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Forensic evaluation of craniometric characteristics of the Kazakhstan population

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ABSTRACT

Background: The human skull is the part of the skeleton most frequently used in population studies, as it was more exposed to genetic factors and less exposed to environmental factors. The skull is an important component in human forensic identification.

Materials and methods: The craniometric characteristics of 186 male and 114 female skulls found on the territory of Kazakhstan were studied. Dimensions were measured using standard anthropometric methods and instruments. The results of measurements of 25 craniometric parameters are presented. Methods of descriptive and parametric statistics were used.

Results: Statistical analysis showed significant regional dimorphism, confirming theindividuality of the Kazakhstan population. Statistically significant deviations werefound in 6 male craniometric characteristics and 4 female craniometric characteristics($p<0.05$). The most dimorphous variables for regional identification in Kazakhstanmales were the higher skull base and frontal chord width , full face height , condylarand bigonial width , and low mandibular body reference values ($p<0.05$). For females,significant statistical discrepancies were seen in the transverse diameter and skullbase width, mastoid and occipital aperture width ($p<0.05$).

Conclusion: The recorded variations and changes in the morphology of the humanskull of the population of Kazakhstan indicate the need to develop and updateosteometric standards used in practice for specific populations. All this will significantlyimprove the accuracy of forensic identification and more fully study the biologicalpatterns of population formation, as well as evaluate the comparative effectiveness ofindividual features in the reconstruction of the population history of various populationgroups.

1. Introduction

The ability to identify individuals is a crucial forensic issue. Molecular and genetic methods currently lead forensic practice,[1–3] but suitable material is not always available, especially in cases involving advanced post-mortem changes or old burials. The skeleton, especially the skull, is a significant element in forensic investigations focusing on identifying unknown remains. Skull and bone form are reliable characteristics, but craniometrics can provide real advantages as the most objective means of generating data.[4] Statistical analysis of the skull is best achieved using reliable, well-established osteometric methods.[5,6] In recent years, craniometric measurements have become an important tool used by anthropologists, forensic experts and reconstructive surgeons. Many researchers using the method have dedicated their research to races and nationalities. Many academic papers exist discussing research into postcranial skeletons in different populations.[4,7–9] Forensic processes in many countries apply the craniometric techniques based on the skull measurements of individuals of known gender and race developed by E. Giles.[1,9,10] Throughout the CIS (Commonwealth of Independent States), including the Republic of Kazakhstan, independently of the population living here, forensic experts use conditionally accepted craniometric criteria developed by V.I. Pashkova et al.[11] The authors developed her reference values by studying 682 skulls belonging to individuals of exclusively Russian nationality who lived in northwest Russia in the 19th and the start of the 20th centuries. Despite this, the criteria have been recognized in the CIS in general for geographically and genetically

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remote populations. At the same time, scientific research is available that confirms the impact of the environment (in a broad sense) on skull form.[5,12–14] The issue around the specific role of genetic, environmental, and stochastic variances in human skulls remains valid.[6,8,13] The majority of scientists do not doubt the impact of environmental factors on the human skull.[3,15–17] Researchers agree that local ecological or genetic factors (among others) do affect relative size and expression.[2,5,18–20] In this case, the accuracy of identification based on reference values CIS which do not apply to specific populations, may be questionable. Reference materials created from single population data are not representative of other populations. However, the regional adaptation of craniometric indicators of the population of the Republic of Kazakhstan have not been studied. Most research focuses on the demographics of archaeological remains, except for several x-ray research projects on the cephalic-dentoalveolar morphology of modern populations of Kazakhstan.[21,22] There has been little research into the skull characteristics of the modern Kazakhstan population, which confirms the importance of and the need to create standards that focus on the Kazakhstan population.

Research objective: to identify population variations in craniometric characteristics of people of Kazakhstan for forensic identification purposes.

2. Materials and methods

2.1. Sampling regions and methodology

The craniometric characteristics of well-preserved adult skulls of 187 men and 114 women found in the territory of Kazakhstan (from 1998 to 2021) have been studied. All samples in question belonged to individuals aged 22–70. Faces with clear inborn or acquired skull pathology were removed from the research due to the possible influence on standard physiology or an inability to identify skull references.

2.2. Data acquisition and ethical approval

Written permission to conduct osteometric measurements and studies was given by law enforcement authorities. The study was conducted based on permission to conduct research using human tissues issued by the Local Commission on Bioethics (protocol No. 4 of June 12, 2021).

2.3. Sample pre-treatment procedures

Initially, the studied samples were cleaned mechanically from soft tissues and soil overlays. Then the purified samples were dried at a temperature of +18-20 °C. After drying, bone objects were degreased in chloroform in an alcohol-ether mixture (1:1). Gluing the bone fragments of the skull, if necessary, was carried out with a water-soluble glue (polyvinyl acetate). The prepared samples were packed, labeled, and stored in a relative humidity of 50 % and a temperature of +18-20 °C.

2.4. Research methods

Each skull was measured using 23 standard craniometric points for 25 craniometric indices. The dimensions of the skull and its formations were determined using standard anthropological craniometric instruments: Caliper, Sliding Caliper, Spreading Caliper with Rounded Ends 300 mm and 600 mm, Steel Tape, and Mandibulometer [Black type] (Model 218). Achievement of adult age was established by the fusion of the main-occipital synchondrosis and the stage of an eruption of the 3rd molar. A summary table of reference values for male and female skulls was used to identify skull gender.[23] To determine skull form we used a cephalic index representing the percentage ratio between skull vault transverse and linear dimensions, which was calculated as: $в \times 100/a$, where $в$ is the transverse skull dimension and a is the linear skull dimension. Race was determined using craniometric attributes and a one-dimensional discriminant model of adult faces as per the dimensions of angles and cephalic indices.[23]

The data was processed using Statistica 13.3 (StatSoft Inc., USA) and SPSS 12.0.2 programs. Descriptive and parametrical (Welch t-criteria for two independent samples) statistics were used. Special Shapiro-Wilk criteria were used to assess the normalcy of continuous variables. Value deviations were recognized as statistically significant for two comparison groups when the probability was over 95 % ($p < 0.05$).

3. Results

Sexual dimorphism was assessed for the 25 craniometric characteristics in skulls discovered in Kazakhstan after all rejections. Descriptive statistics presented as maximum (*max*), minimum (*min)* and mean values (*M*), standard deviations (*SD*), and standard error of the mean (*SEM*) was also calculated. Table 1 presents descriptive statistics for the dimensions of male and female skulls discovered in Kazakhstan and reference values.[11]

The large sizes of male skulls compared to female ones are typical for the population all over the world, which is fully applicable to the proportions of the male and female braincases in the population of Kazakhstan. Averages for men are about 110 % of the corresponding averages for women. Mesocranial skull forms are prevalent among the Kazakhstan population, irrespective of gender, with the cephalic index for men between 76 % and 81 %, and between 75 % and 83 % for women.

Analysis of the craniometric characteristics studied showed that the dimensions of skulls discovered in Kazakhstan and conditionally accepted reference values in CIS[11] used in forensics for identification purposes in Kazakhstan differ. Subsequent separate benchmark studies around distribution normalcy were conducted for males and females. Comparative statistics were analyzed in quantitative terms exclusively with standard-distribution (normal) craniometric characteristics. All other criteria whose distribution differed from standard comparative statistics were not analyzed. A quantitative data analysis established that only 7 craniometric characteristics in males and 14 craniometric characteristics in females, out of the 25 characteristics studied, followed normal distribution rules. Further statistical studies of these criteria were conducted using Welch t-criteria for two independent samples. A comparison of the craniometric characteristics of two unrelated groups with the same age and gender criteria established that the dimensions of skulls discovered in Kazakhstan, irrespective of gender, noticeably differ some of them from generally accepted table data used as reference values in forensics in Kazakhstan. As such, a comparative analysis of 7 craniometric characteristics in males showed that 6 of them: skull base width (au-au), frontal chord (n-b), full face height (gn-n), condylar width, bigonial width (go-go), and mandible body height (gn-id) (Fig. 1) differ significantly in statistical terms from reference values ($p < 0.05$).

The bar diagram presented illustrate the differences between the craniometric characteristics of male skulls in Kazakhstan and conditionally accepted reference values (Fig. 2).

A comparative study of the average values of the sizes of the female skulls of the population of Kazakhstan with generally accepted standard data showed only 4 out of 14 craniometric indicators that obey the law of normal distribution show a statistically significant difference ($p < 0.05$). It should be pointed out that for female skulls discovered in Kazakhstan, craniometric characteristics, such as transverse diameter (eu-eu) ($M = 139.9$ against $M = 138$), skull base width (au-au) ($M = 121.2$ against $M = 117$), mastoid width (m-m) ($M = 102.2$ against $M = 100$) and occipital aperture width ($M = 29.06$ against $M = 28$) exceed the corresponding conditionally accepted reference values significantly (Fig. 3).

Fig. 4 shows statistically significant differences in 4 craniometric parameters in women.

Craniometric characteristics for skulls discovered in Kazakhstan,

Table 1
Comparison of cranial measurements (mm) of skulls in Kazakhstan and reference values used for identification in forensic practice.

No.	Measurements	Abbreviation	Value	MALES		FEMALES	
				Craniometric measurements of the population of Kazakhstan	Conditionally accepted reference values in CIS[11]	Craniometric measurements of the population of Kazakhstan	Conditionally accepted reference values in CIS[11]
1	Lateral diameter (glabella-opisthocranion)	g-op	max	198	200	187	187
			min	145	160	150	151
			M ±SD	181.0 ± 7.0	178.5 ± 6.9	171.6 ± 6.0	172 ± 6.8
			SEM	0.54	0.35	0.79	0.40
2	Transverse diameter (euryon-euryon)	eu-eu	max	168	158	150	152
			min	115	127	127	122
			M ±SD	147.2 ± 6.6	143 ± 5.4	139.9 ± 5.3	138 ± 5.5
			SEM	0.50	0.28	0.68	0.33
3	Height diameter (basion-bregma)	ba-b	max	148	153	139	141
			min	87	121	110	111
			M ±SD	135.2 ± 7.8	134 ± 5.5	127.5 ± 5.2	128 ± 5.3
			SEM	0.59	0.28	0.69	0.32
4	Skull base length (basion-nasion)	ba-n	max	155	114	107	109
			min	92	90	88	82
			M ±SD	104.4 ± 9.0	101 ± 4.2	95.91 ± 4.0	96 ± 4.6
			SEM	0.72	0.21	0.54	0.28
5	Minimal forehead width (frontotemporale-frontotemporale)	ft-ft	max	130	115	113	108
			min	86	86	83	84
			M ±SD	98.62 ± 5.8	98 ± 4.4	94.05 ± 5.3	95 ± 4.6
			SEM	0.46	0.22	0.69	0.28
6	Skull base width (auriculare-auriculare)	au-au	max	144	138	131	133
			min	112	112	108	104
			M ±SD	130.1 ± 6.0	123 ± 5.1	121.2 ± 5.1	117 ± 5.7
			SEM	0.49	0.26	0.70	0.34
7	Asterion width (asterion-asterion)	ast-ast	max	140	126	117	120
			min	77	99	94	94
			M ±SD	116.0 ± 7.3	110.5 ± 4.6	107.7 ± 5.2	107 ± 4.7
			SEM	0.58	0.25	0.69	0.28
8	Mastoid width (mastoidale-mastoidale)	m-m	max	124	120	115	116
			min	94	92	86	86
			M ±SD	110.5 ± 5.8	105 ± 5.1	102.2 ± 5.4	100 ± 5.2
			SEM	0.46	0.27	0.73	0.32
9	Skull circumference (glabella)	–	max	595	560	550	540
			min	490	476	470	465
			M ±SD	529.9 ± 15.3	516.5 ± 15.4	503.6 ± 14.8	500 ± 15.3
			SEM	1.22	0.80	2.02	0.95
10	Sagittal chord (nasion-opistion)	n-opis	max	184	151	188	145
			min	123	123	100	111
			M ±SD	140.7 ± 10.2	134.5 ± 4.8	130.7 ± 10.0	128.5 ± 5.7
			SEM	0.82	0.24	1.34	0.35
11	Frontal chord (nasion-bregma)	n-b	max	130	125	119.7	121
			min	102	99	75	90
			M ±SD	114.8 ± 5.0	111.5 ± 5.0	106.5 ± 6.1	107.5 ± 5.2
			SEM	0.39	0.25	0.82	0.31
12	Bregma chord (bregma-lambda)	b-l	max	140	132	152	124
			min	84	94	80	93
			M ±SD	112.0 ± 7.6	110.5 ± 6.5	105.2 ± 8.5	107 ± 5.9
			SEM	0.61	0.36	1.12	0.37
13	Occipital aperture length (basion-opistion)	ba-opis	max	49	42	41	41
			min	31	30	30	29
			M ±SD	36.8 ± 2.7	36 ± 2.3	34.8 ± 2.3	34 ± 2.4
			SEM	0.21	0.12	0.30	0.14
14	Occipital aperture width	–	max	41	40	35	35
			min	26	25	24	23.5
			M ±SD	31.3 ± 2.4	30.5 ± 2.1	29.1 ± 2.3	28 ± 2.3
			SEM	0.19	0.11	0.30	0.15

(*continued on next page*)

Table 1 (*continued*)

No.	Measurements	Abbreviation	Value	MALES		FEMALES	
				Craniometric measurements of the population of Kazakhstan	Conditionally accepted reference values in CIS[11]	Craniometric measurements of the population of Kazakhstan	Conditionally accepted reference values in CIS[11]
15	Bizygomatic diameter (zygion-zygion)	zy-zy	max	150	147	137	139
			min	92	120	106	107
			M ±SD	134.5 ± 7.6	132 ± 5.4	126.0 ± 5.4	124 ± 6.0
			SEM	0.61	0.27	0.80	0.36
16	Face base length (basion-prostion)	ba-pr	max	114	115	110	107
			min	63	82	82.5	78
			M ±SD	95.7 ± 6.1	97.5 ± 5.2	91.6 ± 5.3	93 ± 5.5
			SEM	0.49	0.27	0.75	0.33
17	Upper face height (nasion-alveolare)	n- alv	max	91	84	76.4	78
			min	58	59	52	55
			M ±SD	72.3 ± 5.2	71 ± 4.5	66.1 ± 4.6	66.5 ± 4.1
			SEM	0.41	0.23	0.64	0.25
18	Full face height (gnation-nasion)	gn-n	max	141	139	124	132
			min	100	100	92	96
			M ±SD	121.4 ± 8.5	119 ± 7.0	111.3 ± 7.4	111 ± 6.9
			SEM	0.89	0.36	1.33	0.44
19	Upper face width (frontomalaretemporale-frontomalaretemporale)	ftl-ftl	max	125	117	108.5	113
			min	94	93	85	87
			M ±SD	107.1 ± 4.6	105 ± 4.1	101.6 ± 4.1	101 ± 4.6
			SEM	0.37	0.22	0.58	0.29
20	Medium face width (zygomaxillare-zygomaxillare)	zy-zy	max	134	106	100	74
			min	71	78	79	104
			M ±SD	96.5 ± 7.0	93.5 ± 5.1	89.8 ± 5.0	89 ± 5.5
			SEM	0.54	0.26	0.69	0.32
21	Nose height (nasion-nasospinale)	n-ns	max	65	60	60	56
			min	36	44	41	42
			M ±SD	54.5 ± 4.0	52 ± 3.2	49.3 ± 3.5	48.5 ± 3.0
			SEM	0.30	0.16	0.46	0.18
22	Orbit width (left) (maxillofrontale-ektokonchion)	mf-ec	max	51	52	49	48
			min	36	38	32	36
			M ±SD	42.7 ± 3.3	43.5 ± 2.0	38.9 ± 2.5	42 ± 2.1
			SEM	0.26	0.10	0.34	0.12
23	Condylar width (between the external surfaces of mandible condyles)	–	max	139	135	125	127
			min	104	105	100	100
			M ±SD	123.3 ± 6.8	118.5 ± 5.6	114.4 ± 5.2	113.5 ± 5.9
			SEM	0.59	0.29	0.84	0.35
24	Bigonial width (gonion-gonion)	go-go	max	122	449	109	112
			min	89	85	83	77
			M ±SD	104.1 ± 6.9	102.5 ± 6.6	95.07 ± 6.2	95 ± 6.3
			SEM	0.62	0.34	1.0	0.37
25	Mandible body height (gnathion-infradentale)	gn- id	max	40	43	34	41
			min	28	27	23	24
			M ±SD	32.6 ± 3.2	33.5 ± 3.1	28.7 ± 3.9	31 ± 3.1
			SEM	0.29	0.19	0.61	0.20

Note. The means (M) and standard deviation (SD) are presented in rows marked M±SD, standard error of the mean (SEM), minimum and maximum values.

irrespective of gender, included increased average skull dimensions, with the exception of mandible body height (gn-id) among males (*M ±SD*) (M = 32.55 ± 3.237 against M = 33.5 ± 3.1). It has been established that place of residence and ethnicity affect skull dimensions significantly, irrespective of gender.

Craniometric characteristics for skulls discovered in Kazakhstan, irrespective of gender, included increased average skull dimensions, with the exception of mandible body height (gn-id) among males (M ±SD) (M = 32.55 ± 3.237 against M = 33.5 ± 3.1). It has been established that place of residence and ethnicity affect skull dimensions significantly, irrespective of gender.

4. Discussion

The study results into the craniometric characteristics of skulls discovered in Kazakhstan show craniometric variations and point to specific morphological skull characteristics in the Kazakhstan population. According to Spradley M. et al.,[5] the human skull is the most commonly used skeletal element in population studies since it is more genetically determined and less influenced by environmental factors. All this indicates its uniqueness in the conduct of archaeological and forensic research. The data received confirms that some craniometric characteristics of skulls discovered in Kazakhstan differ from those reported by other authors for Europe,[24] Asia,[25–27] Africa,[28,29] the USA[30]

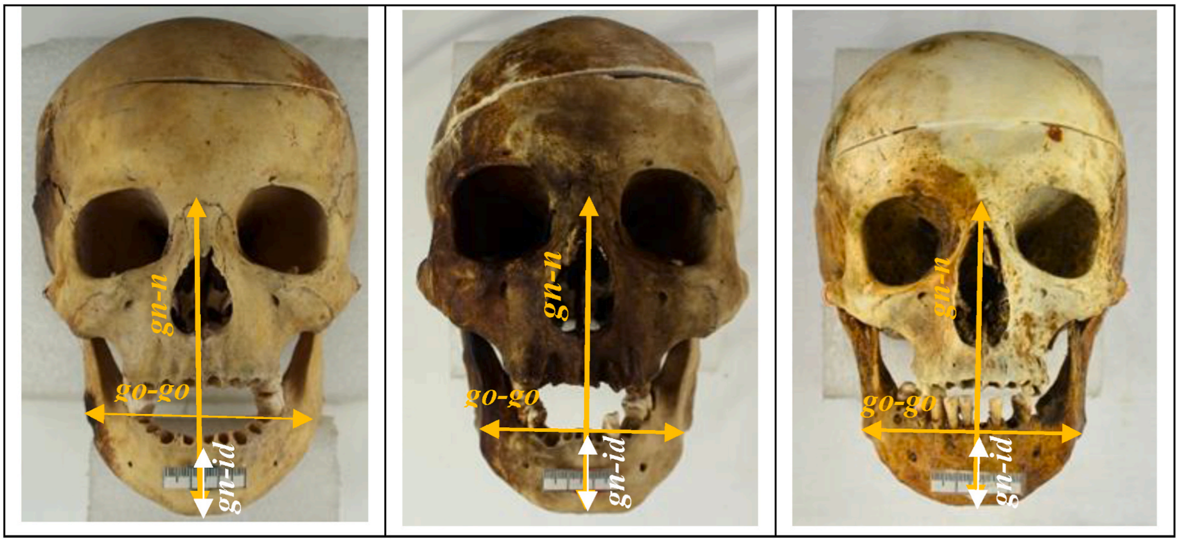

Fig. 1. Identification features of cranial measurements of male skulls in the population of Kazakhstan
Gn: gnathion; N: nasion; Go: gonion; Id: infradentale.

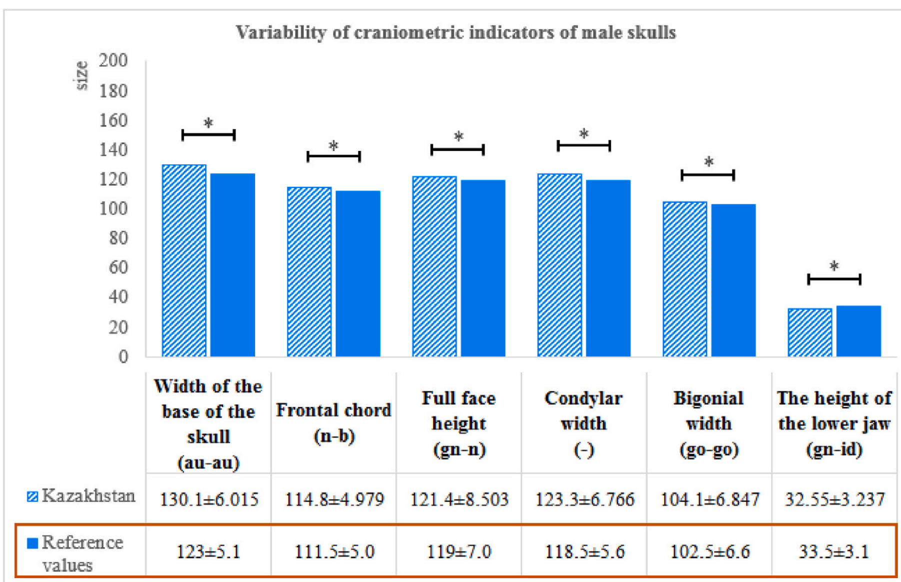

Fig. 2. Vertical column bar graphs (mean with ±SD) representing a comparative analysis of the craniometric indicators of male skulls found on the territory of Kazakhstan and conditionally accepted reference values.
Color coding was chosen in accordance with generally accepted gender designations: reference values (solid bars), craniometric indicators in Kazakhstan (crossed-out bars). The differences between craniometric indicators are significant when $p < 0.05$ (*).

and other countries.[8,31–34] This research confirms the same, i.e., the existence of statistically significant inconsistencies, irrespective of gender, between the dimensions of skulls discovered in Kazakhstan and conditionally accepted reference values used in forensic practice in the CIS.

Even though certain postcranial elements have recently been recognized as more effective in identifying gender,[12,35] the skull remains one of the most dimorphic parts of the skeleton. Recent research by Iscan M. confirmed that gender dimorphism was up to 85.7 % accurate when assessing skull characteristics.[15] Other researchers rate the significance of the various indicators differently, with the most accurate in identifying gender being lateral, height and zygomatic diameters, sagittal and frontal chords, nose height, upper and full face height, upper face width, bigonial and mastoid width, skull base length and width, and skull circumference.[11,12,24,36] Research shows that gender dimorphism in the Kazakhstan population is reflected in the skull dimension, thus guaranteeing highly accurate classification.

The dimensions of skulls discovered in Kazakhstan, irrespective of gender, demonstrate specific features confirming regional dimorphism. Research data received is sufficiently specific and allows us to identify to which population an individual belongs and place of residence according to craniometric characteristics. According to other literary data, skull base width, frontal chord, full face height, condylar width, and bigonial width, for which variances have been noted in this research, are well known as the most dimorphous in the human skull in different populations.[19,26,37] Previous studies also confirm that the significant population distinctions are linked to face width and skull length.[6,17] Analysis of research performed in Kazakhstan showed that the lateral diameter for both genders over the review period remained unchanged, while transverse skull diameter increased gradually, resulting in the

Fig. 3. Variations in cranial measurements and landmarks of female skulls in the population of Kazakhstan *Ast: asterion; M: mastoidale.*

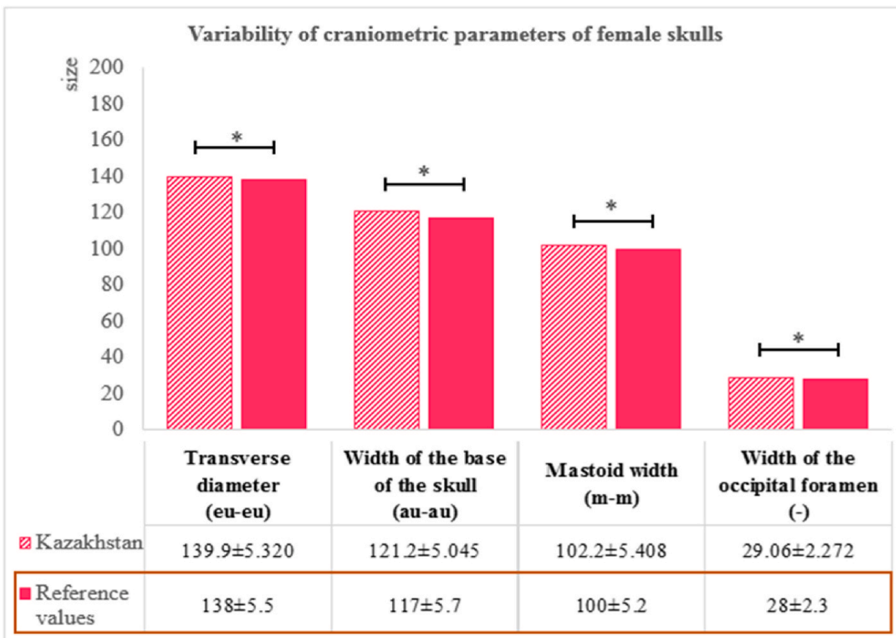

Fig. 4. Vertical column bar graphs (mean with ±SD) representing a comparative analysis of the craniometric indicators of female skulls found on the territory of Kazakhstan and conditionally accepted reference values.
Color coding was chosen in accordance with generally accepted gender designations: reference values (solid bars), craniometric indicators in Kazakhstan (crossed-out bars). The differences between craniometric indicators are significant when $p < 0.05$ (*).

cephalic index becoming mesocranial.[13,21] Studies show that statistically significant distinctions between comparable craniometric characteristics were more evident among males than females. According to Savoldi F. et al.,[38] the misbalance in craniometric characteristic dimensions is caused by several factors. At the same time, according to Liebenberg L. et al.,[39] the increased skull dimensions may be caused by the distinct ethnic makeup of the population, defined by geographic, climate, and other conditions.

We received data comparable with that of other authors, confirming that the relatively large dimensions of the middle part of the face testify to the prevalence of an Asian race.[40] At the same time, general interracial increases in Kazakhstan in recent years now mean that each 10th person born in Kazakhstan is from a mixed ethnicity relationship.[21,22] The racial amalgamation process in Kazakhstan historically has been relatively lengthy. The Kazakhstan population's interim position between Europeans and Asians may be explained by active miscegenation processes and reflects population mobility. Comparable results were received by Woo E. et al.,[26] Ekizoglu O. et al.,[41] and other researchers,[8,14,25] who discovered that natives of South Asia tend to have the highest forehead flatness index in the world, a high symotic index and a moderate maxillary index. At the same time, despite the high level of genetic diversity, the Kazakhstan population is a homogenous group that differ morphologically from other populations. According to Ismagulov O. et al.,[21] in an anthropological sample of the Kazakh population, as demonstrated by the genetic markers of distant biological ancestors, the ratio of Asian characteristics - 70 %, and European - 30 %. However, according to Lacruz R. et al.,[42] genetic relationship and the unity of origin are only one of the factors predetermining the morphological similarity of craniological samples. It may well be the strongest factor, but not the only one.[4,40] The use of craniometrics in population differentiation according to Sardhara J. et al.[43] testifies to the importance of various skull characteristics, not only multi-regional but also intra-regional distinctions within a single geographical region. Like all living, humans are influenced by a range of factors, which lead to modification changes reflecting the organism's reaction to changes in their environment (living conditions in different geographical zones, solar radiation intensity, diet, and others), which have adaptive value. Forensic and anthropological literature provides some explanations of the significance of living conditions in terms of anthropological attributes.[2,25,44] Some researchers have proved a link between facial morphology and climate.[19,45] Other authors believe that climatic adaptation differs in different regions, which is why they cannot be considered together.[7,42] However, there is still no consensus on the mechanisms of adaptation of the population of different climatic zones. Within and between populations, variation in the cranial index is explained by complex interactions between genetic and environmental factors.[6,14,46] Many modern researchers focus on specific aspects of discrepancies in craniometric characteristics based on nationality and place of residence, as well as several other factors.[16,19,31,37] As such, Kazakhstan's geographical location in latitudinal terms corresponds to Mediterranean countries with a humid and subtropical climate, as well as central European countries, which are known for their moderate continental climate. This analysis of data received corresponds to data from other authors on the combined impact of a range of factors that are highly specific to each region and which form a true picture of the deviations of craniometric characteristics compared to benchmark values.[5,18,34,42]

One of the linear dimensions that demonstrated variability compared to conditionally accepted reference values for males was the reduced mandible body height. According to Gillet C. et al.,[47] the mandible is the most dimorphous skull bone. According to findings from earlier evolutionary, experimental, and orthodontic studies, genetics and history of load on it impact the form of the mandible in adults.[17,36,48] Many researchers have tried to track changes in mandible morphology due to dietary habits.[18,33,42,49] This approach has already proven its effectiveness in highlighting mandible form deviations among populations that differed according to their survival strategy.[50,51] In our opinion, the leading factor in reducing the size of the lower jaw is a decrease in chewing load, not ethnicity.

5. Limitations

For comparative assessment of research findings, only those variables or their values that could be assessed using pairwise comparisons were grouped and evaluated. These disproportions and the lack of collinearity in the research and its findings can be treated as objective.

6. Conclusions

The findings in this paper show that features of the middle section of the skull front are best for studying the population history of groups according to craniometric data. The failure to identify beyond the conventionally accepted reference range used in forensic practice indicates the individuality of the craniometric indicators of Kazakhstan due to ethnic individuality, climatic adaptation and the specifics of lifestyle. The Kazakhstan population, thanks to its clearly defined morphological characteristics is clearly different from other comparable ethnic and race samples, while the reality of the independent anthropological status of the modern Kazakhstan population is clear. Differences due to region of origin, social factors, and health status are reflected in the craniometric characteristics of the population of Kazakhstan, so they are of value not only for forensic identification but also for anthropology in the reconstruction of the ancient history of mankind.

Authors' contributions

Saule A. Mussabekova: concept, research, methodology, review, formal analysis, visualisation, drafting of originals, and editing.

Anastasiya O. Stoyan: resources, collection, and first draft.

Kseniya E. Mkhitaryan: data processing and resources.

Saule B. Zhautikova: collection of data in tables, structuring and preparation of tables, diagrams, and illustrations.

Ethical approval

This research was approved by the Local Commission on Bioethics (approval number 4, dated December 6, 2021).

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Patient's/Guardian's consent

We do not have the form Patient's/Guardian's consent because we examined unknown remains found in the territory of Kazakhstan.

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Declaration of competing interest

All authors declare that they have no conflicts of interest.

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