The Gene Pool of the Belgorod Oblast Population: I. Differentiation of All District Populations Based on Anthroponymic Data

I. N. Sorokina[a], E. V. Balanovska[b], and M. I. Churnosov[a]

[a] *Belgorod State University, Belgorod, 308015 Russia; fax: (4722)30-10-12; e-mail: Sorokina@bsu.edu.ru*
[b] *Medical Genetic Research Center, Russian Academy of Medical Sciences, Moscow, 115478 Russia; e-mail: Balanovska@med.gen.ru*

Abstract—The gene pool of the entire population of all the 21 raions (districts) of the Belgorod oblast (region) has been studied using anthroponymic data. Considerable geographic variations of the number of surnames and the degree of population subdivision ($0.00003 < f_r^* < 0.00125$) in the 21 districts have been demonstrated. Districts with low population subdivision levels are mainly located in the central and southwestern raions of the Belgorod oblast, contain an urbanized area (city), and border on Ukraine (they are characterized by a considerable Ukrainian immigration). Urbanization significantly affects the population structure of the Belgorod oblast. In urbanized districts, rural populations lack the relationships between the population size, number of surnames, and population subdivision level (f_r).

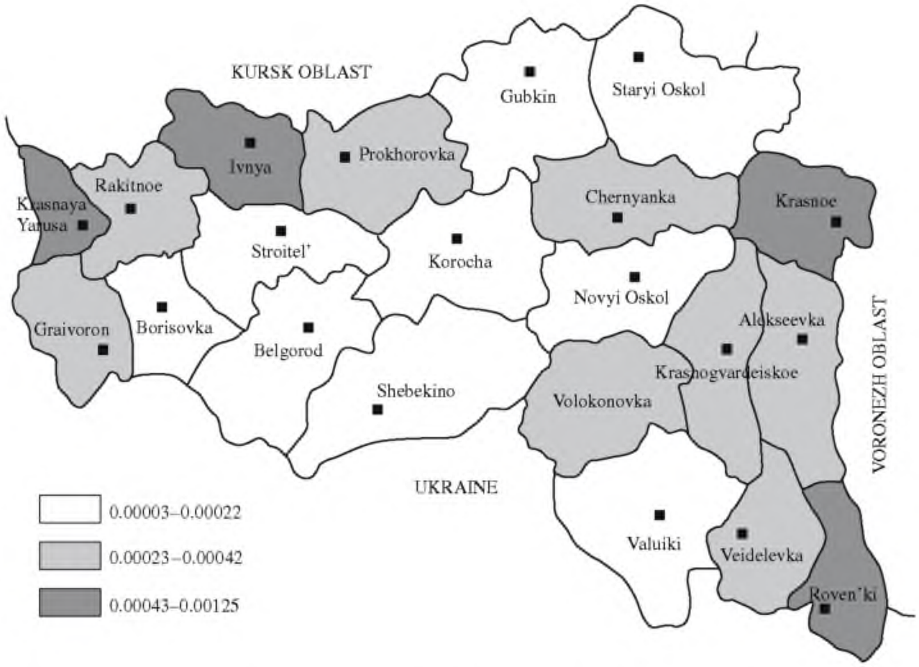
INTRODUCTION

While intense population genetic studies of various ethnic groups of Russia are being carried out, the gene pool of Russians remains one of the most poorly studied. Until recently, researchers focused on Altaian, northern Caucasian, Cis-Ural, central Asian, Siberian, Far Eastern, and other populations, in which a wide range of population demographic, biochemical, and molecular genetic markers was analyzed [1–12]. Although Russians are the largest population group of Russia and inhabits a vast geographic area, its population genetic description is restricted to a relatively small number of populations [1, 6–14]. As noted in [5], many characteristics of the Russian gene pool may be inferred from those of surrounding populations, rather than estimated from the available results of studies in Russian populations themselves. Such studies are now an urgent task in the population genetics of Russia.

The Central Chernozem region of Russia is part of the geographic area originally populated by Russians and is characterized by large population size and density. The population genetic study of this region is especially important because of intense migrations and recent administrative and demographic changes.

The Belgorod oblast (region) is an adequate model for studying the population demographic transformations that are now observed in central Russia. First, the area of the modern Belgorod oblast covers southern portions of the geographic area originally populated by Russians, and the city of Belgorod itself, as well as surrounding settlements, was founded in the 16th century as part of the fortification line along the southern border of Russia [15]. Second, anthroponymic data on southern Russia (mainly represented by the Belgorod oblast) show a "family name portrait" that stands out among other Russian regions [16]. Third, in contrast to mot Russian regions, both urban and rural population sizes of the Belgorod oblast are growing due to intense immigration, despite the low birthrate and high death rate [17]. Fourth, although this region lies in the zone where the Russian ethnic group was formed, the Belgorod oblast itself is "administratively young": it was formed from several raions (districts) of the Kursk and Voronezh oblasts as recently as in 1954. Before our study, the population genetic mechanisms of the formation of so large regional populations had not been studied, and the effects of the types and trends of administrative reorganizations on the population genetic structure had not been estimated. Fifth, the population of the Belgorod oblast, located at the Russian–Ukrainian border, has been contributed by not only Russians, but also Ukrainians and Belarussians [18]. To date, the structural characteristics of the gene pools of Russian populations located at the boundaries between areas populated by different Eastern Slavic ethnic groups have been poorly studied, and their place in the system of the entire Eastern Slavic gene pool has not been determined.

Thus, population genetic study of the Belgorod oblast as a model object offers a unique possibility not only to analyze the gene pool of one of the main Russian population groups located at the interface between two Eastern Slavic ethnic groups, but also to estimate



The map of rural districts (raions) of the Belgorod oblast and their distribution with respect to the population subdivision level (f_r^*).

how administrative reforms and intense migration affect the structure of a contemporary population gene pool.

We studied the differentiation of all district populations of the Belgorod oblast on the basis of anthroponymic data. This publication opens a series of works on detailed analysis of the Belgorod oblast population with respect to a wide spectrum of markers, including quasi-genetic, genetic demographic, classic genetic, and molecular genetic ones.

MATERIALS AND METHODS

Objects of the study. We studied the population of the Belgorod oblast, which is located on the southwestern and southern slopes of the Central Russian Upland. It borders on the Lugansk, Kharkov, and Sumy oblasts of Ukraine in the south and west; the Kursk oblast of Russia in the northwest; and the Voronezh oblast of Russia in the east (figure). The oblast occupies an area of 27.1×10^3 km^2. The population of the oblast is 1511.4×10^3 people (the 2006 estimate), including 509×10^3 rural residents (34%). The Belgorod oblast ranks among the first ones in the Central Chernozem region with respect to the population size and density (55.4 people/km^2). However, the population growth was accounted for by different factors in different periods. These were (1) natural population growth in the 1960s; (2) migrations related to the development of the ore deposit known as the Kursk Magnetic Anomaly in the 1970s; and (3) migration from the NIS, including Ukraine and Central Asian, Transcaucasian, and Baltic countries at the present time [15]. The Belgorod oblast comprises 21 raions (districts), 10 cities, 20 towns, 333 rural municipalities, and 1592 villages.

Population genetic study. We performed anthroponymic study of the total population of all 21 raions of the Belgorod oblast.

The source of information was lists of surnames "totally" covering the entire population of the oblast above 18 years of age. Data on the variation of 53 525 surnames among 885 459 people in 21 rural district of the Belgorod oblast were analyzed. The population genetic characteristics were calculated at the level of district populations, which were regarded as elementary ones.

For comparative analysis of the surname distributions in the rural and urban populations, we added data on the variation of 33 897 surnames among 355 121 people in nine urban populations. The total array of data comprised 42 929 surnames among 583 258 people in nine rural and nine urban populations.

The surname-frequency random inbreeding was estimated by the isonymy coefficient f_r suggested by Crow and Mange [19], which was calculated as

$$f_{r(j)} = I/4,$$

where I is the expected frequency of isonymic marriages (i.e., marriages contracted between persons with the same surname) in the jth subpopulation, i.e., $I = \sum P_i^2$, where P_i is the frequency of the ith surname in the jth subpopulation [19, 20], and the coefficient 1/4 is introduced to take into account that surnames are transmitted only in the paternal line. The random inbreeding

f_r (corresponding to Wright's F_{ST}) estimates the expected frequency of isonymic marriages under the assumption of a complete panmixia (an elementary population without assortative marriages). Note that the value $f_{r(raion)}$ reflects random inbreeding in each particular elementary (raion) population and does not characterize the total population of the Belgorod oblast. The inbreeding level in the elementary (raion) population already contains the contributions of all higher levels of the population system (oblast etc.). Therefore, to obtain the real estimate f_r^*, we subtracted the variation accounted for by the oblast hierarchical level ($f_{r(raion)}$) from the gross (direct) raion estimate ($f_{r(oblast)}$): $f^*_{r(raion\text{-}oblast)} = \bar{f}_{r(raion)} - f_{r(oblast)}$, where $\bar{f}_{r(raion)}$ is the mean inbreeding at the elementary (raion) population level obtained by averaging the f_r estimate over raions and $f_{r(oblast)}$ is the random inbreeding in the total oblast population [21].

The frequencies of all surnames were also used to calculate the migration index (ν), surname diversity index (α), entropy of surname distribution (H), and redundancy of surname distribution (R) suggested by El'chinova [11]. The population migration index (ν) is 0 if all persons in the population have the same surname and 1 if all of them have different surnames. The migration index is used to calculate the surname diversity index (α) depending on the population size. The entropy (H) [11] is 0 if all persons in the population have the same surname and $H_0 = \log_2 N$ if all of them have different surnames (N). The entropy is calculated as $H = -\sum q_i \times \log_2 q_i = -\sum a_i \log_2 a_i / N + H_0$, where q_i is the frequency of the ith surname in the population and a_i is the frequency of carriers of the ith surname there. In fact, this equation does not take into account single carriers of a surname, because log 1 = 0. The surname distribution redundancy (R) is 100 if all persons have the same surname and 0 if all of them have different surnames [11].

$$\nu = (1 - I)/[I(N - 1)],$$

where N is the population size;

$$\alpha = N \times \nu/(1 - \nu),$$

$$R = 100 \times (1 - H/H_0),$$

where $H_0 = \log_2 N$.

RESULTS AND DISCUSSION

Population Genetic Characteristics of Surname Distribution in the Belgorod Oblast

We used surname frequencies at the elementary (rural raion) level to study the genetic structure of all rural districts of the Belgorod oblast.

The surname numbers in raion populations of the Belgorod oblast varied within a wide range (more than an order of magnitude). The number of surnames was the smallest 1272 surnames in a population of 12 737 people) in the Krasnoe raion and the largest (22 135 surname in a population of 187 229 people) in the Staryi Oskol raion (Table 1). The mean number of surnames per raion was 5638.

The mean population subdivision level of raion populations of the Belgorod oblast (Table 1) was f_r^* = 0.00031, individual values varying from 0.00003 in the Belgorod raion to 0.00125 in the Krasnoe raion. Thus, the variation of this parameter in different raion populations was substantial (by a factor 40).

Our data on the subdivision of the Belgorod populations agree with earlier data obtained by one of us (Churnosov [13]) on the population of the Kursk oblast: the mean value was $\bar{f}_r$ = 0.00065, individual values in 11 raions varying from 0.00014 to 0.00157. This parameter was also shown to vary considerably in rural populations of the Kostroma oblast (from 0.0003 to 0.0050) [22] and Kirov oblast (from 0.00021 to 0.00109) [9]. Unfortunately, it is difficult to compare directly our data on the f_r values in the Belgorod population with these values in other regions because of the differences, first, in the hierarchical ranks of the elementary populations (rural municipalities and districts) and, second, in the coefficient k used for calculating f_r (4 and 28): in this study, we analyzed district populations and used a coefficient of 4, whereas researchers that studied the population genetic structures of the Arkhangel'sk, Kirov, Kostroma, and Tver oblasts took rural municipalities to be elementary populations and used a coefficient of 1/28 (taking into account the correction for unequal representation of sexes in intermediate ancestors); the f_r values of elementary populations included the f_r values of higher hierarchical levels [6, 9, 22].

For correct comparison with literature data, we calculated the random inbreeding f_r for two raions of the Belgorod oblast (the Krasnoe and Prokhorovka raions) with the use of the same algorithm as that used in the studies [6, 9, 22]; i.e., first, at the level of rural municipalities, second, with a correction coefficient of 1/28, and third, without subtracting the components accounted for by higher hierarchical levels. In this case, the $\bar{f}_{r(municipality)}$ for ten rural municipalities of the Krasnoe raion was 0.0013, the values for individual municipalities varying from 0.00053 to 0.00187. In the Prokhorovka raion, the $\bar{f}_{r(municipality)}$ for 19 rural municipalities was 0.00076, the values for individual municipalities varying from 0.00028 to 0.00188. These results are comparable to these data on the Kostroma and Kirov oblasts, where this parameter also considerably varied in different rural populations (from 0.0003 to 0.0050 [22] and from 0.00021 to 0.00109 [9], respectively). However, the mean value $\bar{f}_{r(municipality)}$ for the two raions of the Belgorod oblast was considerably higher than these parameters for the rural populations

Table 1. The distributions of the number of surnames, population subdivision level (f_r^*), surname diversity (α), entropy of surname distribution (*H*), redundancy of surname distribution (*R*), and migration index (ν) among raion (district) populations of the Belgorod oblast

Raion	Size of population above 18 years of age	Number of surnames	f_r^*	α	*H*	*R*	ν
Alekseevka	58858	5401	0.00028	65.36	10.67	31.74	0.0119
Belgorod	63042	10643	0.00003	262.15	11.94	25.12	0.0240
Borisovka	19366	3500	0.00022	134.42	10.56	25.88	0.0369
Valuiki	56461	7628	0.00015	122.78	11.22	28.92	0.0158
Veidelevka	19324	2825	0.00033	81.02	10.15	28.69	0.0279
Volokonovka	28230	3704	0.00024	91.81	10.49	29.03	0.0242
Gaivoron	20606	3388	0.00029	100.50	10.37	27.66	0.0288
Gubkin	87926	9999	0.00019	90.23	11.29	31.29	0.0089
Ivnya	18802	2749	0.00048	60.95	9.91	30.23	0.0217
Korocha	30125	4388	0.00022	106.20	10.60	28.73	0.0236
Krasnoe	12737	1272	0.00125	18.23	8.513	37.57	0.0141
Krasnogvardeiskoe	35027	3562	0.00025	68.32	10.28	31.87	0.0188
Krasnaya Yarusa	11589	2064	0.00052	70.38	9.77	27.61	0.0329
Novyi Oskol	38108	5507	0.00019	116.36	10.90	28.36	0.0207
Prokhorovka	22878	3531	0.00039	75.02	10.20	29.57	0.0208
Rakitnoe	26744	3687	0.00029	82.91	10.32	29.80	0.0219
Roven'ki	18507	2311	0.00062	42.45	9.64	32.03	0.0188
Staryi Oskol	187229	22135	0.00007	151.03	12.23	30.16	0.0068
Chernyanka	25871	3987	0.00025	105.15	10.58	27.82	0.0257
Shebekino	73120	9424	0.00016	109.25	11.37	29.62	0.0115
Yakovlevskii	38862	6684	0.00009	200.08	11.34	25.63	0.0291
Average for the oblast	42543	5638	0.00031	102.6	10.59	29.4	0.0211

of the Arkhangel'sk and Tver oblasts [23, 24]. For example, in the Vinogradskii raion of the Arkhangel'sk oblast, the weighted average $\bar{f}_{r(\text{municipality})}$ = 0.00036; in the Udomlya and Ostashkov raions of the Tver oblast, these values were 0.00034 and 0.00037, respectively.

The wide variation of the population genetic characteristics of the Belgorod oblast illustrated by the f_r values is further confirmed by the data on surname diversity (α) and the entropy (*H*) and redundancy (*R*) of surname distribution (Table 1).

We estimated the effectiveness of these parameters in correctly describing the genetic structure of the Belgorod population. The random inbreeding f_r was correlated with *R*, α, and *H*, but not with the migration index (ν) (Table 2). Note that the Krasnoe and Belgorod raions of the Belgorod oblast stood out among all the 21 raions because of polar values of all population genetic parameters. The random inbreeding level was the highest in the Krasnoe raion and the lowest in the Belgorod raion.

Thus, district populations of the Belgorod oblast were characterized by a mean random inbreeding level of f_r^* = 0.00031, the inbreeding levels in individual raions considerably varying (from 0.00003 to 0.00125 in the Belgorod and Krasnoe raions, respectively).

Regarding other population genetic parameters, namely, surname diversity (α), the entropy (*H*) and redundancy (*R*) of surname distribution, and migration index (ν), only the surname distribution redundancy (*R*) proved to be suitable for a correct description of the genetic structure of the Belgorod oblast population. This parameter was significantly but moderately correlated with f_r ($\rho = 0.39$, $P < 0.05$). The surname diversity (α), the entropy (*H*) parameters almost completely corresponded to the population subdivision level, being strongly negatively correlated with f_r (the ρ values were –0.90 and –0.96, $P < 0.001$), whereas the migration index (ν), which, in theory, must be closely correlated with f_r, did not show a significant correlation ($\rho = 0.15$ ($P = 0.52$)).

Effect of Urbanization on the Population Structure

To estimate the effect of urbanization on population subdivision, we analyzed the distribution of surnames and the random inbreeding parameters in the rural and urban populations of the raions that contained an urbanized zone (a city). There were nine (43%) such raions in the Belgorod oblast (Table 3). On average, the rural populations of these nine raions were characterized by a smaller number of surnames, smaller population size, and higher subdivision level compared to the urban populations of these raions. Regarding individual raions, however, this was true for only four out of nine raions (the Alekseevka, Valuiki, Gubkin, and Staryi Oskol raions), where the random inbreeding in the rural populations was, on average, two to four times higher than in the rural populations (Table 3).

In the Korocha raion, the situation was opposite: the inbreeding level of the urban population was higher than in the rural one (0.00052 and 0.00037, respectively). In four raions (the Gaivoron, Novyi Oskol, Shebekino, and Yakovlevskii raions), the f_r values for the rural and urban populations were approximately equal. In the Gaivoron raion, the population size and the number of surnames in the urban population were two times lower than in the rural population, but their f_r values were about the same.

To estimate the patterns, trends, and strengths of relationships of the population subdivision level with the number of surnames and population size, we calculated Spearman's coefficients of correlation (Table 4) between these parameters for the following population groups: all raion populations (21 raions), rural populations of urbanized raions (9 raions), and urban populations of the same 9 raions. In general, the following relationship was found for raion populations: there were significant negative correlations of the subdivision level (f_r) with the number of surnames and population size, these last two parameters being strongly positively correlated with each other. Similar relationships of about the same strength between these parameters were found in urban populations. On the other hand, the subdivision level (f_r) in rural populations of urbanized raions was not correlated significantly with either the number of surnames or the population size, although the relationship between the number of surnames and the population size was still preserved.

Thus, the population subdivision (the random inbreeding f_r) in the Belgorod oblast population was related to the population size and the number of surnames: an increase in the population of a raion led to an increase in the number of surnames, which eventually resulted in a decrease in the random inbreeding in the population. This tendency observed in the total Belgorod oblast population was characteristic of urban populations and disappeared in rural populations of urbanized raions.

In summary, we found a considerable effect of urbanization on the population structure of the Belgorod oblast population. Strong relationships between the population size, surname number, and population subdivision level (f_r) were characteristic of the total population of the Belgorod oblast and urban populations but disappeared in the rural populations of urbanized raions, which suggest that their population structures were substantially altered, i.e., cities caused destruction of the surrounding rural populations.

Table 2. Spearman's coefficients of correlation (ρ) between the surname diversity (α), entropy of surname distribution (*H*), redundancy of surname distribution (*R*), migration index (ν), and population subdivision level (f_r^*) in the Belgorod oblast

Population genetic parameter	f_r^*	
	ρ	*P*
α	–0.90	<0.001
H	–0.96	<0.001
R	0.39	<0.05
ν	0.15	0.52

Grouping the Raion Populations According to the Subdivision Level

We divided all raions of the Belgorod oblast into three groups according to the population subdivision level (figure).

Group I was characterized by a low subdivision level (f_r^* varied from 0.00003 to 0.00022; mean value, 0.00015). This group comprised nine raions (43% of all raions of the Belgorod oblast), mostly those located in the central and southwestern Belgorod oblast. Seven of these nine raions contained urbanized zones (cities), including Belgorod, which is the administrative center of both the Belgorod raion and Belgorod oblast. Four raions of this group (the Borisovka, Belgorod, Shebekino, and Valuiskii raions) border on Ukraine, which may have determined intense immigration from Ukraine to these districts. According to statistical data [16], Ukrainians are the second largest ethnic group in the structure of immigration to the Belgorod oblast in 2000–2004, outranked only by Russians (14.6 and 71.1%, respectively).

Group II was characterized by a moderate subdivision level (f_r^* varied from 0.00023 to 0.00042; mean value, 0.00029). Group II comprised eight raions (38%) mainly located closer to the periphery of the Belgorod oblast than group I raions. Most of them (five raions) were located in the eastern part of the Belgorod oblast.

Group III was characterized by a high subdivision level (f_r^* varied from 0.00043 to 0.00125; mean value, 0.00072). This subdivision level was observed in four "marginal" raions located at the very periphery of the Belgorod oblast.

Thus, analysis of the geographic location of raions with different population subdivision levels (f_r) showed

Table 3. Distribution of family names and subdivision level (f_r) in urban and rural populations of Belgorod oblast

Population	Number of residents aged above 18	Number of family names	f_r
Alekseevskii raion			
rural population	21685	2556	0.00071
Alekseevka	29176	4233	0.00032
Valuiskii raion			
rural population	28908	4106	0.00041
Valuiki	27553	5286	0.00026
Graivoronskii raion			
rural population	16095	2739	0.00048
Graivoron	4511	1396	0.00047
Gubkinskii raion			
rural population	25304	3747	0.00072
Gubkin	62582	8438	0.00027
Korochanskii raion			
rural population	25512	3881	0.00037
Korocha	4613	1346	0.00052
Novooskol'skii raion			
rural population	20760	3463	0.00036
Novyi Oskol	17348	3481	0.00038
Starooskol'skii raion			
rural population	28983	4408	0.00062
Staryi Oskol	158246	20848	0.00016
Shebekinskii raion			
rural population	36185	5701	0.00032
Shebekino	36935	6259	0.00035
Yakovlevskii raion			
rural population	24705	4747	0.00028
Stroitel'	14157	3443	0.00025
Mean			
urban population	25349	3496	0.00048
rural population	39458	6081	0.00033

that raions with a low random inbreeding level were mainly located in the central and southwestern parts of the Belgorod oblast and were surrounded at the western and eastern peripheries by raions with moderate and high inbreeding levels. Raions with a high f_r were characterized by the presence of an urbanized zone (a city); in some of these raions, bordering on Ukraine, a considerable Ukrainian immigration was observed.

Summarizing the result of the anthroponymic study of the gene pool of the Belgorod oblast population, it should be noted that, first, the number of surnames and subdivision level considerably vary in the 21 raions of the Belgorod oblast ($0.00003 < f_r^* < 0.00125$). Most raions with low subdivision levels are located in the central and southwestern Belgorod oblast, contained an urbanized zone (a city), and border on Ukraine (which accounted for a considerable Ukrainian immigration).

Second, urbanization considerably affects the population structure of the Belgorod oblast. In urbanized raions, rural populations lose the relationship between the population size, number of surnames, and subdivision level (f_r) that is characteristic of the total Belgorod oblast population, which suggests that the effect of cities destroys their population structure. Third, among

Table 4. Spearman's coefficients of correlation (ρ) between the number of surnames, population subdivision level (f_r), and population size for all raion populations and tehrural and urban populations of urbanized raions of the Belgorod oblast

Parameters compared	Urban population (nine urbanized raions)		Rural population (nine urbanized raions)		All district populations of the Belgorod oblast (21 raions)	
	ρ	*P*	ρ	*P*	ρ	*P*
Surname number–population size	0.98	<0.001	0.78	<0.001	0.97	<0.001
Surname number–inbreeding f_r	–0.76	<0.001	–0.58	0.10	–0.92	<0.001
Population size–inbreeding f_r	–0.72	<0.001	–0.12	0.77	–0.86	<0.001

the population genetic indices studied, including the surname diversity index (α), entropy of surname distribution (*H*), redundancy of surname distribution (*R*), and migration index (ν), only one parameter, the redundancy of surname distribution (*R*), may be used for a correct description of the genetic structure of the Belgorod oblast population.

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