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ANTHROPOMETRIC STUDIES OF HEAD DIAMETERS IN BOSNIAN HIGH SCHOOL STUDENTS

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Background: Many scientific researches confirm the importance of such studies in the field of forensic science (determination of unknown sex) as well as in the field of geoanthropology (population differences). The aim of this study was to assess the anthropometric head measurements of high school students, compare them between the sexes of the same grade and between grade levels (from the first grade to the fourth) individually for each sex, and examine the correlation between the anthropometric head measurements, age and sex, independently for both males and females and for each individual grade level.

Method: The participants of this study were high school students attending first to fourth grade, 20 students per grade level among which there were ten female participants and ten male participants. The age range of the students was from 14 to 18. The measurements were taken using craniometric methods.

Results: The results showed that all of the measured linear parameters were higher among males, particularly head width, that the probability of a person being female drops with the increase in each of the measured parameters, particularly head width, and that the significance of the impact of all parameters on sex drops with the increase in participants' age. The highest correlation was ascertained between the total face height and forehead width parameters.

Conclusion: Discriminant functional analysis better correctly allocated female (92,5%), than male (82,5%) participant in our sample.

Keywords: morphometry, head diameter, high school.

INTRODUCTION

The utilization of classic morphometry can be found in many studies done on diverse research topics. A great number of studies were done on the sexual dimorphism of the skull, the relationship between the neurocranium and viscerocranium, the symmetry and asymmetry of the skull, linear parameters and their correlation [1, 2]. The scientist who researched and studied the similarities and differences among different populations made a particularly considerable contribution to the field. With this research, we emphasise the need for a careful interpretation of the linear parameters of the head, especially when making a comparison between them in research, and drawing conclusions. Thus, it is immensely important to research the correlation between these parameters and age, sex, all grade levels, and individual grades. Gender assessment based on human skeleton has its significance and application in forensic medicine, anatomy, physical anthropology, archaeology [3]. Purposes for qualitative and quantitative skeletal remains analyses for gender identification may be found in economic prize of DNA analyses, time duration to complete those analyses, possibility of collecting samples, specially from places where mass suffering took place and common scaffold were placed [4]. Quantitative (osteometric-anthropometric) analyze of gender skull dimorphism allows more objective approach than qualitative (osteoscopic-anthroposcopic) analyze. Recent literature referencing a large number of paper in this filed [5,6,7]. Using the multivariate binary logistic regression with respect of population standard are grant for the most effective anthropological provement and as such may be suggested to forensic expertise based on human skull [4].

METHODS AND MATERIALS

The conducted study is prospective, quantitative – anthropometric and comparative research. The research conducted in Sarajevo, in four grades of the secondary Medical School – Bjelave. 80 participants, 40 males and 40 females, aged 14 to 18, were involved in this study. The research included ten female and ten male students from each of the grade levels. Each participant had the following anthropometric measurements taken: total body height, cranial length, cranial width, head height, forehead and face width, upper face and total face height. The measurements were taken using the anthropometric instruments: cephalometer and sliding calliper with the head in the Frankfort horizontal plane.

• The total body height was measured by having the participant stand (with feet flat on the ground) on a flat surface (floor), with heels together (unraised) and with shoulders fully back and relaxed. Thereupon, the researcher would place a measuring instrument behind the subject's back so it touches the surface on which the subject is standing. The horizontal part of the measuring instrument is then raised until it touches the scalp (vertex). The height of the vertex is measured by placing a long enough metal ruler on top of it so that it is parallel to the floor, i.e., it perpendicularly touches the measuring scale.

• The cranial length is the maximal sagittal distance between the anthropometric points of glabella and opisthion.

• The cranial width is the maximal transverse lateral distance between the left and the right porion.

• The head height is measured by placing a sufficiently long ruler on top of the vertex so that it intersects a vertical line from the external auditory meatus. Afterwards, the distance between the ruler and the external auditory meatus i.e. porion is measured using the sliding calliper. When examining the head height, it is necessary to subtract the thickness of the placed ruler from the overall obtained value [8].

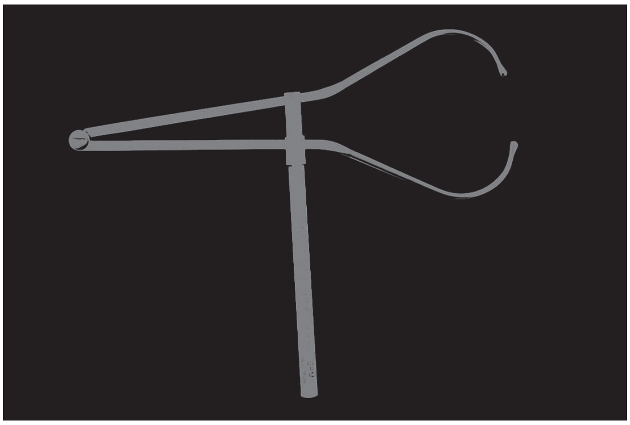
• The forehead width is the maximal transverse lateral distance between the left and the right frontotemporal points.

• The face width is measured between the most lateral points of the cheekbone i.e. os zygomaticum while compressing the soft tissue.

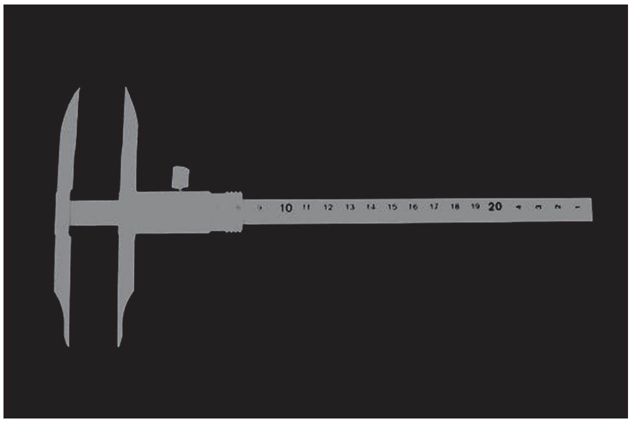
• The upper face height is the vertical distance between nasion and prosthion.

• Total face height is the vertical distance between the nasion and gnathion [9].

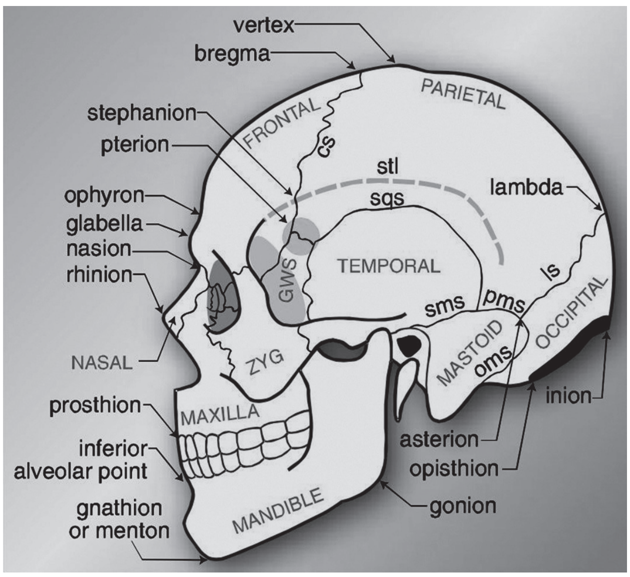
The cranial length and width, as well as the forehead and face width, measurements are taken using the cephalometer (Picture I) whereas the head height, upper and total face height are taken using the sliding calliper (Picture II). Anthropometric points (Picture III).



Picture I. Cephalometer



Picture II. Sliding calliper



Picture III. Craniometric points

Statistical methods

To research the impact of anthropometric diameters of the head on sex, the binary logistic regression model was used as one of the most significant multivariate analysis methods in statistical data analysis. Furthermore, parametric tests (Independent Sample T and One-Way ANOVA) were used to determine the differences between parameters, both sexes and grade levels. Finally, discriminant analysis was used to unveil the differences between the sexes.

The following parameters were analysed:

1. The distribution of anthropometric parameters of the head in relation to sex among the participants of the same grade level.

2. The distribution of anthropometric parameters of the head in relation to grade levels (from the first grade to the fourth) – independently for each of the sexes

3. Univariate impact of certain head diameters on sex.

4. The impact of independent variables (anthropometric diameters – head diameters) on sex was examined using multivariate binary logistic regression.

5. The change in univariate and multivariate impact significance with increases or decreases in age (first grade to fourth grade).

Ethical considerations

All participants participated in the study on voluntary basis. Data are presented in a way the identity of the participants can not be recognized. Adult respondents signed an informed consent. For juvenile respondents in agreement with them the parents signed an informed consent.

RESULTS

The results were elaborated in detail and displayed in absolute numbers, relative numbers, statistical values using statistical indicators and presented in tables and graphs.

The overall number of observations for each of the variables is 80, therefore we conclude that there are no missing values in the database. All independent variables are numeric, continuous variables. The dependent variable of sex is a binary variable with the values of 0– Male and 1– Female (Table I).

Table I. The descriptive statistic of the data from the sample

Variable	Observations	Average Value (cm)	Standard Deviation	Minimum (cm)	Maximum (cm)
Cranial Length	80	17.7875	0.8657	16	19.9
Cranial Width	80	12.9062	0.7082	11.2	14.5
Head Height	80	13.1212	0.7651	11.1	14.9
Forehead Width		10.8437	0.6269	9.1	12.1
Face Width	80	13.6487	0.6334	12.4	15.9
Upper Face Height	80	6.9925	0.4448	6.1	8.4
Total Face Height	80	11.1387	0.6305	10	13.1

Table II shows the results of the estimated impact of cranial length, cranial breadth, auricular head height, forehead width, face width, upper face height, and total face height parameters on the dependent variable of sex.

It is not possible to interpret the coefficients of predictor variables in the Logit model in any common way. Thus, the negative value can be interpreted as a lower probability, while the positive as a higher probability. All coefficients in Table 2 have a negative value which suggests that the probability of a person being female drops with the increase in any of the parameters (Table II).

The preceding four tables show the decrease in impact of the cranial length variable on sex with an increase in participants' age (table III, IV, V, VI).

Table II. Multivariate logistic regression

Sex	Coefficient	Standard Error	Z	P>z	[95% Conf. Interval]
Cranial Length	-1.4898	0.8450	-1.76	0.078	-3.1459
Cranial Width	-1.3020	1.0985	-1.19	0.236	-3.4550
Head Height	-0.6180	0.5908	-1.05	0.296	-1.7760
Forehead Width	-1.0612	0.8317	-1.28	0.202	-2.6913
Face Width	-0.1728	1.0447	-0.17	0.869	-2.2204
Upper Face Height	-0.3098	1.4592	-0.21	0.832	-3.1696
Total Face Height	-0.6661	1.0325	-0.65	0.519	-2.6897
cons	74.7119	17.9194	4.17	0.000	39.5905

Table III. Logistic regression – Impact of Cranial Length on Sex (First Grade)

Sex	Coefficient	Standard Error	Z	P>z	[95% Conf. Interval]
Cranial Length	-3.0659	1.3156	-2.33	0.020	-5.6444
cons	53.4142	2.2870	2.34	0.020	8.5892

Table IV. Logistic regression – Impact of Cranial Length on Sex (Second Grade)

Sex	Coefficient	Standard Error	Z	P>z	[95% Conf. Interval]
Cranial Length	-10.4446	6.8251	-1.53	0.126	-23.8215
cons	187.2089	122.5241	1.53	0.127	-52.9338

Table V. Logistic regression – Impact of Cranial Length on Sex (Third Grade)

Sex	Coefficient	Standard Error	Z	P>z	[95% Conf. Interval]
Cranial Length	-2.4952	1.2184	-2.05	0.041	-4.8831
cons	44.0316	21.5059	2.05	0.041	1.8808

Table VI. Logistic regression – Impact of Cranial Length on Sex (Fourth Grade)

Sex	Coefficient	Standard Error	Z	P>z	[95% Conf. Interval]
Cranial Length	-5.2865	2.7676	-1.91	0.056	-10.7109
cons	95.4281	49.9782	1.91	0.056	-2.5274

In the logistic regression model, the statistical value of cranial width is lower in the second grade than in the first. Statistical significance is the highest in the logistic model of the fourth grade. Therefore, we can conclude that cranial widht has the most significant impact on sex in the fourth grade (table VII, VIII, IX, X).

Table VII. Logistic regression – Impact of Cranial Width on Sex (First Grade)

Sex	Coefficient	Standard Error	Z	P>z	[95% Conf. Interval]
Cranial Widht	-4.6000	2.1612	-2.13	0.033	-8.8359
cons	57.8934	27.1414	2.13	0.033	4.6972

Table VIII. Logistic regression – Impact of Cranial Width on Sex (Second Grade)

Sex	Coefficient	Standard Error	Z	P>z	[95% Conf. Interval]
Cranial Widht	-9.7392	5.4073	-1.80	0.072	-20.3374
cons	125.7083	70.0404	1.79	0.073	-11.5683

Table IX. Logistic regression – Impact of Cranial Width on Sex (Third Grade)

Sex	Coefficient	Standard Error	Z	P>z	[95% Conf. Interval]
Cranial Widht	-1.9336	0.9085	-2.13	0.033	-3.7142
cons	25.2168	11.8514	2.13	0.033	1.9884

Table X. Logistic regression – Impact of Cranial Width on Sex (Fourth Grade)

Sex	Coefficient	Standard Error	Z	P>z	[95% Conf. Interval]
Cranial Widht	-4.3103	1.7753	-2.43	0.015	-7.7899
cons	56.4532	23.2453	2.43	0.015	10.8932

We can notice the greatest extent of correlation between the upper face height variable and the total face height (0.7555) variable. We present the evidence that the established correlation is strong and statistically significant in Table XI given the p-value is 0.000 and greater than 0.05. Thus, we reject the null hypothesis due to a statistically significant correlation between upper face height variable and total face height variable (Table XI).

Table XI. Correlation matrix

	Cranial Length	Cranial Width	Head Height	Forehead Width	Face Width	Upper Face Height	Total Face Height
Cranial Length	1.000						
Cranial Width	0.7425	1.000					
Head Height	0.3635	0.2520	1.000				
Forehead Width	0.6148	0.6775	0.3017	1.000			
Face Width	0.5849	0.6703	0.3112	0.5768	1.000		
Upper Face Height	0.4668	0.3782	0.3418	0.3574	0.3121	1.000	
Total Face Height	0.5354	0.4816	0.2383	0.4705	0.4341	0.7555	1.000

A high correlation has not been established between our independent variables, given that the highest correlation between overall face height and forehead width variables is 0.684. Therefore, we can conclude that the hypothesis on the nonexistence of the perfect correlation between explanatory variables is not rejected (Table XII).

Among the 40 participants who were allocated to group 0 – Male, 33 subjects i.e. 82.5% have been correctly allocated through the discriminatory analysis based on predictors. The remaining 7 subjects have been inaccurately allocated to group 0 instead of to 1 – Female (Table XIII).

Table XII. Correlation Matrix

	Cranial Length	Cranial Width	Head Height	Forehead Width	Face Width	Total Face Height
Cranial Length	1,000	,545	,200	,261	,356	,316
Cranial Width	,545	1,000	,042	,130	,510	,234
Head Height	,200	,042	1,000	,229	,151	,084
Forehead Width	,261	,130	,229	1,000	,110	,684
Face Width	,356	,510	,151	,110	1,000	,226
Total Face Height	,316	,234	,084	,684	,226	1,000

Table XIII. Classification results

	Sex	Estimated group membership	
		0	1
Numerical	0	33	7
	1	3	37
%	0	82.5	17.5
	1	7.5	92.5

a. 87.5% of original grouped cases correctly classified.

DISCUSSION

Many scientists from various fields, especially from the fields of anthropology, biological anthropology, and medical anthropology studied the human skull, contrasting the differences and similarities in their obtained results.

The present study is a quantitative-anthropometric, prospective, and comparative study, and as such, it required a wide range of analyses and interdisciplinary correlations which were conducted and examined in the work. The main goal of this research was to draw attention to the significance and applications of classic morphometry in the evaluation of anthropometric head measurements of high school students of all four grades levels with reference to sex.

The sample was homogeneous in age. After the statistical analysis, we concluded that with the increase in participant's age the significance of the impact of cranial length variable on sex decreases. The decrease of impact of the developmental phase with participant's age increase manifested through the progressive extension of cranial length in the lower grades explains the former claim. Cranial length, which in this case decreased, is of great importance as it was the discriminant function of the highest statistical significance.

The utilization of classic morphometry is evident in numerous studies conducted on different research topics. For example, the issue of sexual dimorphism of the human skull gathered a vast amount of research. The results of the aforesaid research claimed that at around eighty years of age the differences in skeletal structure between the sexes are so pronounced that it is possible to determine person's sex, if unknown, with great accuracy. Moreover, according to studies the female skeleton is smaller in size and built, while the male skeleton is bigger and more robust [10]. The present study came to the same results since males had higher values of all of the measured parameters. More specifically, the conducted data analysis prompted the conclusion that the probability of a person being female decreases with the increase in the measured parameters.

One research carried out on 600 participants per two groups aimed to identify the differences between Chinese and Caucasian head shapes. The head shape measurements were taken on whita race from North America and Europe, while the Chinese head shape measurements were taken only in China. One of the drawbacks of the research was the fact that it did not include female head measurements. The reason behind this being that women have longer and thicker hair so the scientists deemed that women's hair could lead to measurement errors. Due to the drawback, it was not possible to compare the results between the sexes. The taken measurements were: cranial length, cranial width, head height, face width and height. According to the results, there are significant differences between the head shapes of these two groups. Through data analysis, a conclusion was made that the Chinese heads are significantly rounder, while the forehead and the back of the head are flatter as compared to the white race [11]. Through a comparison between the aforementioned study and our study, several things can be noticed. Primarily, the Chinese have the largest cranial breadth with an average value of 158 mm, while the white race average value of cranial width is 154 mm. Subsequently, our data sample shows a significantly lower average value of high school students' cranial breadth – 129 mm. White race have the highest cranial length of 199 mm, while the average cranial length in Chinese participants is 188 mm, and 178 mm in our sample. Chinese participants have the highest average cranial width as they have a characteristic flatter and wider forehead, while the white race have the highest average cranial length due to the much more pronounced occipital specific to the group. It should be taken into account that both values are higher in Chinese and white race participants due to their average age of 40, while the participants in our study are of high school age.

Interesting research was carried out in Poland on 56 vocal students, 36 males and 20 females aged between 19 and 26. The study aimed to compare the acquired values of cranial and facial indexes to the values of non-singing students. The results showed that the vocal students have larger heads and mandibles than non-singers [12]. By comparing the results of this research with our research results, we can confirm that the measured parameters are higher among vocal students than among the participants of our study. Vocal students' average value of cranial length is 195.5 mm, while the average for high school students is 178 mm. Similarly, vocal students' average value of cranial breadth is 162.3 mm, while high school students' average value is lower at 129 mm. The average value of forehead width is significantly higher in vocal students at 125.6mm, while in our sample it is 108.4 mm. The average face width of students is 140.4 mm, and the average of high school students is 136.4 mm. Therefore, our research confirms this study since vocal students have higher measured parameters than our participant group, even though the age difference is not significantly large between these two groups.

Another research done in India recorded comprehensive measurements of 225 participants, 93 males and 132 females. The participants were aged between 18 and 25 and inhibited the region in and around Bangalore, India. The aim was to explore if a correlation between the height of the human body and head height exists. The study suggests that head height is not a certain indicator of body height [13]. A similar study was carried out in Nigeria, where 200 participants, 100 males and 100 females, were examined. The study aimed to explore the relationship between craniofacial parameters and total body height. The results showed that some craniofacial parameters increase as height increases, some yet decrease, while others stay the same. For example, with the increase in height, we can notice an increase in person's mouth width, while on the other side the increase in height results in smaller head circumference, smaller head breadth and narrower biocular width. In regards to these values, cranial length and height remain constant, regardless of a person's height. The research concluded that males have significantly wider mouths and larger head circumference when compared to females, while females have a larger base of the skull i.e. basis cranii. When comparing this study to ours we can conclude that in our research the body height did not significantly impact the changes in other measured parameters as sex and age did.

Furthermore, research similar to ours was done on 2472 participants of younger school age (7 to 15 years) in Novi Sad. The goal of the research was to highlight the variations in cephalic measurements of school children in correlation to sex and age. Cranial length and width were measured [14]. As in our research, the average values of both parameters increased as the age increased, although there was an exception in participants of both sexes at age of 12 whose cranial width was smaller than that of 11-year-old participants. Additionally, boys had higher examined values than girls. The average cranial length of students in the mentioned study was 176 mm, while for our group of participants it was 178 mm. These results are expected since the participants in the present study are older.

Anthropometric measurements of cranial length and breadth were also done on 7784 participants under the systematic research of physical development of 20-year-olds. Similarly, the aim of the study was determining cranial width and height [15]. The average value of cranial length in the sample of the mentioned study was 183.5 mm, compared to 178 mm in our sample, while the average value of cranial width was 155.9 mm, compared to our recorded value of 129 mm. Upon contrasting the results of these two studies it can be noticed that the first study has higher values of both parameters. The reason for that might be the participant's higher age in the first study, as well as the overall higher number of participants.

In the South part of Iran, Shiraz, a study was conducted which included boys and girls who similar to our research were of high school age between 14 and 18. 867 girls and 960 boys participated in the study which measured their cranial length and width [16]. An interesting fact is that the participants of the Iranian study have significantly higher values of both parameters, even though both groups of participants are of the same age. The average value of their cranial length is 183.2 mm, while for the participants of our study it is 178 mm. The average value of cranial width in Iranian participants is 169.6 mm, while the average value of cranial width we recorded is 129 mm. By comparing our studies, a conclusion can be made that the reason for the higher values of parameters in Iranian students is geographical (population) nature.

CONCLUSION

Based on the results of the carried-out research the following conclusions can be made:

1. The average body height of male participants is higher than the average body height of female participants.

2. There is no statistically significant difference between the grade levels for all the parameters that have a value higher than 0.05, apart from the forehead width parameter as the p-value for this parameter is 0.008.

3. The probability of a person being female drops with the increase in value of all of the measured parameters: cranial length and width, head height, forehead and face width, and upper and total face height. The increase in head breadth has the highest statistical significance.

4. With the increase in age of the participants, the significance of impact of the following variables drops: cranial length, head height, forehead and face width, and total face height. In all grade levels except the fourth, the significance of impact increases only for the upper face height variable.

5. Cranial length variable has the highest average value in comparison to average values of other variables, and as such it contributes the most to group differentiation.

6. No high correlation was discovered between the measured independent variables, but the highest correlation was recorded between total face height variable and forehead width variable.

7. Discriminant function analysis correctly allocated 82.5% of male participants in our sample.

8. Discriminant function analysis correctly allocated 92.5% of female participants in our sample.

9. Discriminant function analysis correctly allocated 87.5% of participants in the total of our sample.

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