skull. The brain and skull are interacting in terms of size and shape. Present asymmetry of the skull may also arise from discrepancies, conditioned by the growth of cartilage and osseous part of the head (Tomić, 1982). Using craniometrical method, cranial capacity will be estimated which is based on the measurement of length, width and height of the skull. We studied the measurable characteristics of the skull by using this method. This way, we evaluated the quantitative size of the cranial capacity, which serves as an indicator of gender dimorphism and racial backgrounds. Or, based on it, we could get valuable data about the demographic characteristics of the skull from the particular area of the country, which is then domain of anthropography - as part of anthropology. Furthermore with this study, we set the question of the factors which in the most dominant way affect the definition of cranial capacity and that way achieve a leading role in the skull formation.

Furthermore, this study should represent a contribution to current studying of the cranial capacity, its correlation to other parameters and causality. This is a prospective study, based on a pool sample of skulls, that have been determined in the length (from glabella to opisthion), width (between the right and left porion) and height (between the vertex and porion), and the required cranial capacity was calculated by Pearson correlation using gender specific constants.

Statistical analysis shows that there is no significant difference in the average age by gender, i.e. that age as a factor did not affect any gender differences. By statistical analysis of the average length of the examined skulls, it was shown that the average length of male skulls was 16.23 cm (± 0.87), and it was higher in comparison to the average length of the female skulls 15.44 cm (± 0.78) (Fig. 4). Thus, there is a statistically significant difference in the average length of the skull by gender, which is higher in male persons.

By statistical analysis of the average width of the examined skulls, it was shown that the average width of the male skulls was 12.73 cm (± 0.52), and the average width of the female skulls was 12.25 cm (± 0.56) (Fig. 4). The average width of the male skulls was higher than that of the female skulls, and there was a statistically significant difference in the average width by gender.

By statistical analysis of average height of the examined skulls, it was shown that male skulls are higher, and their average height is 11.36 cm (± 0.52), unlike female skulls where the average height is 11.13 cm (± 0.50) (Fig. 4). The height difference by gender is statistically significant.

The study, which was conducted among three ethnic groups of north-eastern Nigeria, included a total of 300 skulls, 150 male and 150 female skulls. Craniometrical method was applied and the cranial length, width and height were measured. It has been shown that cranial dimensions in all three major ethnic groups were higher in male skulls in comparison to the female skulls (Maina et al., 2001). This coincides with our study, in which we get that the male skulls, on average are longer, wider and higher than female skulls. Statistical analysis of the cranial capacity in the conducted study showed that male skulls had an average capacity of 1217.92 cm³ (± 91.82), which was higher than the capacity of female skulls, which was 1088.17 cm³ (± 77.94). Differences

in the average cranial capacity by gender were statistically significant. Similar results in terms of conditioning of the skull capacity with the gender of the skull, and its higher values in males we found in numerous studies.

Thus, for example Stephan Gould refers the results that show that the male skulls on average have larger cranial capacity for 14% comparing to the female skulls (Gould, 1978). Conditionality of the cranial capacity by gender dimorphism we found in the work of Nigerian authors (Maina et al., 2011), which also referred larger cranial capacity of male persons.

Correlation analysis of the cranial capacity with the length, width and height of the examined skulls from the total pool sample showed a high positive correlation in terms of increasing the capacity of the skull by growth in length, width and height of the skull. The capacity of the skull correlates with gender. Male skulls have bigger cranial capacity in comparison to the female skulls. These results can be found in the study of Nooranipour M., Farahan RM, which refers that male skulls have an average cranial capacity of 1343.45 cm³ (± 102.37) and female skulls of 1163.02 cm³ (± 115.76) (Nooranipour and Farahan, 2008). It also shows that the values of the cranial capacity are higher in males, which coincides with our results, and they can be used as one of the signs of gender dimorphism. Gender dimorphism is in adequately treated in literature. What would be interesting, related to our theme is the study of I. Bubić who studied osteometric values and did the correlation with morphognostic features of the skull, specific for each gender. The author follows the typical nine male and female morphognostic marks and calculates their frequency. The author notices that the length of the skull gradually decreases as the number of male gender features is decreasing. The author finds the highest values of the length of the skull in the cases with are the most male gender features. Furthermore, the author notices that width of the skull is the highest in male and female skulls which have only four characteristic gender features. The author classifies the skull in three groups.

The first group consists skulls with (0, 1, 2 and 3) morphognostic marks. The second group are skulls with (4, 5 and 6) morphognostic marks, and the third group are skulls with (7 and 8) morphognostic marks (Bubić, 1973). In fact, it is possible to observe morphological-anatomical features of the skull by anthroposcopy and describe the qualitative features of the observed skull. We also noticed some transitional forms in female skulls which prone to male features and vice versa by using osteometric methods.

Our results show that the cranial capacity is not in correlation with age, regardless of gender structure (Table 1). This result can be explained if we look at the age structure of the sample, which shows an average age of 57.97 years (± 18.45). The youngest skull was 21 years old and the oldest skull aged 96 years. It is evident that the growth and development of the skull in the selected sample is completed.

When we talk about the demographic characteristics of the skull from particular area of the country, which is the domain of anthropography-as part of anthropology, we should have on mind that we can't directly compare all the results referenced in the literature one with the other, considering the different approaches in calculating of cranial capacity. So in the paper in which the cranial capacity had been determined within the

Korean population measuring the length, width and height of the skull was performed. The values obtained are included in the formula: MALE SKULL: Capacity= $307.5 + 333 \times 10^{-6} \times (\text{length} \times \text{width} \times \text{height})$ FEMALE SKULL : Capacity= $12.0 + 435 \times 10^{-6} \times (\text{length} \times \text{width} \times \text{height})$. The results obtained in this study were 1470 ± 107 cm³ for male and 1317 ± 117 cm³ for female skulls (Hwang et al., 1995). Having in mind that we didn't use this formula to calculate the cranial capacity, we couldn't directly compare our research with that one. However, we can observe that mentioned study proved that gender has a significant effect on the cranial capacity value, which is higher in male persons, as well as in our sample.

What is extremely important to emphasize, is that the length of the skull stands out as the most dominant factor in determining cranial capacity. The correlation is high and positive ($r=0.837$, $p<0.0005$) in the total pool sample ($r=0.839$, $p<0.0005$) for male skulls and ($r=0.755$, $p<0.0005$) for female skulls (Table 1). Therefore was constructed for both gender separately, linear regression equation for calculating the cranial capacity on the length basis (Fig 6,7). Differences in mean values for cranial capacity by measuring the length, height and width of the skull with knowing of Pearson's gender-specific constants and capacity obtained with the help of linear equation is not statistically significant, $p=0.999$ (male) and $p=0.949$ (female). That means, the obtained equation is reliable for measuring of cranial capacity on the basis of its length. This result can't be compared with literary data, considering that such solutions in terms of calculating cranial capacity are not referred. Therefore, we believe that these results represent our humble contribution for determining cranial capacity, its correlation with other parameters and causality. These results have their practical validity and applicability, since in this way the time required for calculating cranial capacity is shorter due to only one parameter is needed to be known-length of the skull. Thinking about the presented facts, we set the question: Why is the length of the skull, the most dominant factor in determining the cranial capacity compared to its height and width? We remind that it is defined by the longest sagittal distance between anthropometric points: glabella and opisthion. In humans, skull balances on the top of a vertical spine, whereat there is a balance between the nuchal muscle tone action at the rear part of the skull and an action of the visceral part of the skull gravity (Jo, 1964). By cranial base flexion the posterior cranial fossa is lowered, that follows position change of the vertebral column and increases the sphenoid angle. This way the brain obtains a new space for its development, and process of flexion of cranial base allows more intensive development of neurocranium and increases the capacity of cranial cavity (Tomić, 1982). Just by lowering the posterior cranial fossa, the length of the skull increases, with regard to the position of opisthion-which corresponds to the lowest point of cranial base, located in the centre of the posterior edge of the foramen magnum. At the same time, the afore mentioned process (cyphosis of the cranial base) will bring about torsion of the pyramid, as well as the rotation of the whole temporal bone, which causes formation of the skull asymmetry (Hadžiselimović, 1974). At the same time it also affect the skull height and width value, considering that mentioned processes influence the position of porion, which as an anthropometric point is important in determining the

value of skull height and width, that have positive correlation with the cranial capacity and the same is confirmed by (in) our results.

Particular field is studies evaluation the cranial capacity using Automating Estimation. This way opens up possibilities for design of clinical studies, which would be observed for cranial capacity with neurological disorder, such as epilepsy, dementia, alzheimer. So, in study Sargolzaei all emphasizes the importance in the choice of the right sampling period in the manual estimation of ICV, which are shown to depend largely on the demographics of the targeted population, the imaging parameters of the MR machine, as well as the neurological disorder under study (Sargolzaei et al., 2014).

Our specific results can conclude our study on this way:

The capacity of the skull of both genders is in positive and strong correlation with the skull length, width and height. The age structure of the skull is not in correlated with their cranium capacity regardless to gender structure. On average male skulls are longer, higher and wider than the female skulls. On average male skulls have a higher cranium capacity than the female skulls. Length of the skull represents the factor that is the most dominant in determining cranial capacity. We propose to apply linear regression equation for calculating the cranial capacity of the skull in relation to its length as a pattern for future tests of cranial capacity.

All given opinions, there are open spaces and opportunities for further researches in terms of the illuminating these complicated processes in the formation of a human skull.

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