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Assessment of the Possibilities of Forensic Identification Population of Kazakhstan by Craniometric Indicators

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Abstract

BACKGROUND: Craniometric indicators are one of the most reliable sources of information about the population. Despite the development of genetic methods, skull measurements are extremely important in anthropology and forensic medicine. In addition to the history of population development, environmental factors such as climate and lifestyle contribute to variations in human skull shape. Due to the high variability of human individuals, the anthropological research of the population is carried out selectively, with a comparison of different population groups (ethnic, professional, age, and gender). The lack of clear ideas about the typical parameters and proportions of the skull among the people of Kazakhstan creates a certain gap in forensic-medical identification.

AIM: The aim of the research is to check the hypothesis about the relationship between variations in skull morphology and changes in craniometric indicators with climatic conditions and the specifics of lifestyle in populations living in different territories of Kazakhstan.

METHODS: 187 male and 114 female adult skulls found on the territory of the two largest regions of Kazakhstan were examined. The variable variation of 25 craniometric indicators of skulls found on the territory of Central and South Kazakhstan was studied. All osteometric changes were performed using standard anthropometric instruments, followed by the calculation of craniometric indices. Multidimensional statistics was applied.

RESULTS: The two populations demonstrate differences in craniometric indicators formed in different geographical and ecological conditions, regardless of gender. It was found that the sizes of the skulls found in the two studied regions of Kazakhstan statistically significantly differ in 5 craniometric indicators for men and 8 craniometric indicators for women. Significant changes were noted in the size of the full and upper height of the face, medium face width, the mandible body height, and the nose height in men. The most dimorphic variables for forensic medical assessment in the studied populations of female skulls were transverse, height and bizygomatic diameters, mastoid width, skull base width, foramen magnum breadth, upper face height, and nose height. The shape of the skulls found in the studied territories is predominantly brachycephalic. The cranial index was >81.1% - at men, >83% - at women. The research showed that race affects the size of the skull, regardless of gender. Craniometric parameters in male and female skulls vary according to different criteria. In women between races, there are statistically significant differences in the size of the foramen magnum breadth and the medium face width. Statistically significant differences in the skull base width, the bizygomatic diameter, and medium face width between the Caucasoid and Mongolian races were revealed in the studied regions in men. The established differences made it possible to form additional differential diagnostic criteria.

CONCLUSION: The identification of the features inherent in the population living in certain territories provides auxiliary information for medical and forensic identification of a person. In this research, population-specific craniometric indicators have been developed for inhabitants of two regions of Kazakhstan, which expand and complement identification capabilities when categorizing skeletal remains found in these territories.

Introduction

One of the special cases of forensic identification is the identification of the dead based on the analysis of certain signs. Conventionally, forensic medical identification of the dead has a narrow focus. It is focused on the search for an individual set of physical characteristics for each person, such as gender, age, race, anatomical and morphological features, and measurement indicators [1], [2]. Bony skeleton is less susceptible to destructive changes and is a source of important information for a forensic medical expert. The human skull is a complex object with a large number of anatomical variations in different populations and racial groups [3], [4]. Currently, when conducting forensic medical examination on the territory of the CIS countries, including Kazakhstan, unified craniometric criteria developed by Pashkova and Reznikov are used [5]. These criteria are recognized as common for geographically and genetically remote populations. However, the literature presents the results of scientific research confirming the influence of the environment (in a broad sense) on the shape of the skull [4], [6], [7]. A number of studies have noted the low heritability of most craniometric signs [8], [9]. The data of population genetics researchers indicate that the morphological and genetic classifications of workforce significantly differ from each other [10], [11], [12], [13]. The question of the relative role of human skull variability factors - genetic, environmental, stochastic - remains actual [14], [15], [16], while most researchers have no doubts about the influence of environmental factors on the variability of the human skull [2], [8], [14], [15]. The researchers note that their relative value and expression vary under the influence of (among others) local environmental or genetic influences [3], [9], [11], [13], [16]. In this case, the accuracy of identification when applying standards used on the territory of the CIS (Commonwealth of Independent States) that do not relate to specific populations and standards, specific for population, may be questionable. This underlines the importance and necessity of forming standards aimed at the population of Kazakhstan as a whole and its regions separately. In Kazakhstan, forensic medical identification of a person does not yet have a good anthropometric base, and the lack of clear ideas about the parameters and proportions of the skull of the population living in various territories of modern Kazakhstan creates a certain gap when conducting medical forensic and criminalistic researches. The presence of national characteristics of craniometry among the population of Kazakhstan involves a detailed study of the characteristics of craniometric indicators and the development of specific reference values for them.

Aim of the research

The aims is to evaluate the osteometric dimensions of the human skull in different regions of Kazakhstan, to establish the limits of variability of craniometric indicators in the process of human adaptation to environmental conditions and to detect identification criteria for forensic medical identification.

Materials and Methods

Sampling area and sample collection

The craniometric parameters of well-preserved 187 male and 114 female adult skulls found on the territory of Central and South Kazakhstan were examined. Retrospective researches from 1998 to 2015 were conducted according to archival samples and forensic medical reports. In the period from 2016 to 2021, the research was carried out on the basis of current expert studies conducted in the regional branches of the Center for Forensic Examinations of the Ministry of Justice of the Republic of Kazakhstan. All the samples studied belonged to persons in the age category from 22 to 70 years. Persons with obvious congenital or acquired cranial pathology, due to possible influence on normal physiology or inability to accurately determine the required cranial landmarks, were excluded from this research. The quantitative characteristics of the conducted researches are presented in Table 1.

Data acquisition

For osteometric measurements, researches of archival and actual samples, in accordance with the standard legal procedure in the Republic of Kazakhstan, in all cases, a written permission of law enforcement bodies was obtained.

The research was approved by the Committee on Bioethics of Scientific Research of the NP JSC "Medical University of Karaganda" (Record No.4 of 06.12.2021) for the use of human tissues. The material was collected in accordance with the rules adopted by the Ethical Commission of Karaganda Medical University (Republic of Kazakhstan).

Sample preliminary processing procedures

Preliminary processing of the studied samples from soft tissues and soil overlays was carried out by mechanical cleaning. Then cleaned samples were dried at room temperature. Dried bone objects, if necessary, were degreased in chloroform in an alcohol-ether mixture (1:1). If necessary, bone fragments of the skull were glued together with water-soluble glue (polyvinyl acetate). The samples prepared in this way were packed, labeled, and stored in a dry place at room temperature until the research was carried out.

Research methods

Each skull was measured using 23 standard craniometric points. Measurements were carried out on 25 craniometric indicators. A unified craniometric technique was used to determine the size of the skull and its individual formations, recorded in numerical values using standard anthropological craniometric instruments. Reaching adulthood was established on the basis of fusion of basal occipital synchondrosis and, additionally, the stage of the eruption of the 3rd molar. The results were entered into an electronic database containing the medical and biological characteristics of the studied persons. To determine

Table 1: Quantitative description of the conducted research (by region)

Person's gender	Central Kazakhstan						South Kazakhstan					
	Skull shape			Race			Skull shape			Race		
	Dolichocranes	Mesocranes	Brachycranes	Caucasoid	Mongolian	Mestizoes	Dolichocranes	Mesocranes	Brachycranes	Caucasoid	Mongolian	Mestizoes
Men	18	34	54	35	38	33	11	32	38	7	65	9
Women	12	20	39	23	28	20	9	32	40	9	61	11
In total	30	54	93	58	66	53	20	64	78	16	126	20

the sex of the skull, data from the summary table of reference values of the sizes of male and female skulls were used [17]. To determine the shape of the skull, a cranial index was used, representing the percentage ratio between the transverse and longitudinal dimensions of the cranial vault and calculated by the formula: *в* x 100/*а*, where *в* – transverse size of the skull, *а* – its longitudinal size. The diagnosis of race was carried out according to craniometric signs using a one-dimensional discriminant model of mature persons based on the calculation of the size of angles and cranial pointers [17].

The obtained data were processed using statistical software packages Statistica 13.3 (StatSoft Inc., USA) and SPSS 12.0.2. Methods of descriptive, parametric (Welch's *t*-test for two independent samples, Pearson's Chi-square test) and non-parametric statistics (the Mann–Whitney criterion for comparing quantitative features in two independent samples when analyzing quantitative data by region, the Kruskal–Wallis criterion and the median test for comparing three independent groups when conducting quantitative data comparison by race) were used. Differences in values were considered statistically significant at a probability level of more than 95% ($p < 0.05$) for two comparison groups, $p < 0.0170$ for three comparison groups [18].

Results and Discussion

Results

Descriptive statistical data were calculated, and sexual dimorphism was estimated for 25 craniometric indicators studied in two regions of Kazakhstan after the exclusion of outliers. The data of descriptive statistics of the sizes of male and female skulls found in the southern and central parts of Kazakhstan are presented in Table 2. Further, comparative studies and analysis were carried out depending on the normality of the distribution for men and women separately. The analysis of 25 craniometric indicators under research showed that the size of the skull, regardless of gender, found in the territories of the Central region and the Southern region of Kazakhstan, differ.

When evaluating quantitative data, it was found that only 7 indicators in men and 13 indicators in women out of 25 craniometric indicators studied obey the law of normal distribution. Further statistical studies on these criteria were carried out using the Welch t-criterion for two independent samples. In the process of studying the differences between these seven craniometric indicators of male skulls found in different regions of Kazakhstan, statistically significant differences were revealed only by two craniometric indicators: full face height (gn-n) and mandible body height (gn-id). Hence, the size of full face height (gn-n) at male skulls found in the southern part of Kazakhstan 123.4±7.7 мм (M±SD), which statistically significantly exceeds the similar size of 119.0 ± 8.9 mm in the skulls of men found on the territory of the central part of the Republic of Kazakhstan (*t*-value = −2.515; df = 90; p = 0.014). The size of the mandible body height (gn-id) of male skulls in the southern region is 33.6 ± 2.8 mm (M±SD), the same size in the central region is 31.9 ± 3.4 mm (*t*-value = −2.471; df = 68; p = 0.015). Figure 1 presents the craniological characteristics of these parameters of male skulls found in the Central and South regions of Kazakhstan.

In a pairwise comparison of 13 craniometric indicators obeying the law of normal distribution, it was found in women that the sizes of female skulls found on the territory of Central Kazakhstan, 5 of them, are statistically significantly smaller than the corresponding sizes of female skulls found on the territory of Southern Kazakhstan. Table 3 presents comparative statistical data of the Welch test for five craniometric indicators of the size of female skulls in the two regions studied.

Next, quantitative craniometric indicators having a different distribution from normal were analyzed using the Mann–Whitney criterion. The comparative analysis of craniometric indicators of male skulls in the two studied regions statistically significantly differs in 3 indicators. Thus, the upper face height (n-al), the medium face width (zm-zm), and the nose height (n-ns) in male skulls found in the central part of Kazakhstan are significantly less than the corresponding parameters in male skulls found in the southern part. The results of the corresponding statistical analysis of the studied craniometric indicators are presented in Table 4.

In a similar analysis of the size of female skulls, it was found that female skulls found in the central part of Kazakhstan differ in smaller sizes according to three craniometric indicators from the skulls of women found in the southern part. Comparative characteristics of craniometric indicators of female skulls by region are presented in Table 5.

As shown in Table 5, the median values of parameters in the skulls of women in the central and southern parts of Kazakhstan ($p < 0.05$) differ significantly. This applies to such craniometric indicators of female skulls as the height diameter (b-ba), the foramen magnum breadth, and the bizygomatic diameter (zy-zy).

Attention is drawn to the fact that, in general, the sizes of skulls found on the territory of the southern part of Kazakhstan are larger in men by 5, and in women by 8 craniometric indicators. Figure 1 shows the difference in the size of the skull in the two studied regions in men, Figure 2 shows similar parameters for women. It is obvious that the size of the skulls, regardless of gender, found on the territory of Southern Kazakhstan is much larger than that of their counterparts from Central Kazakhstan.

Table 2: Descriptive statistics of craniometric indicators by region (mm)

Serial number	Craniometric indicators	Abbreviation	Value	Male		Female	
				Central Kazakhstan	South Kazakhstan	Central Kazakhstan	South Kazakhstan
1	Longitudinal diameter (glabella-opistokranion)	g-op	Maximum	197	198	187	182
			Minimum	168	145	150	161
			Median/q25–q75	180/177–185	186/182–186	172/166.5–176	173/163–175
2	Transverse diameter (euryon-euryon)	eu-eu	Maximum	161	168	150	150
			Minimum	125	115	127	133
			Median/q25–q75	147/143–151	147/144–153	137/134–140	142/136–143
3	Height diameter (basion-bregma)	ba-b	Maximum	170	148	133	139
			Minimum	110	87	110	120
			Median/q25–q75	135/132–138	136/132.5–141	127/122–29	130/127–133
4	Skull base length (basion-nasion)	ba-n	Maximum	141	155	104	107
			Minimum	95	92	90	88
			Median/q25–q75	103/100–106	102/100–107	95/94–99	95.4/93–98
5	Minimal forehead width (frontotemporale-frontotemporale)	ft-ft	Maximum	130	123	104	113
			Minimum	86	90	83	84
			Median/q25–q75	98/95–102	98.2/95–100.5	94/89–97	94/91.5–97
6	Skull base width (auriculare-auriculare)	au-au	Maximum	144	143	130	131
			Minimum	112	114	108	112
			Median/q25–q75	131/127–135	129/125–133	120.5/117–122	123/120.35–126
7	Asterion width (asterion-asterion)	ast-ast	Maximum	140	138	116	117
			Minimum	77	103	98	94
			Median/q25–q75	116/112–120.5	115/112–119	107.5/102–111	109.5/107–112
8	Mastoid width (mastoidale-mastoidale)	m-m	Maximum	124	120	112	115
			Minimum	94	96	86	96
			Median/q25–q75	110/107–115	112/107–115	101/97–105	104/101.45–105
9	Skull circumference (by glabella)	-	Maximum	595	560	550	525
			Minimum	490	504	470	480
			Median/q25–q75	530/520–539	530/520–540	503.25/494–514	500/494–516
10	Sagittal chord (nasion-opistion)	n-o	Maximum	183	184	145	188
			Minimum	123	123.6	123	100
			Median/q25–q75	138.5/135–142	139/135–143	128.5/127–133.5	130/127–134
11	Frontal chord (nasion-bregma)	n-b	Maximum	128	130	117	119.7
			Minimum	105	102	75	101
			Median/q25–q75	114/112–118	115/111–119.3	106/103–110	107/104.75–111
12	Bregma chord (bregma-lambda)	b-l	Maximum	140	135	152	113.6
			Minimum	97	84	80	94.3
			Median/q25–q75	111/108–115	112/108–116.5	103/101–108	105.5/102–109
13	Foramen magnum length (basion-opistion)	ba-o	Maximum	49	47	40	41
			Minimum	31	31	30	31
			Median/q25–q75	37/36–38	36.5/34.8–37	34/33–35	35.3/34.2–36
14	Foramen magnum breadth	-	Maximum	41	36	34	35
			Minimum	27	26	24	25
			Median/q25–q75	31/30–33	31/29–32	28/27–30	30/28–30.8
15	Bizygomatic diameter (zygion-zygion)	zy-zy	Maximum	150	150	132	137
			Minimum	92	115	106	121
			Median/q25–q75	134/131–139	137/133–139	124.5/122–127	127.2/126–131
16	Face base length (basion-prostion)	ba-pr	Maximum	114	108	110	98
			Minimum	84	63	83	82.5
			Median/q25–q75	95/92–98.5	96.6/93.7–100	92/87–94	92/89.2–94
17	Upper face height (nasion-alveolare)	n-al	Maximum	91	89.3	71	76.4
			Minimum	58	63	52	60
			Median/q25–q75	72/68–75	73.45/70–76	64.5/63–67.5	68.3/64–70.1
18	Full face height (gnation-nasion)	gn-n	Maximum	140	141.2	124	122
			Minimum	100	108	92	100
			Median/q25–q75	121/114–125	123.45/117–127.4	108.8/105.5–111.5	114/110–119
19	Upper face width (frontomalaretemporale-frontomalaretem-porale)	fmt-fmt	Maximum	120	125	108	108.5
			Minimum	94	99	85	96
			Median/q25–q75	106/104–109	107/105–110.2	102/98–104	102/100–105
20	Medium face width (zygomaxillare-zygomaxillare)	zm-zm	Maximum	134	113.2	99	100
			Minimum	71	89	79	82
			Median/q25–q75	95/91.25–99	97/94–101	89/85–93	90/88–93
21	Nose height (nasion-nasospinale)	n-ns	Maximum	65	64.4	55	60.1
			Minimum	45	36	41	46.4
			Median/q25–q75	54/52–56	55.45/53.05–57.95	48/47–49	50/48–52
22	Orbit width (left) (maxillofrontale-ektokonchion)	mf-ek	Maximum	51	49	42	49
			Minimum	36	37	32	36
			Median/q25–q75	43/40–45	42/39.4–44	39/37–40	39/38–40.3
23	Condylar width (between the external surfaces of mandible condyles)	-	Maximum	139	138.3	119	125
			Minimum	104	107	99.5	105
			Median/q25–q75	123/117–127	123.5/120–128	113/112–117	117/111.5–119.5
24	Bigonial width (gonion-gonion)	go-go	Maximum	122	116	102	108.7
			Minimum	89	90	84	83
			Median/q25–q75	103/100–109	105.25/100–108	95/91–98	94.7/92–102
25	Mandible body height (gnathion-infradentale)	gn- id	Maximum	43	40.2	44	34
			Minimum	23	28	21	23
			Median/q25–q75	32/29–34	33.9/31.5–34.7	29/26–31	29/26.1–30.7

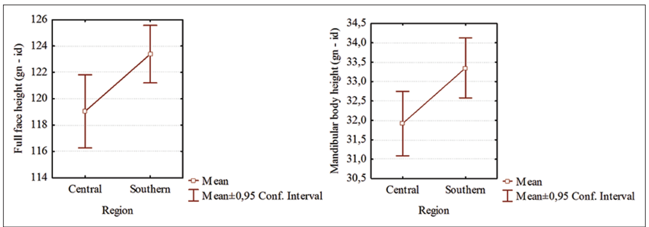

Figure 1: Comparative characteristics of craniometric indicators of full face height (gn-n) and mandible body height (gn-id) in male skulls depending on the region (Welch-test)

Data on the ethnicity of each examined skull were obtained during the research, but the sample as a whole was taken as representative of the "typical" population of Central and Southern Kazakhstan for specific frequency statistics. For all the studied skulls of both genders, regardless of the region of detection, the predominance of brachycrane and mesocrane forms of the skull was noted. The cranial index in brachycephaly was > 81.1% in men, >83% in women, in mesocephaly in men - 76% to 81%, in women - from 75% to 83%.

Table 3: Comparative characteristics of craniometric indicators of female skulls depending on the region (Welch-test)

Craniometric indicators	Mean ± SD		t	df	p	Mean 1 - Mean 2	Confidence	
	Central Kazakhstan	South Kazakhstan					−95.00%	95.00%
Transverse diameter (eu-eu)	137.7 ± 4.7	142.1 ± 5.0	−3.483	59	0.001	−4.35806	−6.86211	−1.85402
Skull base width (au-au)	119.7 ± 4.9	122.8 ± 4.7	−2.390	56	0.020	−3.04524	−5.59758	−0.49289
Mastoid width (m-m)	100.7 ± 6.2	103.7 ± 4.1	−2.140	53	0.037	−3.02262	−5.85571	−0.18952
Upper face height (n-al)	64.5 ± 4.4	67.9 ± 4.4	−2.798	51	0.007	−3.36029	−5.77159	−0.94899
Nose height (n-ns)	47.9 ± 3.1	50.6 ± 3.4	−3.176	56	0.002	−2.8621	−4.3806	−0.99181

The means, SD are presented in rows marked mean ± SD. SD: Standard deviation.

Table 4: Comparative characteristics of craniometric indicators of male skulls depending on the region (Mann–Whitney criterion)

Craniometric indicators	Central Kazakhstan, median/q25-q75	South Kazakhstan, median/q25-q75	U	Z	p
Upper face height (n-al)	72/68–75	73.45/70–76	2625	−2.00311	0.045166
Medium face width (zm-zm)	95/91.25–99	94/97–101	2603.5	−2.2242	0.026136
Nose height (n-ns)	54/52–56	55.45/53.05–57.95	2784	−2.46568	0.013676

The median, the lowest quartile (q25), and the highest quartile (q75) values are presented in rows marked Me/q25–q75.

Table 6 presents data on descriptive statistics of skulls found in the territories of Central and Southern Kazakhstan, according to the shape of the skull and races. The research showed that race affects the size of the skull base width (au-au) (U = 105.8, Z = 4.49, p = 0.002869), the bizygomatic diameter (zy-zy) (U = 111.8, Z = 5.53, p < 0.001) and the average width of the face (zm-zm) (U = 115.0, Z = 4.2, p = 0.00005) in men. Pairwise comparison of independent groups using the Mann–Whitney U-test shows statistically significant differences between the Mongolian and Caucasoid races according to these craniometric indicators. Male skulls also have statistically significant differences in the size of the condylar width and mastoid width (m-m) between races.

Table 5: Comparative characteristics of craniometric indicators of female skulls depending on the region (Mann–Whitney criterion)

Craniometric indicators	Central Kazakhstan, median/q25-q75	South Kazakhstan, median/*q25-q75*	U	Z	p-level
Height diameter (ba-b)	127/122–129	130/127–133	211	−3.0879	0.002016
Foramen magnum breadth (-)	28/27–30	30/28–30.8	258	−2.18733	0.028719
Bizygomatic diameter (zy-zy)	124.5/122–127	127.2/126–131	122	−2.9848	0.002838

The median, the lowest quartile (q25), and the highest quartile (q75) values are presented in rows marked Me/q25–q75.

Pairwise comparison of the skull base length (ba-n) in men, there were no statistical differences between the Mongolian, Caucasoid races, and mestizoes. At the same time, it should be noted that in female skulls found in the studied territories, the difference in the size of the skull between the races is less expressed. A comparative analysis of female skulls revealed statistically significant differences in 4 craniometric indicators out of the studied 25: foramen magnum breadth (N = 10.5, df = 3, p = 0.0146) (χ^2 = 11.4, df = 3, p = 0.0099), skull circumference (N = 10.9, df = 3, p = 0.0125) (χ^2 = 9.3, df = 3, p = 0.0255), medium face width (zm-zm) (N = 16.0, df = 3, p = 0.0012) (χ^2 = 16.1, df = 3, p = 0.0011) and the mandible body height (gn-id) (N = 12.0, df = 3, p = 0.077) (χ^2 = 8.8, df = 3, p = 0.0323) in the Kruskal–Wallis test and in the Median test.

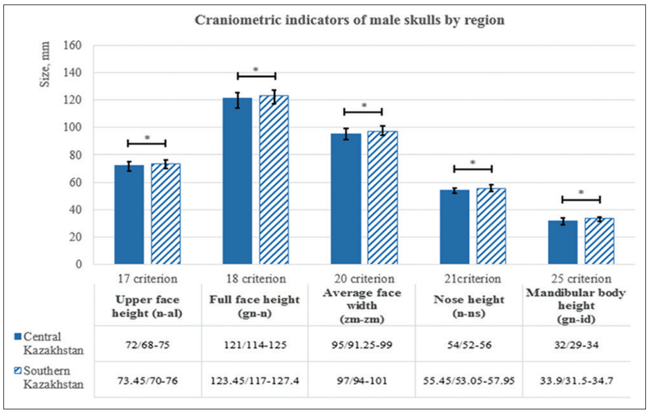

Figure 2: Comparative characteristics of craniometric indicators of male skulls by region

Statistically significant differences were revealed in the median test for 2 craniometric parameters: such as the frontal chord (n-b) ($\chi2$ = 9.1, df = 3, p = 0.0281) and the full face height (gn-n) (χ^2 = 7.9, df = 3, p = 0.0485). Statistically significant differences in the Kruskal-Wallis test were established only when evaluating such a craniometric indicator as the foramen magnum length (ba-o) (N = 9.5, df = 3, p = 0.0231). It should also be noted that there are statistically significant differences in the size of the foramen magnum breadth and the medium face width in the skulls of women between races.

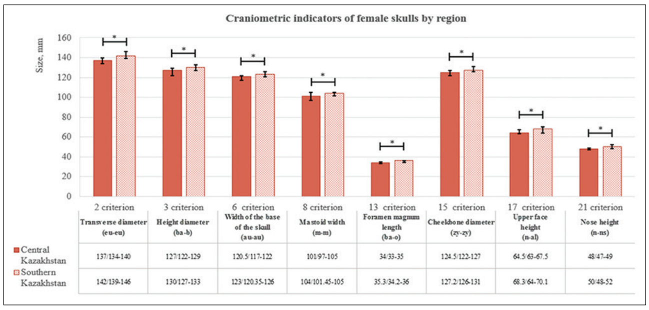

Figure 3: Comparative characteristics of craniometric indicators of female skulls by region

Discussion

The main hypothesis adopted in this work is the presence in human populations of morphological features of the skull structure with changes in craniometric parameters depending on the place of residence in the territory of the Republic of Kazakhstan due to climatic, ecological, nutritional characteristics,

Table 6: Descriptive statistics of craniometric indicators depending on the shape of the skull and race, mm

Serial number	Craniometric indicators	Abbreviation	Value	Men			Women		
				Mestizoes	Mongolian	Caucasoid	Mestizoes	Mongolian	Caucasoid
1	Longitudinal diameter (glabella-opistokranion)	g-op	Maximum	197	192	198	182	176	187
			Minimum	169	145	168	159	176	150
			Median/q25–q75	180.5/174–188	181/175–185	182/178–186	174/170–175	176/176–176	171/166–175
2	Transverse diameter (euryon-euryon)	eu-eu	Maximum	158	157	168	150	143	149
			Minimum	142	115	125	133	143	127
			Median/q25–q75	147/144–150	147/144–154	147/143–150	142/137–144.5	143/143–143	138/136–147
3	Height diameter (basion-bregma)	ba-b	Maximum	144	170	155	139	130	133.2
			Minimum	125	87	110	123	122	110
			Median/q25–q75	134.5/130.5–137	136/132–140	135/132–140	130.5/127–133	126/122–130	127/124–130
4	Skull base length (basion- nasion)	ba-n	Maximum	109	155	155	107	94	104
			Minimum	97	95	92	90	90	88
			Median/q25–q75	102/100–103	102/100–107	103/100–107	97/94–99	92/90–94	95/93–98
5	Minimal forehead width (frontotemporale-frontotemporale)	ft-ft	Maximum	112	130	110	100.6	95	113
			Minimum	92	87	86	84	93	83
			Median/q25–q75	98/95–103	97.25/93.7–101.5	98.2/95.5–100.8	93/90–97	94/93–95	94.5/91–97
6	Skull base width (auriculare-auriculare)	au-au	Maximum	136	143	144	131	127	127
			Minimum	125	116	112	112	115	108
			Median/q25–q75	132/128–136	133.85/128–136	128/125–132	123/119.5–126	121/115–127	121/117–123
7	Asterion width (asterion-asterion)	ast-ast	Maximum	128	125	140	117	111	115
			Minimum	103	108	77	98	108	94
			Median/q25–q75	115/114–120	117/114–120	115/111–119	110/108–113	109.5/108–111	107/101–110
8	Mastoid width (mastoidale-mastoidale)	m-m	Maximum	124	122	120	112	105	108
			Minimum	101	96	97	96	105	86
			Median/q25–q75	114.5/107–117	113/110–116	110/107–114	105/102–08	105/105–105	101/98–103
9	Skull circumference (by glabella)	-	Maximum	559	575	595	525	523	550
			Minimum	500	517	500	485	510	470
			Median/q25–q75	525/520–538	530/520–538	530/520–540	504/500–516	516.5/510–523	495/490–507
10	Sagittal chord (nasion-opistion)	n-o	Maximum	149	184	183	139	130	188
			Minimum	123	131	123.6	100	127	123
			Median/q25–q75	139/135–142	138.85/135.5–142	139/135–143	132.3/128–134	128.5/127–130	128/127–134
11	Frontal chord (nasion-bregma)	n-b	Maximum	120	127	130	114	107	113.1
			Minimum	105	105	102	101	103	75
			Median/q25–q75	114/112–117	116/112–119	114/112–118	107/104.5–111	105/103–107	105.5/103–107
12	Bregma chord (bregma-lambda)	b-l	Maximum	124	125	140	112.4	107	152
			Minimum	97	84	98	94.7	107	80
			Median/q25–q75	112/109–118	11/108–114.4	112/108–117	104/102–108	107/107–107	105/102–108
13	Foramen magnum length (basion-opistion)	ba-o	Maximum	42	47	44	40	34	41
			Minimum	33	33	31	32	33	30
			Median/q25–q75	37.5/35–38	36.9/35–38	37/36–38	35/34.55–36	33.5/33–34	35/34–36
14	Foramen magnum breadth	-	Maximum	41	38	37	35	28	33
			Minimum	28	26	27	25	27	26
			Median/q25–q75	31/29–32.5	31/29–32	31/29.75–33	30/28.5–31	27.5/27–28	28/28–30
15	Bizygomatic diameter (zygion-zygion)	zy-zy	Maximum	141	150	148	137	132	130
			Minimum	126	115	92	117	126	106
			Median/q25–q75	135/134–139	140/137–145	133/129.5–137	127/125.5–131	129/126–132	124/122–127.2
16	Face base length (basion-prostion)	ba-pr	Maximum	106	108	114	97	93	100
			Minimum	88	63	82	82.5	85	83
			Median/q25–q75	96/95–99	97/92–100	96/93–98.8	92.4/89.5–94	89/85–93	92/87–94
17	Upper face height (nasion-alveolare)	n- al	Maximum	77	89.3	91	72.2	71	76
			Minimum	65	63	58	60	66	52
			Median/q25–q75	72/69–74.5	74.2/70–77	72/68–75	67.4/64–70	68.5/66–71	64/62.5–68
18	Full face height (gnation-nasion)	gn-n	Maximum	125	141.2	140	121	122	124
			Minimum	114	100	100	100	98	92
			Median/q25–q75	116/114–125	125.5/121–127.5	120.5/116–126	114.35/110.5–118	112/110–114	109/104–111
19	Upper face width (frontomalaretemporale-frontomalaretem-porale)	fmt-fmt	Maximum	117	125	118	100	104	85
			Minimum	94	99	96	108.5	105	108
			Median/q25–q75	107/102–112	107/106–111	107/104–110	101/100–105	104.5/104–105	102/98–103
20	Medium face width (zygomaxillare-zygomaxillare)	zm-zm	Maximum	108	134	112.2	99.2	99	99
			Minimum	91	89	71	81	94	79
			Median/q25–q75	97.5/95–100	100.5/96–105	94/91–98.75	91.5/89–93	96.5/94–99	87.5/85–89
21	Nose height (nasion-nasospinale)	n-ns	Maximum	63	65	64.4	57	48	56
			Minimum	49	42	36	45	45	41
			Median/q25–q75	55/53–57	55.5/52–58	54/52–56	50/47.65–51.6	46.5/45–48	48/47–51
22	Orbit width (left) (maxillofrontale-ektokonchion)	mf-ek	Maximum	51	49	50	49	39	42
			Minimum	39	38	36	36	37	35
			Median/q25–q75	44/41–46	42/40–44	42/40–45	39/38–40.3	38/37–39	39/38–40

(Contd...)

Table 6: *(Continued)*

Serial number	Craniometric indicators	Abbreviation	Value	Men			Women		
				Mestizoes	Mongolian	Caucasoid	Mestizoes	Mongolian	Caucasoid
23	Condylar width (between the external surfaces of mandible condyles)	-	Maximum	135	138	134	125	117	121
			Minimum	112	106	104	99.5	117	107
			Median/ q25–q75	126/123–128	125/122–131.5	122/117–125.4	114/109.5–118.7	117/117–117	114.5/112–118
24	Bigonial width (gonion-gonion)	go-go	Maximum	112	116	122	108	95	102
			Minimum	96	89	90	83	95	83
			Median/ q25–q75	102.5/100–106	107/101–110.4	103/99–108	95.6/93.6–101	95/95–95	93.75/90.5–97
25	Mandible body height (gnathion-infradentale)	gn-id	Maximum	33	40.2	43	32	26	44
			Minimum	29	28	23	25.5	26	21
			Median/ q25–q75	31/31–32	34/32–35	32/30–34.7	29/26.1–30.7	26/26–26	27.5/25–30

and other endo- or exogenous factors. According to Francisco *et al.* [7] and von Cramon-Taubadel [15], the good preservation of the skull, provided by the strength of the bone structure, makes craniometry of the skull a unique tool for both archaeological and forensic medical research. The proportions of the human skull in both men and women are not only strictly individual but also extremely stable [1], [10], [19], [20]. However, the results obtained by studying the size of skulls found on the territory of the two largest regions of Kazakhstan clearly show the dependence of the size of the skull in permanent residents of a particular area. Analysis of the obtained data indicates that some craniometric indicators in the skull samples of residents of the two regions of Kazakhstan differ from those reported by other authors for different regions of Europe [21], Asia [2], [11], [22], [23], [24], Africa [25], USA [26], CIS [27], [28], and others [1], [29], [30], [31]. A characteristic feature of the craniometry of the population of the central region of Kazakhstan in representatives of both genders is the smaller size of the upper face height and nose height, as well as the full face height, medium face width, mandible body height - in men and the size of the transverse and height diameters, skull base width, medium face width and foramen magnum length - in women. According to Hartley *et al.* [32], the difference in craniometric indicators is mainly due to the difference in the ethnic composition of the population. Today's Kazakhstan is a state with a multi-ethnic composition of the population. According to official data, at the beginning of 2021, Kazakhs make up 69.01% of the population, Russians - 18.42% and other nationalities 12.57% [27], [33]. The population of Kazakhstan is ethnically diverse and its composition varies significantly in different regions of Kazakhstan. Thus, in the southern region of Kazakhstan, the Kazakh ethnic group prevails; this region is more mono-national. At the same time, it is impossible not to note the presence in this region of representatives of such nationalities as Uighurs, Koreans, Chinese, Uzbeks and others. The central part of Kazakhstan is mainly populated by descendants of immigrants from the middle part of Russia - Germans, Russians, Ukrainians, and Belarusians. Thus, the combination of the predominant sizes of the upper face height and full-face height, the medium face width, the nose height, and the mandible body height in men is characteristic only for inhabitants of the Southern region and, according to some authors [23], [28], is most likely due to the special predominance in the ethnic composition of the nationalities of the Mongolian race, which, as a rule, is accompanied by an increase in the size of the width of the face. On the other hand, the size of the nose height varies greatly in different populations [19], [31], [34], [35]. In many countries and populations, different research formats have been carried out in different years to understand the morphological parameters of the ethnic nose, which made it possible to develop special indicators in regions with typical Korean, Chinese, Japanese, Mediterranean, African-American craniometric indicators [2], [25], [30], [31]. In addition, Maddux *et al*. [36] and some other researchers have substantiated the relationship between the nasal index and climate [15], [23]. It is possible that the detected differences in the size of certain craniometric indicators are associated with completely different climatic conditions in the two studied regions of Kazakhstan. The climate in the central part of Kazakhstan is sharply continental with hot temperate summers and cold, snow-free winters, and the southern part is continental with moderately warm winters and hot, long summers. According to the literature data, when a person moves from southern latitudes to the north, the shape of the nose changes [37], [38], what is consistent with the results of our research.

It should be noted that according to Iscan, the size of the facial skeleton depends on latitude and is partly related to temperature diversity [3]. Nutritional characteristics and altitude above sea level are also variables that mainly explain variations in the shape of the skull, while the average annual temperature also plays a role [7], [10], [39]. However, the relationship between climatic factors and variations of the skull ranges from low to moderate, while the average annual temperature explains almost 40% of the variations in the shape of the entire skull, facial skeleton, and cranial vault, according to some researches [13], [40]. Moreover, according to several studies, changes in the nutrition depending on the characteristics of the national cuisine were associated with the gracilization of the chewing apparatus [14], [15]. Okkesim and Sezen Erhamza *et al.* [41] suggested that a decrease or increase in loads explains the morphological differences of the mandible in modern people. Our results indicate that climatic factors could also have a partial influence on the shape of the face and arch and, consequently, moderately contribute to the diversification of the population of the southern part of Kazakhstan. It is possible that cranial variability in Kazakhstan was formed under the influence of a complex of factors.

It is also necessary to take into account the dependence of the size, general shape of the person on age, gender, race, constitutional and individual characteristics of the organism. The latter are formed under the influence of hereditary factors and also depend on the physical condition, the presence or absence of pathological changes, social status (nutrition, speech), and other factors [16], [20]. There is a correlation between the development of the face and the degree of development of the visual organ, upper respiratory tract, jaw apparatus, and oral organs [32], [39]. The proportions of the parts of the face vary depending on age. According to Noble *et al*. [29], while aging, one of the main factors of changing the proportions of the face is changes in the maxillary apparatus associated with atrophy of the alveolar processes of the upper and lower jaws after tooth loss, as a result, the height of the upper and lower jaws decreases. As a result of complete loss of teeth, the face becomes much wider, and the general trend of face change with age is expressed by a decrease in the height of the facial skull [35], [40], [41].

Our results show that the average absolute size of the cranium in the compared ethnic groups does not differ very much. According to the literature data, Tuvinians and Bashkirs are noticeably distinguished by their large size of the skull [33], [42], while the cranial box in the form of both they and Kazakhs is usually medium-high in shape with the dominance of meso- or brachycrania, which is fully confirmed by the conducted researches.

According to Lacruz *et al*., the specific features of the anthropological type of Kazakhs were formed and developed mainly on the basis of the ancient Kazakh Caucasoid race with prolonged contact with the new coming Mongolians [16]. According to Ismagulov *et al.* [33], in the classification of races, Kazakhs are assigned to the central group of the Turkish subspecies of the Mongolian race, which have a brachiocephalic type of skull with a cephalic index from 85 to 87, the nose is straight and prominent, the face is oval, the zygomatic bones are prominent and expand laterally. In addition, according to some data, the Kazakh nose is quite wide, its width is greater than that of representatives of the Caucasoid and Mongolian populations but less than that of the Negroid race [27], [28]. The conducted intergroup analysis of the complex of morphophysiological indicators of the modern population of the Republic of Kazakhstan as a whole demonstrates that, according to all anthropological signs of high taxonomic significance, the Kazakh population occupies an intermediate position between representatives of the Mongolian and Caucasoid large races. The population of Kazakhstan, regardless of the region of residence, has been a representative of a biosocial community for many years; people constantly create a circle of consort relations in the same specific territory, thereby transferring population-genetic characteristics to subsequent generations. According to the conducted researches, the physical type of the population of Kazakhstan appears to be mixed and does not exclude belonging to a mixed Turanoid race according to the anthropological classification [33], within which it forms its own Kazakh version.

The present analysis of the data obtained is consistent with the data obtained by other authors [1], [8], [23] on the influence of the place of residence on the size of the skull in inhabitants of different countries and peoples, creating a certain characteristic picture of variations in craniometric indicators in a particular area. Thus, the craniometric indicators of the population of Kazakhstan have specific anthropometric differences and are not typically “Asian,” and some of their proportions turned out to be more characteristic of Caucasoid. It can be assumed that the process of anthropological mixing (the process of craniological homogenization) in the populations of South Kazakhstan is less pronounced than in the central region of Kazakhstan. Summarizing the obtained data, it should be noted the increased size, regardless of gender, nose height, and upper face height in inhabitants of the southern region, which differ significantly from those in the central region. The revealed craniometric differences are quite specific, unchangeable, and allow the analysis of specific quantitative craniometric indicators to determine the region of permanent residence of a person.

This research has some limitations related to the limited number of skulls examined since craniometric studies were carried out only with respect to cadaveric material. In addition, restrictions are associated with a detailed study of the size of skulls found only in two regions of Kazakhstan. The absence of macro statistical data reflecting the reference values of craniometric indicators of the skull size of the population of Kazakhstan did not allow us to establish the difference between the regions in relation to the reference values. In addition, the limitations of the research also apply to comparative research. When assessing the conjugacy of some data, it should be noted that in the comparative evaluation of the results of the research, only those variables or their values that could be estimated by paired comparison were grouped and evaluated. These disproportions can be attributed to the objective limitations of the research.

Conclusion

In recent years, there has been increased awareness of the need for research toward the development of anthropological standards focused on specific populations, resulting in a growing collection of published forensic anthropological standards for many different groups of the world's population. At the same time, there is a general paucity of such researches concerning the modern population of Kazakhstan, especially with regard to statistically quantitative standards for assessing the size of the skull. The most practical solution to solve this shortcoming is to obtain the necessary biological data from medical modalities. This research is part of a broader ongoing research program aimed at strengthening the capabilities of Kazakhstani forensic practitioners by developing anthropological standards targeting specific populations by region.

Author's Contribution

Anastasia Stoyan: Resources, collection of materials, writing of the initial version. Saule Mussabekova: Conceptualization, research, methodology, verification, formal analysis, visualization, writing of original and editing. Ksenia Mkhitaryan: Data processing, resources, preparation of graphic support.

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