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Sex-Specific Phenotypic Plasticity as a Complex Reaction of Human Organism to Different Environmental Conditions

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ABSTRACT

Complex anthropological investigations of modern students were carried out in the three big cities of Russian Federation (Samara, Arkhangelsk, Saransk), as well as in the villages of Mordovia. The program of morphofunctional investigation included body characteristics, body mass components (evaluated with the bioelectrical impedance analyzer "Medass-1"), physiological characteristics of cardiovascular and respiratory systems, right hand grip strength (dynamometry). To evaluate the level of sexual dimorphism, coefficient of sexual dimorphism (CSD) was used in this study. The total number of the studied subjects was 476 young women and 375 young men, from 17 to 23 years old. The results of ANOVA analyses show the presence of non-random variations for the majority of studied characteristics in the examined groups. On this basis, it is possible to consider that different environmental conditions exert significant influence on human organism, which is the core of the adaptation process. The largest distance separates the groups from the city of Saransk and Mordovian villages. It shows that the impact of social and environmental factors for rural and urban inhabitants is much larger as compared to ecological ones, e.g., latitude of the location. Comparison of the CSD values in all groups showed that the degree of adaptation potentials is considerably different in males and females for many characteristics. Thus, for body mass components, characteristics of respiratory system, height and BMI, males are more sensitive to environmental influences. For the cardiovascular system traits, the degree of fat tissue development and body mass, the strength of adaptation changes is practically equal in men and women, with slight advantages in men.

Keywords: *anthropometry, sexual dimorphism, environmental impacts, body mass index, cardiovascular system, Russia*

Introduction

Large surveys of various populations revealed significant statistical differences between groups living in different ecological conditions [1, 2]. Cardiovascular system (CVS), respiratory system, degree and pattern of fat accumulation, muscle mass development and even such stable indicators of body structure as height and body mass, are influenced by environmental factors. As a result of such influence, adaptation of the organism to specific external factors occurs[3, 4]. Sex is an important biological determinant of adaptation to the influence of different factors. But the degree in which sex assignment affects adaptation potentials is estimated differently by different authors. The theory arguing that males are more ecosensitive is widely spread. However the studies dealing with this problem do not give a simple answer about both sexes reaction[5–9]. One of the latest research directions in human biology deals with understanding of sex influence on the results of clinical investigations, in the studies of morbidity level and health indicators [10–14]. It is often not clear in what degree sex assignment contributes to the differences between groups.

Main indicators evaluating physiological and morphological health status of humans are discussed in this paper. Their changes could be considered as a result of adaptation to climatic and social factors, as well as the result of differences in the lifestyle [15]. The studied groups of young men and women live in highly diverse surroundings. First, it is urbanization level from megapolis to rural settlements. Also the population density is different, air pollution, climatic variables.

Aim of the present study is to evaluate adaptation potentials of the organism to some non-critical environmental influences and to understand general patterns in variability of sex differences.

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Materials and Methods

Complex anthropological investigations of modern students were carried out in the three big cities of Russian Federation (Samara, Arkhangelsk, Saransk), as well as in the villages of Mordovia. Data on 476 young women and 375 young men, of Russian ethnicity, from 17 to 23 years old are presented in this paper. Ethnicity was evaluated by the questionnaire when the subjects were asked about their parents' nationality, and was important for homogeneity of the compared samples. All those studied were born and lived in the same locality during their lifetime. Sample organization was based on voluntary participation in the survey, in accordance with bioethical principals (expert agreement of Bioethical Committee of Lomonosov Moscow State University, application N 22-ch, protocol N 55 of 26.03.2015). Informed consent protocols were signed by each participant, all obtained data were depersonalized.

The program of morphofunctional investigation included the following measurements: height and body mass, trunk circumferences and skinfold thickness. Body mass components were evaluated with the bioelectrical impedance analyzer "Medass-1". Among physiological characteristics, the following ones were studied: cardiovascular system (CVS) – systolic and diastolic blood pressure (SBP and DBP correspondingly), heart rate (HR); respiratory system – forced vital lung capacity (FVC), forced exhaled volume for the 1st sec (FEV1); skeletal-muscular system – right hand grip strength (dynamometry).

In addition, several complex indices that characterized adaptive potentials of different body systems were calculated: Body Mass Index (BMI) in the first place, then Blood Stroke Volume (BSV) of Starr formula [16] which measures how well the cardiac muscle is trained and its ability to meet the necessities of the organism under increased physical demands. An important characteristic is cardiac output per minute (COM). Stable increase in energetic costs of the organism leads to a proportional increase of COM. Vital index was also used as FVC divided by body mass, and Strength index (hand grip strength divided by body mass) as an indicator of training degree of respiratory system and muscle strength.

To evaluate the level of sexual dimorphism, coefficient of sexual dimorphism (CSD) [17–19] was used in this study.

$$CSD = \frac{M_m - M_w}{S^2}, \text{ where } S^2 = \sqrt{\frac{(N_m - 1)\cdot S_m^2 + (N_w - 1)\cdot S_w^2}{N_m + N_w - 2}}$$

, where N – sample size, M – mean value for men and women, S – standard deviation in male and female samples, N – number of investigated men and women.

Statistical analysis was performed with the package "*Statistica-10.0*". To check for the normal distribution of morphofunctional traits, the Kolmogorov-Smirnov test was used (Lilliefors version). All of the traits had unimodal distribution. Statistical significance of intergroup differences was determined by One-Way ANOVA and consequent pair comparisons with the Scheffe test. This method helped to receive non-skewed, consistent and effective estimate.

To study intergroup differences in morphofunctional characteristics canonical discriminant analysis was used. Significance of differences between the means was assessed with one-sample Student's t-test. It was possible to use the parametric test in our case because of the large sample sizes, unimodal distributions and strong power of the selected test[20].

Results

To evaluate the degree of intergroup differences ONE-WAY ANOVA was used for male and female groups separately. In Table 1 the results of F-test are given. It is possible to conclude the presence of significant differences between the territorial groups practically for all examined traits.

TABLE 1

ANOVA RESULTS

	In 4 groups of men			In 4 groups of women		
Variable	MS Effect	MS Error	P	MS Effect	MS Error	P
Body mass	908.0*	139.1*	0.000	145.8	76.3	0.127
Height	208.6*	43.3*	0.003	67.0	32.3	0.102
Waist circumference	209.5*	57.7*	0.013	59.5	37.7	0.194
Hip circumference	54.8	49.8	0.349	127.8*	40.6*	0.025
Average skinfold thickness	551.4*	40.4*	0.000	563.9*	29.9*	0.000
BMI	43.9*	11.8*	0.012	9.8	9.2	0.362
Fat mass	115.5	47.0	0.063	434.1*	35.1*	0.000
Active cell mass	675.4*	21.3*	0.000	169.5*	16.1*	0.000
Muscle-skeletal mass	453.6*	11.7*	0.000	119.4*	12.2*	0.000
SBP	1180.2*	235.9*	0.002	601.9*	133.5*	0.004
DBP	365.7*	84.6*	0.005	50.4	71.7	0.551
HR	714.9*	189.3*	0.011	952.1*	155.9*	0.000
BSV (Starr)	0.0	0.0	0.085	0.0	0.0	0.063
COM (Starr)	3.5*	1.3*	0.042	5.8*	0.9*	0.000
FEV1 (l)	6.7*	0.4*	0.000	2.4*	0.3*	0.000
FVC (l)	10.1*	0.6*	0.000	0.7	0.3	0.092
Vital index	227.8	154.5	0.231	55.2	108.7	0.603
Right hand grip strength	213.1*	66.1*	0.023	119.6*	22.9*	0.001
Strength Index	0.0	0.0	0.335	0.0	0.0	0.120

p – significance level with Fisher F-test; * – significant inter-sample differences ($p<0.05$), BMI – Body mass index, SBP – Systolic blood pressure, DBP – Diastolic blood pressure, HR – Heart rate, BSV - Blood stroke volume, COM – Cardiac output per minute, FEV1 – forced expiratory volume in the first second, FVC – forced lung capacity

Two discriminant canonical analyses were also performed separately for male and female groups. 96% and 93.5% of total variation of the traits (for males and females correspondingly) was estimated for two variables but significance of correct discrimination for this model was much lower: 68.8% and 73.1% (for males and females correspondingly) (Figure 1).

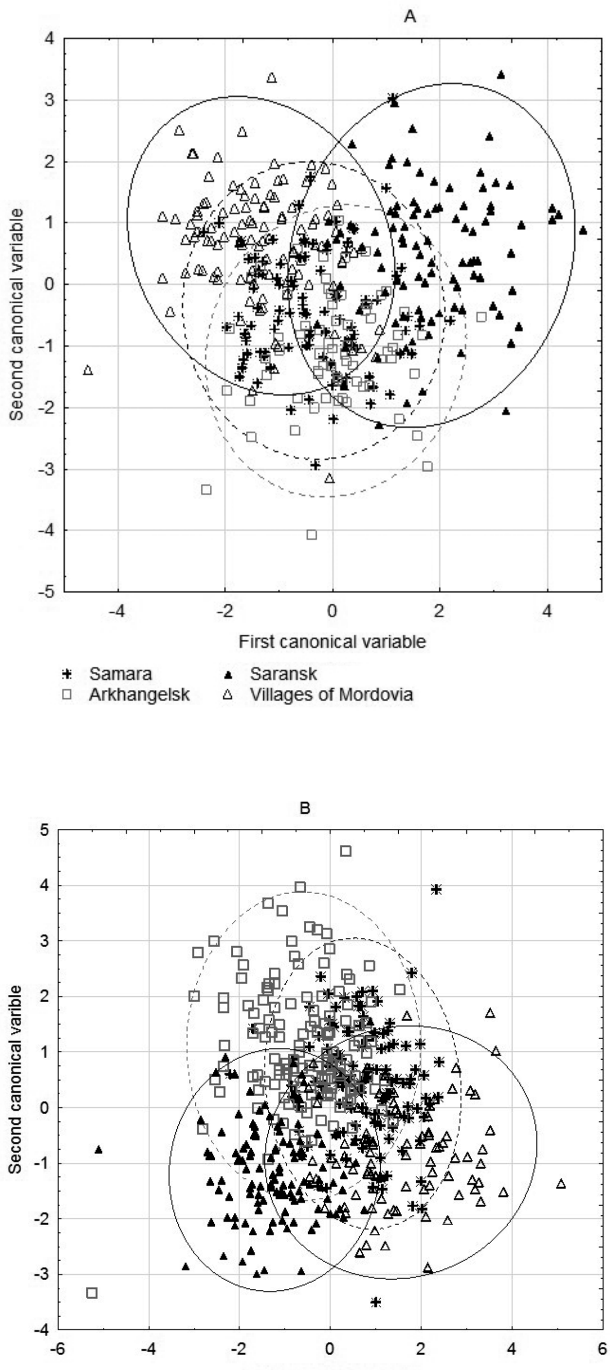

Fig. 1. Individual values of canonical variables for males (A) and females (B).

Main statistical parameters for all groups were calculated for the analysis of the degree of sex differences. Values of the parameter in the combined sample were considered as mean values, while any deviation from those was interpreted as caused by specific environmental conditions. The differences between the values in the combined sample and those in each territorial group were calculated for all traits. For each trait the CSD values were calculated as well as their differences from the corresponding mean CSD value. These results are presented in Table 2.

Discussion

The results of ANOVA analyses show the presence of non-random variations for the majority of studied characteristics in the examined groups. On this basis, it is possible to consider that different environmental conditions exert significant influence on human organism, which is the core of the adaptation process. Moreover, the differences in some traits are expressed in the representatives of both sexes. They are: mean value of skinfold thickness, active cell mass (ACM), skeletal-muscle mass (SMM), SBP, HR, COM, hand grip strength. Thus, it can be concluded that those traits – both morphological and physiological ones, are more influenced by environmental conditions, hence more adaptable. For some other set of traits, significant differences were revealed only for males or females. But there were three characteristics, which did not demonstrate any intergroup variability: BSV, Vital index and Strength index.

Discriminant analysis allows evaluating the degree of environmental impact. As can be seen from Figure 1, discrimination between the male and female groups is not total – the overlap area is large. Morphological variation of the Samara groups is totally included in the variation range of the other groups and is centrally located. The largest distance separates the groups from Saransk city and Mordovian villages. It is evidence to much larger impact of social and environmental factors for rural and urban inhabitants as compared to ecological ones, e.g., latitude of the location (Arkhangelsk vs. Samara and Saransk). It was shown in many studies that modern urbanization processes exert inevitable influence on human morphological health[1,4] and physiological adaptation[3,21].

To evaluate the degree of environmental impact on health indicators as sex dependent, and to test the theory of higher ecosensitivity in males, those traits were revealed, which were more deviating from the average level for males as compared to females and vice versa. In other words it was calculated what was the difference between "Mean value in the given group" minus "Mean value combined" for males and females (Column "Difference" in Table 2). To exclude unreliable conclusions, only significant differences from average level, even in one of the sex groups, will be further analyzed ($p<0.05$, Student's t-test). It turned out that in the majority of cases it was exactly the males who showed the biggest differences: of 39 cases of significant differences, 25 were more expressed in

TABLE 2

ANALYSIS OF VARIABLES BY THE DEGREE OF SEXUAL DIFFERENCES

		Men				Women			Sexual dimorphism		
Variable	><	Mean	± ΔM	p	><	Mean	± ΔM	p	Response	><	CSD
Combined group											
Body mass (kg)		70.7	0.62			56.6	0.40				1.36
Height (cm)		176.5	3.45			163.4	2.61				2.13
Waist circumference (cm)		77.7	3.96			69.1	2.82				1.25
Hip circumference (cm)		95.1	3.65			93.9	2.94				0.18
Average skinfold thickness (mm)		12.9	0.34			18.1	0.26				-0.84
BMI (kg/m^2)		22.6	0.18			21.2	0.14				0.46
Fat mass (kg)		12.1	0.36			15.2	0.28				-0.48
Active cell mass (kg)		35.9	0.27			24.2	0.19				2.53
Muscle-skeletal mass (kg)		32.5	0.20			20.8	0.16				3.13
SBP		138.0	0.81			122.1	0.54				1.17
DBP		75.1	0.49			75.0	0.39				0.01
HR		76.6	0.73			80.4	0.59				-0.28
BSV (Starr)		0.1	0.00			0.1	0.00				0.97
COM (Starr)		5.4	0.06			5.0	0.04				0.41
FEV1 (l)		4.3	0.04			3.1	0.03				1.97
FVC (l)		4.6	0.05			3.3	0.03				1.92
Vital index		66.5	0.71			59.1	0.57				0.65
Right hand grip strength		46.3	0.43			27.7	0.22				2.84
Strength Index		0.7	0.01			0.5	0.00				1.68
Samara											
Weight (kg)		68.9	1.18	0.134		57.6	0.92	0.288			1.10
Height (cm)		176.2	0.71	0.643		163.8	0.48	0.488			2.02
Waist circumference (cm)		77.0	0.77	0.389		69.6	0.65	0.377			1.07
Hip circumference (cm)		94.1	0.71	0.143		95.0	0.64	0.090			-0.14
Mean fat thickness (mm)		12.1	0.71	0.281	>	16.7*	0.58*	0.024	W	>	-0.75*
BMI (kg/m^2)		22.2	0.35	0.166		21.4	0.31	0.384			0.22
Fat mass (kg)		12.4	0.70	0.631	<	16.8*	0.67*	0.018	W	<	-0.68*
Active cell mass (kg)	>	34.1*	0.46*	0.000	>	22.8*	0.22*	0.000	M	>	2.46*
Muscle-skeletal mass (kg)	>	31.2*	0.36*	0.000	>	19.9*	0.19*	0.000	M	>	3.03*
SBP	>	135.1*	1.44*	0.047	>	119.5*	1.02*	0.013	M	>	1.15*
DBP		74.9	1.04	0.887		74.8	0.75	0.801			0.02
HR		75.1	1.49	0.317	>	77.0*	1.10*	0.002	W	>	-0.14*
BSV (Starr)		0.1	0.00	0.176		0.1	0.00	0.077			0.95
COM (Starr)	>	5.2*	0.12*	0.049	>	4.7*	0.08*	0.000	W	<	0.48*
FEV1 (l)		4.3	0.07	0.484	<	3.2*	0.04*	0.032	W	>	1.89*
FVC (l)		4.6	0.08	0.670		3.3	0.04	0.166			1.78
Vital index		67.6	1.31	0.420		59.2	0.90	0.929			0.73
Right hand grip strength		45.6	0.92	0.457	<	28.7*	0.41*	0.023	W	>	2.59*
Strength Index		0.7	0.01	0.579		0.5	0.01	0.212			1.65

	Men				Women				Sexual dimorphism		
Variable	><	Mean	± ΔM	p	><	Mean	± ΔM	p	Response	><	CSD
Arkhangelsk											
Body mass (kg)		71.8	1.39	0.429		57.3	0.76	0.362			1.40
Height (cm)		176.1	0.90	0.584		163.8	0.47	0.429			1.99
Waist circumference (cm)		77.4	0.82	0.798		68.3	0.49	0.148			1.33
Hip circumference (cm)		95.1	0.84	0.997		93.9	0.54	0.966			0.18
Mean fat thickness (mm)		13.8	0.78	0.284		18.8	0.46	0.101			-0.82
BMI (kg/m^2)		23.1	0.39	0.215		21.3	0.27	0.529			0.56
Fat mass (kg)	<	13.9*	0.86*	0.042	<	16.4	0.46	0.013	M	>	-0.39*
Active cell mass (kg)		35.4	0.49	0.405		24.8	0.54	0.279			2.31
Muscle-skeletal mass (kg)	>	31.2*	0.39*	0.002		20.9	0.45	0.857	M	>	2.77*
SBP	<	143.3*	2.21*	0.020	<	124.8*	1.05*	0.012	M	<	1.37*
DBP	<	77.7	1.20*	0.029		74.4	0.77	0.436	M	<	0.38*
HR	<	81.0*	2.03*	0.035		79.9	1.17	0.656	M	<	0.09*
BSV (Starr)		0.1	0.00	0.648	<	0.1*	0.00*	0.046	W	>	0.74*
COM (Starr)		5.7	0.17	0.126		5.1	0.08	0.376			0.59
FEV1 (l)											
FVC (l)											
Vital index											
Right hand grip strength		45.7	0.81	0.464		28.0	0.41	0.505			2.70
Strength Index		0.6	0.01	0.216		0.5	0.01	0.852			1.53
Saransk											
Body mass (kg)	<	74.7*	1.12*	0.001		55.8	0.68	0.289	M	<	1.82*
Height (cm)	<	178.7*	0.57*	0.000		163.7	0.51	0.662	M	<	2.44*
Waist circumference (cm)	<	79.8*	0.73*	0.005		68.7	0.49	0.506	M	<	1.61*
Hip circumference (cm)		95.9	0.65	0.264	>	92.6*	0.53*	0.011	W	<	0.49*
Mean fat thickness (mm)	<	15.9*	0.71*	0.000	<	20.6*	0.48*	0.000	M	>	-0.75*
BMI (kg/m^2)	<	23.4*	0.35*	0.029		20.8	0.24	0.193	M	<	0.79*
Fat mass (kg)		11.3	0.63	0.191	>	12.7*	0.47*	0.000	W	>	-0.22*
Active cell mass (kg)	<	39.7*	0.50*	0.000	<	25.4*	0.24*	0.000	M	<	3.10*
Muscle-skeletal mass (kg)	<	35.7*	0.37*	0.000	<	22.2*	0.26*	0.000	M	<	3.63*
SBP		140.1	1.54	0.189		121.8	1.08	0.731			1.35
DBP		76.1	0.87	0.262		75.0	0.75	0.915			0.11
HR		77.9	1.15	0.284	<	83.5*	1.14*	0.007	W	<	-0.43*
BSV (Starr)		0.1	0.00	0.762		0.1	0.00	0.821			0.96
COM (Starr)		5.5	0.10	0.389	<	5.2*	0.08*	0.032	W	>	0.32*
FEV1 (l)	<	4.6*	0.07*	0.001		3.1	0.05	0.298	M	<	2.30*
FVC (l)	<	5.0*	0.08*	0.000		3.3	0.05	0.778	M	<	2.40*
Vital index		67.3	1.27	0.525		59.7	0.93	0.536			0.67
Right hand grip strength	<	48.5*	0.74*	0.004		27.6	0.41	0.854	M	<	3.18*
Strength Index		0.7	0.01	0.429		0.5	0.01	0.579			1.56
Villages of Mordovia											
Weight (kg)	>	68.0*	1.20*	0.030		55.1	0.80	0.076	M	>	1.25*
Height (cm)	>	175.3*	0.60*	0.044	>	162.1*	0.66*	0.046	W	<	2.15*
Waist circumference (cm)		76.5	0.79	0.152		69.8	0.62	0.224			0.98

	Men				Women				Sexual dimorphism		
Variable	><	Mean	± ΔM	p	><	Mean	± ΔM	p	Response	><	CSD
Hip circumference (cm)		95.4	0.73	0.722		94.3	0.63	0.585			0.17
Mean fat thickness (mm)	>	10.4*	0.46*	0.000	>	15.4*	0.42*	0.000	W	>	-0.80*
BMI (kg/m^2)		22.1	0.34	0.102		21.0	0.27	0.447			0.35
Fat mass (kg)		11.4	0.69	0.327		14.6	0.54	0.254			-0.49
Active cell mass (kg)	>	34.3*	0.45*	0.001	>	23.6*	0.23*	0.014	M	>	2.31*
Muscle-skeletal mass (kg)	>	31.7*	0.31*	0.007	>	20.3*	0.19*	0.005	M	>	3.05*
SBP		135.8	1.44	0.120		122.2	1.10	0.936			1.00
DBP	>	72.9	0.82	0.008		76.0	0.85	0.227	M	<	-0.36*
HR		74.4	1.27	0.079		81.7	1.17	0.264			-0.55
BSV (Starr)	<	0.1*	0.00*	0.037		0.1	0.00	0.857	M	<	1.20*
COM (Starr)		5.4	0.10	0.817		5.1	0.11	0.410			0.30
FEV1 (l)	>	4.0*	0.06*	0.000	>	2.9*	0.07*	0.005	M	>	1.87*
FVC (l)	>	4.3*	0.07*	0.000		3.2	0.06	0.116	M	>	1.67*
Vital index		64.9	1.14	0.166		58.2	1.18	0.460			0.59
Right hand grip strength		45.3	0.83	0.250	>	26.1*	0.56*	0.005	W	<	2.94*
Strength Index		0.7	0.01	0.321		0.5	0.01	0.061			1.97

p – Calculated for the difference between the means in the combined group and territorial group by Student's t-test; * - significant differences (p<0,05), «Response» - indicates which sex is characterized by a greater difference from the average value in the combined group; «><» - indicates an increase (<) or decrease (>) in the variable value relative to the level in the combined group. Indicators «Response» and «><» are noted only in the case of significant differences for at least one sex.

CSD – coefficient of sexual dimorphism, M – men, W – women, BMI – Body mass index, SBP – Systolic blood pressure, DBP – Diastolic blood pressure, HR – Heart rate, BSV - Blood stroke volume, COM - Cardiac output per minute, FEV1 – forced expiratory volume in the first second, FVC – the forced lung capacity.

males (64.1%). It means that adaptation potentials in males surpass those of females, although the biological importance of the traits varies.

As it can be seen from the results, in all cases both males and females show like-directed differences – either increasing or decreasing from the average level. The question of possible presence of sex-specific selection of morphological traits in humans is still of great importance[9]. There are some data for height that confirm the presence of sex-antagonistic selection leading to sex differences in this trait[22]. For the other characteristics there are no data indicating to the existence of separating impact of environmental conditions. In our study the groups differed from each other by the level and quality of environmental influences, which did not show any effect on sex divergence. In other words, both in males and females the deviations from the average values occurred in the same direction.

Besides the separating effect of external factors, which could be accounted for differently directed changes in men and women, mediated influence on the degree of sexual differences could also exist. Males and females can react differently to the changes of living conditions, which would lead to different levels of adaptation and health status. Several studies confirm such sex differences by the example of height[23–28]. Climatic stress, education level or socioeconomic status may have a negative impact. Caverlaas and coauthors even suggested that the level of sexual dimorphism in height could be used as a complex indicator of living conditions in the population reflecting the degree of stress[26]. However not all researchers agree with the theory of different sensitivity to external influences in the two sex groups. Sohn argues that even strong economic changes during 50 years did not lead to the changes in the differences between mean values of height[29]. He suggests that the males are really more sensitive to environmental changes and stress impact but due to compensatory mechanisms the differences in the level of sexual dimorphism are not revealed.

When sensitivity of the males was evaluated separately for different sets of the traits, it was found that in the majority of sets women were characterized with the lower reaction strength in the majority of sets. Thus, for body mass components and respiratory system characteristics the advantages in the reaction strength in favour of the males are fundamental: in 80% of significant differences, the males prevailed.

For morphological traits and CVS characteristics the differences were not that obvious. Variations of the CVS characteristics were basically the same. It is known that sexual dimorphism in the CVS characteristics is mostly determined by internal factors associated with sex assignment[30]. In particular the level of sexual dimorphism in SBP and DBP remains stable in different populations and equals 122/74.5 in young men and 111/69.7 in young women[30].

As for adiposity traits, it is still not clear how the differences between men and women are developed. It is known, that 70% of BMI variations are determined by genetic factors, sex assignment being not the last one among those[14, 31, 32]. Metabolism of the fat tissue, its volume and topography highly varies in men and women[14, 31, 33]. That is why it is logically to suggest that external factors responsible for the adaptation of human organism will have different impact on men and women. In our study no differently directed adaptation was found in morphological parameters associated with the fat component. But the reaction strength turned out to be different in males and females of the groups studied. Thus, from six cases of significant differences in means of such traits as average skinfold thickness and fat mass, in four cases women showed greater changes.

In main body parameters, such as height, body mass, BMI, significant differences from the means occurred not often: only in 5 cases out of 12. In height and BMI men in all cases showed more mobility than women, which coincides with the conclusions made by Caverlaas and his coauthors[6]. In body mass males and females were equally mobile. It could be suggested that such traits as height, body mass and BMI due to their complexity and low variability, depend on numerous factors. They are more genetically determined; the level of environmental influences that was studied with the example of our samples does not lead to serious changes and adaptations.

When the samples are considered separately, it is clear that an advantage in the reaction force of males does not always exist. In the Samara group, males were more sensitive only in three cases. But it is exactly this group that takes a central location. When the values of CSD were considered in more details, it became evident significant differences from the means did not lead to the considerable changes in the CSD values: for all traits with significant differences, the CSD differences did not exceed 0.2 normalized standard deviation values. Consequently, adaptation processes in Samara do not lead to the changes of differences between sexes.

In other groups males demonstrated stronger reaction to the external factors. Thus, in the Arkhangelsk group significant differences were found almost in all characteristics of CVS and body composition. Furthermore, in five cases out of six, males showed stronger changes. An increase in the CVS might be caused by adaptation to the Northern climatic condition[16, 34] and explained as compensatory mechanism the impact of low temperatures. And under such circumstances the males adapt quicker. In the group from Saransk major direction of changes was revealed in morphological characteristics. In all traits associated with the general dimension of the locomotor system and muscle strength characteristics Saransk males were significantly larger than their counterparts from other regions. The same tendency was typical for the girls as well. However in two characteristics of fat tissue the girls were significantly lower. It is possible to suggest that in this particular territorial group there is a certain factor, or complex of various factors that brings to developing of a tall strong version of body build with low amount of fat. It is evident that males are more susceptible to such influence. The last territorial group – Mordovian villages, differs from all others by significant reduction of all morphophysiological traits. A certain proportion of these differences is significant. As was already said, the changes go in the same direction, and for the body composition characteristics, CVS and respiratory system traits men decrease relatively to the basic level stronger than women, thus confirming the theory of stronger sensitivity of the male sex.

The difference in the strength of changes relatively to the average level does not always coincide with the increase or decrease in the degree of sexual dimorphism. Pattern of changes of the CVS values is determined by the direction of changes, the ratio of trait values in men and women in average, and by the ratio of the rate of changes between two sexes. It is clearly demonstrated in the column "><" for CSD in Table 2. The number of cases with the increased CSD values relatively to the average level is equal to the number of cases with their decrease (20 and 19 correspondingly). If such a proportion is analyzed separately, for each territorial group, than in the two groups the values of CSD increase more often, and in the two others decrease more often. When morphological sets of date are being considered, then it appears that the CSD changes are also characterized with mosaic pattern. Basing on that, it can be concluded that the influence of external factors on sexual dimorphism changes is not connected with males' sensitivity but reflects some other biological mechanisms.

Conclusions

For all of the indicators of the health status studied in the four groups no cases of differently directed changes were found. It confirms the viewpoint that under noncritical impact of such environmental conditions as climate or urbanization degree, it is impossible to observe the divergence of sexes in morphofunctional parameters. However the degree of adaptation potentials is considerably different in males and females in many characteristics. Thus, for body mass components, characteristics of respiratory system, height and BMI, males are more sensitive to environmental impact. For the CVS traits, the degree of fat tissue development and body mass, the strength of adaptation changes is practically equal in men and women, with slight advantages in men.

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SPOLNO SPECIFIČNA FENOTIPSKA PLASTIČNOST KAO SLOŽENA REAKCIJA LJUDSKOG ORGANIZMA NA RAZLIČITE OKOLIŠNE UVJETE

S A Ž E T A K

Složena antropološka ispitivanja suvremenih učenika provedena su u tri velika grada Ruske Federacije (Samara, Arhangelsk, Saransk), kao i u selima Mordovije. Program morfofunkcionalnog ispitivanja uključivao je karakteristike tijela, komponente tjelesne mase (procijenjene bioelektričnim analizatorom impedancije "Medass-1"), fiziološke karakteristike kardiovaskularnog i dišnog sustava, stisak šake desne ruke (dinamometrija). Za procjenu spolnog dimorfizma korišten je koeficijent spolnog dimorfizma (CSD). Ukupan broj ispitanika uključio je 476 djevojaka i 375 mladića, u dobi od 17 do 23 godine. Rezultati ANOVA analize pokazuju prisutnost neslučajnih varijacija za većinu ispitivanih karakteristika u ispitanim skupinama. Na temelju toga je moguće zaključiti da različiti uvjeti okoline imaju značajan utjecaj na ljudski organizam, što je srž procesa prilagodbe. Najveća udaljenost razdvaja skupine između grada Saranska i mordovskih sela. To pokazuje da je utjecaj društvenih i okolišnih čimbenika na ruralne i urbane stanovnike mnogo veći u usporedbi s ekološkim, npr. zemljopisnom širinom lokacije. Usporedba vrijednosti CSD-a u svim skupinama pokazala je da se stupanj adaptacijskih potencijala kod muškaraca i žena znatno razlikuje po mnogim karakteristikama. S obzirom na komponente tjelesne mase, karakteristike dišnog sustava, visinu i BMI, muški su osjetljiviji na utjecaje okoline. Što se tiče kardiovaskularnog sustava, razine masnog tkiva i tjelesne mase, snaga prilagodbe praktično je jednaka u oba spola, s malim prednostima kod muških ispitanika.