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 3\(^{rd}\) 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       | Dolichocranes | Mesocranes       |
|                 | Mesocranes        | Brachyocranes    | Caucasoid   | Mongolian        |
|                 |                    |                  |             | Mestizoes        |
| Men             | 18                 | 34               | 54          | 35               | 38               | 33               | 31               | 32               | 38               | 7                | 65               | 9                |
| Women           | 12                 | 20               | 39          | 23               | 28               | 20               | 9                | 32               | 40               | 9                | 61               | 11               |
| In total        | 30                 | 54               | 53          | 58               | 66               | 53               | 20               | 64               | 78               | 16               | 125              | 20               |

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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: \( \frac{b}{a} \times 100/Z \), where \( b \) – transverse size of the skull, \( a \) – its longitudinal size. The diagnosis of race was carried out according to cranio metric 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 cranio metric 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 cranio metric 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 cranio metric 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 cranio metric indicators of male skulls found in different regions of Kazakhstan, statistically significant differences were revealed only by two cranio metric 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 mm (\( \text{M±SD} \)), 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 (\( \text{M±SD} \)), 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 cranio metric 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 cranio metric indicators of the size of female skulls in the two regions studied.

Next, quantitative cranio metric indicators having a different distribution from normal were analyzed using the Mann–Whitney criterion. The comparative analysis of cranio metric 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 cranio metric indicators are presented in Table 4.

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 cranio metric 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 cranio metric 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 Central Kazakhstan | Female Central Kazakhstan | Male South Kazakhstan | Female South Kazakhstan |
|---------------|-------------------------|--------------|-------|------------------------|------------------------|------------------------|------------------------|
| 1             | Longitudinal diameter (glabella-opisthokranion) | g-op         | Maximum | 197 | 188 | 187 | 182 | 168 | 145 | 150 | 161 | 187 | 134 | 135 | 137 |
| 2             | Transverse diameter (euryon-euryon) | eu-eu        | Maximum | 180/177–185 | 186/182–186 | 172/166.5–176 | 173/163–175 | 135 | 125 | 130 | 135 | 130 | 130 | 135 | 135 |
| 3             | Height diameter (basion-bregma) | ba-b         | Maximum | 170 | 148 | 133 | 133 | 110 | 87 | 110 | 120 | 136 | 133 | 130 | 127 |
| 4             | Skull base length (basion-nasion) | ba-n         | Maximum | 141 | 155 | 104 | 107 | 36 | 36.5 | 34.8–37 | 36 | 36.5 | 34.8–37 | 36 | 36.5 |
| 5             | Minimal forehead width | fl-ft        | (frontotemporale-frontotemporale) | Maximum | 130 | 123 | 124 | 124 | 112 | 114 | 108 | 112 | 112 | 112 | 112 | 112 |
| 6             | Skull base width (auriculare-auriculare) | au-au        | Maximum | 144 | 143 | 130 | 131 | 86 | 90 | 83 | 84 | 86 | 90 | 83 | 84 |
| 7             | Asterion width (asterion-asterion) | ast-ast      | Minimum | 140 | 138 | 116 | 117 | 77 | 84 | 98 | 94 | 77 | 80 | 98 | 94 |
| 8             | Mastoid width (mastoideol-mastoideol) | m-m          | Maximum | 124 | 120 | 112 | 115 | 90 | 96 | 96 | 96 | 90 | 96 | 96 | 96 |
| 9             | Skull circumference (by glabella) | -            | Maximum | 595 | 560 | 550 | 525 | 50 | 54 | 48 | 48 | 50 | 54 | 48 | 48 |
| 10            | Sagittal chord (nasion-opistion) | n-o          | Maximum | 183 | 184 | 145 | 188 | 39 | 40 | 41 | 41 | 39 | 40 | 41 | 41 |
| 11            | Frontal chord (nasion-bregma) | n-b          | Maximum | 128 | 130 | 117 | 119.7 | 97 | 100 | 90 | 100 | 97 | 100 | 90 | 100 |
| 12            | Bregma-chord (bregma-lambda) | b-l          | Minimum | 140 | 135 | 152 | 133 | 97 | 84 | 80 | 94.3 | 97 | 84 | 80 | 94.3 |
| 13            | Foramen magnum length (basion-opistion) | ba-o         | Minimum | 49 | 47 | 41 | 41 | 31 | 31 | 30 | 31 | 31 | 30 | 31 | 30 |
| 14            | Foramen magnum breadth | -            | Maximum | 37/36–38 | 36.5/34.8–37 | 34.3/33–35 | 35.3/34.2–36 | 36 | 35 | 35 | 35 | 35 | 34 | 35 | 34 |
| 15            | Bivymgomatic diameter (zygion-zygion) | zy-zy        | Maximum | 150 | 150 | 137 | 137 | 92 | 92 | 106 | 121 | 106 | 121 | 106 | 121 |
| 16            | Face base length (basion-prostenio) | ba-pr        | Minimum | 114 | 108 | 110 | 98 | 84 | 63 | 83 | 82.5 | 84 | 63 | 83 | 82.5 |
| 17            | Upper face height (nasion-allelveol) | n-al         | Median | 7268–75 | 73.45/70–76 | 64.5/63–67.5 | 68.3/64–70.1 | 121 | 114 | 125 | 125 | 108 | 125 | 125 | 125 |
| 18            | Full face height (ignation-nasion) | gn-n         | Median | 140 | 141.2 | 124 | 122 | 57 | 63 | 52 | 62 | 57 | 63 | 52 | 62 |
| 19            | Upper face width | (frontotemporale-frontotemporale) | fntfnt     | Median | 120 | 125 | 108 | 108.5 | 94 | 95 | 95 | 95 | 94 | 95 | 95 | 95 |
| 20            | Middle face width (zygomaillare-zygomaillare) | zm-zm       | Median | 134 | 134 | 113.2 | 99 | 71 | 89 | 98 | 89 | 98 | 71 | 89 | 98 |
| 21            | Nose height (nasion-nasospinale) | n-ns         | Median | 95/91.25–99 | 97/94–101 | 98/95–102 | 98/95–102 | 95 | 95 | 95 | 95 | 95 | 95 | 95 | 95 |
| 22            | Orbit width (left) (maxillofrontale-ektokonzione) | mf-ek        | Median | 51 | 49 | 42 | 42 | 36 | 37 | 32 | 36 | 36 | 32 | 36 | 32 |
| 23            | Condylar width (between the external surfaces of mandible condyles) | -           | Minimum | 116 | 116 | 116 | 116 | 89 | 89 | 84 | 84 | 89 | 84 | 84 | 84 |
| 24            | Bigonal width (gonion-gonion) | go-go        | Minimum | 104 | 104 | 107 | 107 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 |
| 25            | Mandible body height (gnathon-infradental) | gn-id        | Median | 103/100–100 | 105/100–105 | 99/91–98 | 94.7/92–102 | 103 | 103 | 106 | 106 | 103 | 106 | 106 | 106 |

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 brachycephaly 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%. The predominant width of the skull width was > 81.1% in men, >83% in women, in mesocephaly 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 95.00% | Confidence 95.00% |
|-------------------------|--------------------|------|----|------|-----------------|-------------------|-------------------|
| Transverse diameter (eu-eu) | 137.7 ± 4.7        | -3.483 | 59 | 0.001 | -4.35806       | -6.86211 to -1.85402 |
| Skull base width (au-au) | 119.7 ± 4.9        | -2.390 | 56 | 0.020 | -3.04249       | -5.99758 to -0.45289 |
| Mastoid width (m-m)    | 100.7 ± 6.2        | -2.140 | 53 | 0.037 | -3.02262       | -5.85571 to -0.19852 |
| Upper face height (n-al)| 64.5 ± 4.4         | -2.798 | 51 | 0.007 | -3.36029       | -5.77159 to -0.94899 |
| Nose height (n-m)      | 47.9 ± 3.1         | -3.176 | 56 | 0.002 | -2.88621       | -5.43806 to -0.39181 |

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 = 0.00289), 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 | Mean ± SD          | t    | df | p    | Mean 1 - Mean 2 | Confidence 95.00% | Confidence 95.00% |
|-------------------------|--------------------|------|----|------|-----------------|-------------------|-------------------|
| Height diameter (ba-b)  | 127.22±122-129     | 282/27-30 | 258 | -2.18733 | 0.028719       | -2.9848 to -0.98238 |
| Foramen magnum breadth  | 130/127-133        | 251   | 3.0879 | 0.002016  | -3.0879        | -5.9201 to -0.2573 |
| Bizygomatic diameter    | 127.21±126-131     | 122   | -2.9848 | 0.002838  | -2.9848        | -5.9201 to -0.2573 |

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 differences 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) (χ² = 11.4, df = 3, p = 0.0099), skull circumference (N = 10.9, df = 3, p = 0.0125) (χ² = 9.3, df = 3, p = 0.0255), medium face width (zm-zm) (N = 16.0, df = 3, p = 0.0012) (χ² = 16.1, df = 3, p = 0.0011) and the mandible body height (gn-id) (N = 12.0, df = 3, p = 0.077) (χ² = 8.8, df = 3, p = 0.0323) in the Kruskal–Wallis test and in the Median test.

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

| Serial number | Craniomteric indicators | Abbreviation | Value | Men | Mesztizes | Mongolian | Caucasian | Women | Mesztizes | Mongolian | Caucasian |
|---------------|-------------------------|-------------|-------|-----|-----------|-----------|-----------|-------|-----------|-----------|-----------|
| 1             | Longitudinal diameter (glabella-opisthokranion) | g-op | Maximum | 197 | 152 | 198 | 182 | 176 | 187 | 155 | 168 | 174 |
| 2             | Transverse diameter (eurony-euryon) | eu-eu | Maximum | 158 | 157 | 168 | 150 | 143 | 149 | 139 | 140 | 146 |
| 3             | Height diameter (basion-bregma) | ba-b | Maximum | 144 | 170 | 155 | 139 | 130 | 132 | 134 | 132 | 134 |
| 4             | Skull base length (basion-nasion) | ba-n | Maximum | 575 | 130 | 132 | 125 | 123 | 119 | 125 | 125 | 125 |
| 5             | Minimal forehead width (frontotemporale-frontotemporale) | ft-ft | Maximum | 112 | 130 | 110 | 100.6 | 95 | 113 | 109 | 111 | 111 |
| 6             | Skull base width (auriculare-auriculare) | au-au | Maximum | 136 | 143 | 144 | 131 | 127 | 127 | 127 | 127 | 127 |
| 7             | Asterion width (asterion-asterion) | axt-axt | Maximum | 128 | 125 | 125 | 117 | 111 | 115 | 113 | 115 | 115 |
| 8             | Mastoid width (mastoidale-mastoidale) | m-m | Maximum | 124 | 122 | 122 | 112 | 105 | 108 | 105 | 108 | 108 |
| 9             | Skull circumference (by glabella) | - | Maximum | 559 | 575 | 595 | 525 | 523 | 550 | 495 | 490 | 507 |
| 10            | Sagittal chord (nasion-opistion) | n-o | Maximum | 149 | 184 | 183 | 139 | 130 | 148 | 123 | 133 | 138 |
| 11            | Frontal chord (nasion-bregma) | n-b | Maximum | 120 | 127 | 130 | 114 | 107 | 111 | 113 | 111 | 113 |
| 12            | Bregma chord (bregma-lambda) | b-l | Maximum | 124 | 125 | 140 | 112.4 | 107 | 152 | 152 | 152 | 152 |
| 13            | Foramen magnum length (basion-opistion) | ba-o | Maximum | 42 | 47 | 44 | 40 | 34 | 41 | 30 | 30 | 30 |
| 14            | Foramen magnum breadth | - | Maximum | 41 | 38 | 37 | 35 | 28 | 33 | 26 | 26 | 26 |
| 15            | Bizygomatic diameter (zygion-zygion) | zy-zy | Maximum | 141 | 150 | 148 | 137 | 132 | 130 | 130 | 130 | 130 |
| 16            | Face base length (basion-proston) | ba-pr | Maximum | 106 | 108 | 114 | 97 | 93 | 100 | 93 | 93 | 93 |
| 17            | Upper face height (nasion-alveolare) | n-al | Minimum | 77 | 89.3 | 91 | 72.2 | 71 | 76 | 65 | 63 | 68 |
| 18            | Full face height (gnathion-nasion) | gn-n | Minimum | 65 | 63 | 58 | 60 | 66 | 52 | 62 | 62 | 62 |
| 19            | Upper face width (frontotemporale-frontotemporale) | fmt-fmt | Minimum | 117 | 125 | 118 | 100 | 100 | 98 | 92 | 92 | 92 |
| 20            | Medium face width (zygomaticaxial-zygomaticaxial) | zm-zm | Minimum | 108 | 134 | 112.2 | 99.2 | 99 | 99 | 99 | 99 | 99 |
| 21            | Nose height (nasion-nasospinale) | n-ns | Minimum | 49 | 42 | 36 | 45 | 44 | 41 | 41 | 41 | 41 |
| 22            | Orbit width (left) (maxillofrontale-ektokonchion) | m-ek | Minimum | 39 | 38 | 36 | 36 | 37 | 35 | 35 | 35 | 35 |

Abbreviation: q25–q75 - q25, q75; Median/Minimum - Median/Minimum; Maximum - Maximum; Minimum - Minimum; Median - Median; g-op - g-op; eu-eu - eu-eu; ba-b - ba-b; ba-n - ba-n; ft-ft - ft-ft; au-au - au-au; axt-axt - axt-axt; m-m - m-m; zy-zy - zy-zy; ba-pr - ba-pr; fmt-fmt - fmt-fmt; q25–q75 - q25, q75; Median/Minimum - Median/Minimum.
and other endo- or exogenous factors. According to Francisco HW D’P [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 is the smaller size of the facial skeleton depending on latitude and 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 HWD Q[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 brachycranian, 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 Caucasian race with prolonged contact with the new coming Mongolians [16]. According to Ismagulov &WD0 [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 Caucasian 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 Caucasian 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 Caucasian. 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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