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The Ability to Determine the Length of the Human Body by the Parameters of the Skull

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Abstract

The aim of the work was to study the possibility of determining the length of the human body by the size of his skull. The material for the study was a craniological series of Azerbaijani skulls in the amount of 120 (70 male, 50 female) from the museum collection of the Person of Public Law Association "Forensic Medical Examination and Pathological Anatomy" of the Ministry of Health of the Republic of Azerbaijan. For each skull, the body length of the individual to whom it belonged was known.

120 craniometric features were studied on each skull (80 features were taken from standard craniometric programs, 40 were proposed by us). The database of craniometric parameters and body length was subjected to statistical analysis. Based on the results of correlation and regression analysis, 71 multiple linear regression equations (34 for men; 37 for women) were implemented to predict the length of a human body based on the parameters of his skull. Most of the developed equations have the value of the standard error of the forecast + 4-5cm and, in certain practical situations, can be used in personality identification examinations. In this article, we have presented 12 equations of the total number of equations developed by us.

Keywords: Craniometric parameters; Height determination; Regression equations; Person identification; Persons missing in war

Introduction

Personal identification in forensic medicine continues to be one of the urgent tasks [1-3]. The presence of the skull, or even its large fragments, allows the forensic expert to determine most of the group personality traits [4,5].

However, regarding the establishment of the length of the human body by the size of the skull, there is extremely little information in the forensic literature. While working on the project for the development of diagnostic methods for identifying a person (adapted for the population of Azerbaijan), we also did some work to study the possibility of calculating the length of an individual's body using craniometric parameters. We present a summary of this study below.

Materials and Methods

The craniological collection of Azerbaijanis of known height, sex and age from different regions of the republic, which is stored in the medical forensic department of the Person of Public Law, the Association of SME and PA of the Ministry of Health of the Republic of Azerbaijan, served as the material. The craniological series was collected in the 70s of the last century and includes more than 200 skulls. This collection of skulls adequately reflects the craniological characteristics of the modern population of Azerbaijan, has been introduced into scientific discussion since 1995 and has repeatedly become material for various studies [3,5]. From this collection, taking into account the craniometric representativeness of objects, as well as population homogeneity, 120 skulls (70 males; 50 females) were selected. 120 craniometric features were studied on each skull. Standard craniometry procedures were used according to well-known recommendations [6]. Most of the parameters were measured from skulls mounted on a Mollison stand in the Frankfurt horizontal plane. Of the studied skull sizes, 80 features were taken from standard craniometric programs previously proposed by various authors [6,7]. The remaining 40 craniometric dimensions are either proposed by us or mentioned in studies by various authors, as having a correlation with body length. Of these parameters, 17 are used in the equations we present in this article. Therefore, we present their detailed description and measurement technique:

S1 - The sum of the sagittal curve (Mart25) and the transverse curve (Mart24) on the skull (hereinafter, the abbreviation "Mart" and the number denote the number of the feature from the standard craniometric program R.Martin [6]).

S2 – The sum of the length of the foramen magnum (Mart7) and the width of the foramen magnum (Mart16).

S3 - The sum of the values of the longitudinal diameter of the skull (Mart1) and the length of the foramen magnum (Mart7).

M3 - Length of linea nuchalis superior. It is measured with a soft cloth tape or a curvimeter along the surface of the line itself on the skull from the left border of the occipital bone to its right border, through the inion point.

M6 - Length of linea nuchalis inferior. Also measured as size M3.

S4 - Sum of dimensions M3 and M6.

M7 - Length of crista occipitalis externa. The shortest distance along the surface of the skull from the point of inion to the point of opistion. It is measured with a soft cloth tape or a curvimeter along the surface on the skull.

S7 - The sum of the greatest distance between the margo articularis condylus occipitalis (between the most lateral points on the margo articularis condylus occipitalis) and the smallest distance between the articular edges of the occipital condyles (between the most medial points of the margo articularis of the right and left condylus). The articular edges of the condyles were marked with a pencil, and measurements were taken with a digital caliper.

M8 - The average value of the largest dimensions of the foramen rotundum (right and left). Measured with a digital caliper. The legs of the caliper are inserted into the hole and moved apart, then, moving the legs along the perimeter of the hole, the largest diameter is found. The diameters on the right and left are summed and then divided by two.

M9 - Length of the anterior section of the inner base of the neurocrane. Distance from the most protruding point of the endocran on the border with the cranial vault to the middle of tuberculum sellae turcica.

S9 - The sum of the length and width of the posterior cranial fossa. The length of the fossa is measured from the base of the dorsum sellae turcica to the protuberantia occipitalis interna. The width of the fossa is the distance between the bases of the two temporal pyramids (the point of intersection of the upper edge of the sulcus sinus sigmoidei with the sutura occipitomastoidea was marked as reference points on the right and left).

M11 - The smallest distance between the foramina ovalia on the outer base of the skull. The legs of the digital caliper are inserted into the foramen ovale (each into one) and shifted, the value of the attribute is the index of the compass with the legs maximally shifted in this position.

M12 - The smallest distance between the foramen canalis caroticus on the outer base of the skull. It was determined similarly to M11.

M14 - Length parameter of the left processus mastoideus. As a long-length characteristic of the mastoid process, a chord is used, which is a perpendicular restored from the mastoid point to a conditional line on the lateral surface of the skull. This line is drawn parallel to the Frankfurt horizontal through the highest point at the transition point of the upper edge of the external auditory opening to the root of the zygomatic process of the temporal bone. The technique of taking this size is described in the work of Galli G., Galli S. [8].

M16 - Arithmetic mean of the length of the left processus mastoideus and the length of the right processus mastoideus. The length of the right processus mastoideus is measured similarly to M14.

M17 - The greatest distance between the foramen canalis opticus. The size was measured between the most distant points of the upper edges of the openings of the visual channels. A sliding compass is used.

M18 - The smallest distance between the foramen rotundum from the side of the middle cranial fossa. Using a caliper, the minimum distance between the medial walls of the right and left round holes is fixed.

As we noted above, all other skull sizes that we present in this work were taken from standard craniometric programs. To analyze the results of craniometry, we used standard methods of variation statistics, as well as correlation and regression analysis [9].

Mathematical modeling and calculations were performed using the MATLAB statistical software package (version 8.6).

Research Results

After the skulls were selected from the collection (a blind method was used, focused only on the absence of defects on the skulls), we considered the order of their distribution by age and body length. Since the archival collection of skulls was studied, the age of individuals and their lifetime body length (we are talking about people who owned the studied skulls) were known. Tables 1 and 2 provide data on the distribution by sex, age, and height of individuals whose skulls made up the studied craniological series. Age periodization and body length rubrication in the tables are conditional and correspond to our arbitrary ranking.

Gender	Age								
	16 – 24	25 – 34	35 – 44	45 – 54	55 – 64	65 – 74	75 – 80	Total	Average age
Male	14	17	13	11	8	5	2	70	39
Female	13	10	10	7	4	3	3	50	38,2
Total	27	27	23	18	12	8	5	120	39,4

Table 1: Distribution of the studied material by sex and age.

Gender	Body length										
	140-144.9	145-149.9	150-154.9	155-159.9	160-164.9	165-169.9	170-174.5	175-179.9	180-184.9	185 and more	Total	Average body length
Male	0	0	2	4	11	19	17	10	4	3	70	169,7
Female	2	6	10	13	9	6	2	1	1	0	50	159,2
Total	2	6	12	17	20	25	19	11	5	3	120	166,4

Table 2: Distribution of the studied material by sex and body length.

As can be seen from the tables, the skulls of individuals whose age was in the range of 16-80 years were studied. However, we note that, in general, there were very few skulls of elderly and senile age (in the combined group of men and women, the proportion of skulls corresponding to the age of over 60 did not exceed 14%). Also unevenly distributed were data on the lifetime length of the body of individuals whose skulls were the objects of study. Individuals who had high or low growth during their lifetime turned out to be less than 25% of the total. That is, in the study sample, there were mainly men and women of average height.

After the measurement procedure, the obtained numerical indicators of craniometric signs were grouped in tables separately for male and female. Here we present the statistical parameters of some of these features (these are the features that were included in the regression equations we modeled). Statistical characteristics of the studied craniometric parameters on male skulls are presented in Table No. 3, and in Table No. 4, statistical characteristics of the dimensions of female skulls.

Conditional abbreviation	Craniometric signs (number and names according to Martin, as well as own designations)	Statistical parameters			
		N	*x*	σ	Sx
Z1	1. Longitudinal diameter	70	180,7	5,92	0,7078
Z2	8. Transverse diameter	70	143,8	6,78	0,8104
Z3	17. Height diameter	70	136,8	5,9	0,7052
Z7	10. The greatest width of the forehead	70	121,4	6,03	0,7207
Z12	25. Sagittal arch	70	373,4	13,94	1,6662
Z15	28. Occipital arch	70	118,3	7,29	0,8713
Z16	29. Frontal chorda	70	113,8	5,38	0,6430
Z22	7. The length of the foramen magnum	70	36,6	2,18	0,2606
Z24	45. Zygomatic diameter	70	133,0	5,33	0,6371
Z25	43. The width of the upper part of the face	70	105,2	4,36	0,5211

Z33	43(1). Bimalar width	70	97,8	4,4	0,5259
Z43	51. Width of orbit from maxillofrontal	70	43,7	2,27	0,2713
Z44	51a. Orbit width from dacryon	70	40,6	2,51	0,3000
Z46	MC. Maxillofrontal width	70	18,9	1,94	0,2319
Z67	66. Corner width	70	100,6	5,64	0,6741
Z70	70. Branch height	70	63,9	5,5	0,6574
Z72	67. Front width	70	44,9	2,45	0,2928
Z73	69. Height of symphysis	70	31,6	3,15	0,3765
S1	The sum of the sagittal and transverse arches	70	695,6	21,49	2,5686
S2	The sum of the length and width of the foramen magnum	70	68,1	3,51	0,4195
S3	The sum of the longitudinal diameter with the length of the foramen magnum	70	217,3	7,15	0,8546
S4	The sum of the lengths of the upper and lower nuchal lines	70	280,0	18,22	2,1777
S7	Distance between the articular margins of the occipital condyles (max+min)	70	71,23	4,94	0,5904
S9	The sum of the length and width of the posterior cranial fossa	70	197,7	9,72	1,1618
M3	Total length of the upper nuchal line	70	143,4	9,55	1,1414
M6	Total length of the lower nuchal line	70	136,6	12,27	1,4666
M7	Arc between inion and opistion points	70	56,3	6,33	0,7566
M8	Half sum of largest sizes foramini rotundum	70	3,93	0,64	0,0765
M9	Length of the anterior cranial fossa	70	52,8	4,13	0,4936
M11	Smallest distance between foramina ovalia	70	60,9	3,3	0,3944
M12	Smallest distance between foramina canalici carotici	70	53,0	4,0	0,4781
M14	Length of the left mastoid process	70	34,4	3,37	0,4028
M16	Half the length of the mastoid processes	70	35,1	3,13	0,3741

Table 3: Statistical parameters of craniometric features, correlated with body length (in a series of male skulls).

Conditional abbreviation	Craniometric signs (number and names according to Martin, as well as own designations)	Statistical parameters			
		N	*x*	σ	Sx
Z1	1. Longitudinal diameter	50	172,1	6,05	0,8556
Z3	17. Height diameter	50	130,9	5,76	0,8146
Z4	20. Ear height	50	115	4,39	0,6208
Z5	5. Length of the base of the skull	50	98,6	4,6	0,6505
Z12	25. Sagittal arch	50	361,3	15,01	2,1227
Z10	23. Horizontal circle	50	503,4	14,5	2,0506
Z11	24. Transverse arch	50	315	14,72	2,0817
Z15	28. Occipital arch	50	115	8,53	1,2063
Z26	46. Medium face width	50	90	5,05	0,7142
Z27	48. Upper face height	50	67,9	4,5	0,6364
Z28	47. Full face height	50	114,3	6,25	0,8839
Z50	DC. Dacrial width	50	21,2	1,63	0,2305

Z72	67. Front width	50	43,2	2,08	0,2942
S3	The sum of the longitudinal diameter with the length of the foramen magnum	50	207,2	6,08	0,8598
S4	The sum of the lengths of the upper and lower nuchal lines	50	255,9	14,08	1,9912
S7	Distance between the articular margins of the occipital condyles (max+min)	50	67,0	4,67	0,6604
M3	Total length of the upper nuchal line	50	138	6,04	0,8542
M6	Total length of the lower nuchal line	50	117,8	9,42	1,3322
M9	Length of the anterior cranial fossa	50	48,4	4,15	0,5869
M14	Length of the left mastoid process	50	30,6	3,12	0,4412
M17	The greatest distance between foramini canalici optici	50	24,8	2,34	0,3309
M18	Smallest distance between foramini rotundum	50	34,6	3,94	0,5572

Table 4: Statistical parameters of craniometric features, correlated with body length (in a series of female skulls).

Next, we conducted a correlation analysis, which showed that among the studied craniometric dimensions, more than 60 parameters had a good or moderate relationship (r = 0.3-0.7) with body length. At the same time, craniometric parameters that correlate well with body length in men did not always show the same relationship in the sample of female skulls. Having a sufficiently large number of features that have a relationship of medium and above average degree with body length, we began to develop equations of multiple linear regression, which could to a certain extent predict the growth of an individual by the size of his skull.

The method of stepwise linear regression was used, the essence of which is to sequentially introduce features into the regression model depending on the degree of their correlation with the predicted factor. At the same time, the criterion for selecting features (regressors) in the format of a specific diagnostic model is their maximum correlation with the predicted parameter and weak among themselves. This condition is fundamental in mathematical models similar in structure and functions, since it minimizes the phenomenon of multicollinearity. Without dwelling in detail on the relevant theoretical aspects, we note that compliance with this rule increases the reliability of the equations being created. Taking into account this factor, we calculated the correlation coefficients of the traits we studied for all possible combinations in pairs (separately for the skulls of men and women).

In total, r values were obtained for 2278 pairs of traits in the male sample, and 2211 pairs of traits for the female series. The analysis of correlation matrices to determine the compatibility of craniometric dimensions as part of a specific regression equation made it possible to predict the construction of a very large number of equations (for example, using only two features more than 110 for each sex). However, in mathematical constructions, similar to the equations of multiple linear regressions, the quality of the forecast increases significantly when the integral consideration of factors related to the reconstructed value is taken into account. Therefore, associating as many regressor features as possible into the format of one specific model is an extremely effective approach. The focus on the heterogeneity of the composition of dynamic models was dictated by practical considerations related, for example, to the examination of a fragmented skull, when the presence of a defect automatically excludes some of the craniometric features from the general flow of potential determinants of body length. In such situations, equations with slightly different regressors, which are measured in the perimeter of the skull destruction zone, lose their operational life in a complex way.

In accordance with these considerations, by means of mathematical modeling, we constructed regression equations separately for the skulls belonging to the male (total 34) and female (total 37) sex. After the procedure for calculating the statistical parameters of the equations and evaluating the forecast, the designed models were implemented into functioning ones. A brief review of the work and the entire package of proposed equations, as well as recommendations for their application, are presented in a separate monograph [10]. Below we present 12 equations from our set (equations with the abbreviation K are for the study of male skulls, equations with the abbreviation Q for the study of female skulls):

K1. L = 23,9254 + 0,7876xM16 + 0,0816xZ12 + 0,2475xZ33 + 0,0783xM3 + 0,1768xZ2 + 0,7233xZ22 + 3,966

K2. L = – 10,4004 + 0,3518xZ1 + 0,2179xZ67 + 0,2436xZ46 + 0,5522xM11 + 0,4285xZ43 + 0,1383xZ16 + 0,1951xZ72 + 0,0921xM6 + 4,01

K3. L = 27,0135 + 0,6371xM14 + 0,0754xZ12 + 0,2672xZ33

+ 0,0931xM3 + 0,1678xZ2 + 1,3861xM8 + 0,6325xZ22 + 4,018

K4. L = 50,5189 + 0,8644xM16 + 0,0571xS1 + 0,1049xS4 – 0,0128xZ24 + 0,0461xZ70 + 0,2944xZ44 + 1,5371xM8 + 4,151

K5. L = 26,1981 + 0,1352xZ25 + 0,5237xS2 + 0,325xZ67 + 0,2129xZ15 + 0,234xZ7 + 0,1332xM7 + 4,374

K6. L = – 3,5717 + 0,3717xZ1 + 0,1863xZ3 + 0,0457xZ24 + 0,5645xZ43 + 0,1612xS9 + 0,1285xM6 + 4,387

Q1. L = – 79,391 + 0,4776xZ28 + 1,6073xZ72 + 0,3862xZ1 + 0,1286xS4 + 0,4392xM18 + 5,321

Q2. L = – 123,8375 + 0,7412xS3 + 1,473xZ72 + 0,1727xM6 + 0,4752xM18 + 0,2227xZ3 + 5,333

Q3. L = – 42,8738 + 0,2078xZ10 + 0,9852xM14 + 1,1887xZ50 + 0,108xS4 + 0,1093xM18 + 0,1513xS7 + 5,391

Q4. L = – 51,9107 + 1,0246xM14 + 0,116xZ12 + 0,8135xZ50 + 0,3527xM3 + 0,0387xZ11 + 0,2629xM18 + 0,2372xS7 + 0,3467xZ5 + 5,536

Q5. L = – 36,8554 + 0,4131xZ28 + 0,1772xM17 + 0,345xZ26 + 0,5862xZ4 + 0,263xZ15 + 0,3206xM9 + 6,139

Q6. L = – 66,7968 + 1,6412xZ72 + 0,227xZ12 + 0,4086xM18 + 0,4706xZ27 + 0,1411xZ5 + 0,0995xZ3 + 6,155

In these equations, “L” is the parameter being set (i.e. body length), all other numbers are the equation constant, regressor coefficients (craniometric features) and the standard error of the equation. Information about the craniometric features used and the technique for measuring them are given in the text.

Discussion of the Research Results

As we indicated, a total of 34 equations were developed for diagnosing growth on male skulls and 37 equations for corresponding examinations of female skulls. In each of these equations, from 5 to 8 regressors are used, and the errors in determining the length of an individual’s body during life range in these equations from 4 cm to 6.2 cm. To verify our equations, we used the cross-validation method. The material submitted for examinations of personality identification was examined (out of context) using the proposed equations. With a positive outcome of identification, we checked the accuracy of the coincidence of the real height of a person with the data obtained by our equations. We were able to conduct such cross-checking in 20 cases. Note that the correlation between real data on human height and predicted data was about r=0.8. Starting work on studying the possibility of predicting body length from the skull, we understood that this was an unpromising direction. In the literature, we found very few works that provide at least some information about determining the height of the skull, or the size of the head [11-14]. However, in our case, practice required at least some scientific data in this matter due to the presence of a military conflict on the territory of our country [15]. After this conflict, about 4,000 people were listed as missing. Most of these people are soldiers whose remains will have to be identified. Since people who disappeared in the war are mostly young men, when analyzing mass graves and completing skeletons, taking into account body length becomes of paramount importance in segregation (compared to sex and age).

However, regarding the accuracy of the proposed equations, we note that we have no right to expect perfect results. Using all the proposed equations (easily implemented in Excel) and determining the average value from them turns out to be the closest to the true growth value (within an error of 4-5 cm). That is, relatively speaking, the equations clearly recognize the difference, for example, between a body length of 175cm and 185cm. At the same time, the solution of the problem, when it is necessary to classify the skull as an individual with a body length of 170 cm, or 175 cm, will have a less reliable answer. It should also be borne in mind that our equations were developed on the basis of osteological material from people of average height, so our diagnostic method will probably be less accurate when studying short or tall populations. Regarding populations, we also note that in the anthropology of the modern population of Azerbaijan, 4 anthropological types are distinguished: Caspian, Pontic, Western Asian and the type of population of the Caucasus mountains [5]. However, the most common is the Caspian type (more than 65%), and we studied precisely the skulls from this group. Perhaps that is why the equations we designed turned out to be a little more accurate, because it is known that body proportions are more stable within anthropological types.

Thus, the above analysis shows that the developed equations for determining the length of the body from the skull have some limitations for their unconditional application in forensic practice. This diagnostic method has the best prospects in the study of bone remains from the territory of Azerbaijan. At the same time, in the absence of a legal incident and a setting for undoubted accuracy (for example, in archeology, during historical restoration work, etc.), for an approximate calculation of the length of an individual’s body, the equations may turn out to be quite acceptable.

Conclusion

Some craniometric indicators studied on the skulls of modern Azerbaijanis are interconnected by correlation-regression relationships with body length. This relationship can be described using multiple linear regression equations. Taking into account these mathematical prerequisites, the corresponding diagnostic equations for practical application have been developed. But according to modern standards for making expert decisions in forensic medicine, they cannot be unconditionally recommended for widespread use, since verification of the used of these prediction equations on other population groups is necessary. Nevertheless, under certain circumstances (some works in anthropology, archeology, etc.), the proposed equations are of practical value as an independent method for diagnosing the lifetime body length.

References

1. Iscan MY, Steyn M (2013) The Human Skeleton in Forensic Medicine. Charles C.Thomas, Springfield, IL.
2. Popov VL, Musaev ShM (2009) Forensic Medicine. St. Petersburg, pp: 520.
3. Ibragimov ASh (2004) The study of the possibility of predicting the length of the human body by craniometric signs and its forensic significance. PhD dissertation, Baku, pp: 130.
4. Tomilin VV (2000) Medico-forensic identification. Moscow, Norma, pp: 466.
5. Musayev ShM (1999) Medico-criminalistic identification populations of the Caucasus on skull. Baku, pp: 127.
6. Martin R, Saller K (1956-1962) Lehrbuch der Anthropologie in systematischer Darstellung. Gustav Fischer Verlag Stuttgart, pp: 579-991.
7. Alekseev VP, Debets GF (1964) Craniometry. Methods of anthropological research. Moscow, Nauka, pp: 128.
8. Galli G, Galli S (1977) Etudes antropologiques a propos du proces mastoidien et proposition d'un nouvel index. Acta Anat 99(3): 268.
9. Glantz ST (2011) Primer of Biostatistics. 7th (Edn.). McGraw Hill Professional, pp: 320.
10. Ibragimov ASh (2017) Determining the length of the human body by the size of the skull. Saarbrücken: LAP LAMBERT Academic Publishing, pp: 178.
11. Haack HP (1967) Bestimmung der Korperhohe aus Kopf- und Gesichtsmassen unter Berucksichtigung von Alter und Geschlecht. Inaugural Dissertation. Leipzig.
12. Pashkova VI, Reznikov BD (1978) Forensic identification of a person by bone remains. Saratov, pp: 211-268.
13. Zaichenko AA (1986) Determination of the length of the fetus by the size of the anterior fontanel. Forensic medical examination 4: 29-31.
14. da Silva M (1987) Estimativa da estatura do indivyduo com a utilizato de um grupo de dentes da mandybula. Revista Paulista de Odontologia, pp: 18-28.
15. First Nagorno-Karabakh War.