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Characteristics of functioning of respiratory and cardiovascular systems in Teenagers Residing in the conditions of chemical pollution of the environment

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ABSTRACT

The state of the present environment is characterized by a significant increase of the anthropogenic impact. More and more territories on the planet, including Russia, have the influence of chemical pollution. The child's body is especially sensitive to the effects of chemical pollution of the environment. Respiratory and cardiovascular systems are leading adaptive body systems. Therefore, today there is a question about degree of exposure to chemical pollutants on bodies of adolescents. Purpose of the study is to evaluate the functioning of cardiovascular and respiratory systems of adolescents exposed to chemical pollution of the environment. The study presents data of the anthropogenic effects impact on the cardiovascular and respiratory systems of the adolescents' bodies (15-17 years of age), living in conditions of environment's chemical pollution (n = 222: 102 boys and 120 girls). As a control group, the study involved adolescents living in environmentally friendly conditions (n = 180: 90 boys and 90 girls). To assess the activity of the cardiovascular (CVS) and respiratory systems (RS), we used indicators of external respiration, blood pressure and the study of the hart's functional intervals. A persistent effect of chemical pollutants on the cardiovascular and respiratory systems of adolescent organism was established as a result of data obtained. More significant changes were found in boys as compared to the girls. Considering the age-related dynamics of changes, we can conclude that maximum abnormalities occur at the peak of puberty in both – boys and girls (14, 16 and 13, 14 years, respectively), which can have negatively affect the further developmental.

Key words : *Adolescents, Chemical pollution, Cardiovascular system, Respiratory system, Adaptation*

Introduction

A large amount of scientific information has appeared on the impact of the ecologically unfavorable environment on the physical development and functional state of child's body in recent decades (Agadzhanyan and Ermakova, 1994; Vel'tishchev, 1994; Butova, 1999; Strel'cov, 2002; Kapranov and Koktyshev, 2017; Gubareva *et al.*, 2017; Budkevich, 2017; Milashechkina, 2005; Milashechkina, 2019). Pollution's assessment of the area according to each measure has to evaluate not only generally accepted indicators but local features too. For example, not only the usually studied Cs^{137} and Sr^{90} influence to

the radioactive background of the region forming. They can't exceed average marks. However, K^{40}, Th^{232}, Ra^{226} give its influence to format of the gamma background of studied Russian region. It's due to the specialties of parent rocks and active agricultural activities (Fink *et al.,* 2018). The general laws of adaptive changes in organism to the influence of environmental factors of various natures are disclosed. Data show that each environmental situation contributes to the formation of certain phenotype (Ahverdova *et al.*, 2001; Lysenko, 2003; Gubareva *et al.*, 2017; Buckner *et al.,* 2017; Cunanan *et al.*, 2018).

An important place in the formation of adaptation to external environmental influences is the state of cardiovascular and respiratory systems. Since, participating in the processes of deployment and implementation of the genetic program, the circulatory system determines the development of other systems of the growing organism (Milashechkina *et al.*, 2018). Familial hypercholesterolemia is associated with high risk of early atherosclerosis and cardiovascular death (Hrechanina *et al.*, 2019). The medical-social significance of the arterial hypertension (AH) in the world is determined by its high prevalence, which allows name it as non-infectious pandemic of today (Yumashev *et al.*, 2019).

The purpose of the study is to apprize the functioning of cardiovascular and respiratory systems of adolescents' body exposed to chemical pollution of the environment.

Materials and Methods

The study was conducted on the basis of North-Caucasus Federal University in time of 3 years. The influence of chemical environmental factors on the body of adolescents was investigated in the setting of an experiment of nature. The study participants were adolescents aged 13-14 and 16-17 years old, which were divided into groups: the 1st was control group (n = 180) – 90 boys and 90 girls living in relatively favorable ecological region of Stavropol; the 2nd was experimental one (n = 222) – 102 boys and 120 girls living in conditions of chemical pollution of the environment in the city of Nevinnomyssk, Stavropol territory.

To determine the functional state of respiratory system, we used indicators of vital capacity (VC). To determine the condition of circulatory system, we used indicators of cardiointervalography: heart rate (HR), stress index (SI), mode (Mo), mode amplitude (MoA), range (⊗X), and mean root square deviation (MSD, ∫), as well as the value of blood pressure (BP).

All measurements were made with written consent of minors' parents and they have agreed to the publication of research materials.

The values of VC in adolescents living in chemically contaminated areas are presented in Table 1. It shows that environmental pollution with chemical waste leads to a significant ($P<0.05$) decrease in VC in boys of all studied age groups. No significant differences were found in girls ($P>0.05$).

The data presented in Table 2 show that for girls 13 years of age and for boys 13-14 years of age living in the area with chemical pollution of the environment, the indicators of systolic and diastolic blood pressure are significantly higher ($P<0.01$) than in children of the control group. Moreover, in girls aged 13 years, blood pressure indicators are higher than in boys. At the same time, at the age of 14 years, these values are greater for boys than for girls.

Comparing the indicators of heart rate in girls

Table 1. VC measurements in adolescents living in a chemically contaminated area, l

Age	Control group	Experimental group	Ð
		Girls	
13 years	2.23±0.04	2.25±0.07	>0.05
14 years	2.38±0.05	2.27±0.08	>0.05
16 years	2.54±0.05	2.71±0.07	>0.05
17 years	2.81±0.06	2.66±0.07	>0.05
		Boys	
13 years	3.21±0.07	2.34±0.05	<0.001
14 years	3.34±0.05	2.29±0.15	<0.001
16 years	3.23±0.04	2.97±0.13	<0.05
17 years	3.5±0.06	3.19±0.13	<0.001

Table 2. Values of blood pressure in adolescents from different environmental conditions, mm Hg

	Control group		Experimental group	
	Age		BP	
	SBP	DBP	SBP	DBP
		Girls		
13 years	101.54±0.99	62.69±0.50	124.50±3.44***	76.40±1.70***
14 years	99.29±1.70	59.29±0.29	109.7±1.70**	63.77±1.52*
16 years	112.96±1.92	69.82±1.69	117.45±1.95	71.48±1.34
17 years	107.12±2.91	67.65±3.78	115.55±2.02*	71.10±1.67
		Boys		
13 years	103.10±1.15	63.33±0.58	117.40±2.63**	73.5±1.81***
14 years	99.17±0.52	57.92±0.52	121.26±2.59***	76.6±1.34***
16 years	116.16±2.80	70.37±1.49	122.77±2.72	71.23±1.21
17 years	116.33±2.20	70.42±1.05	125.90±3.35*	72.85±3.29

Note: * - P<0.05; ** - P<0.01; *** - P<0.001.

from environmentally friendly and chemically contaminated areas, was found that environmental pollution leads to a significant (P<0.05) increase in heart rate in all studied age groups (Fig. 1). Especially significant differences are observed in girls of 13-16 years of age, by 17 years, the heart rate value approaches the physiological norm for given age.

Boys from different ecological regions with chemical pollution of the environment also showed a violation of the age-related dynamics of heart rate (Fig. 1). In this case, there are no significantly evident differences in heart rates in boys of 13 years of the experimental and control groups, and in adolescents of 16 and 17 years of age living in a chemically contaminated area, heart rates significantly exceed those of boys in the control group (P<0.05).

The state of adaptive processes in the cardiovascular system, as well as the degree of influence of the sympathetic and parasympathetic autonomic nervous system on heart rate control, allows us to judge the mathematical analysis of variational pulsometry (Baevskij *et al.*, 1987; Arushanjan, 2000; Milashechkina, 2005; Kitney and Rompelman, 1980, Yaribeygi *et al.*, 2017). Use of stress testing does not always allow establishing the correct diagnosis as well due to its lower specificity in women compared to men (Isayeva, 2014).

The results of the study of cardiointervalography in adolescents from the chemically contaminated area are presented in Table 3.

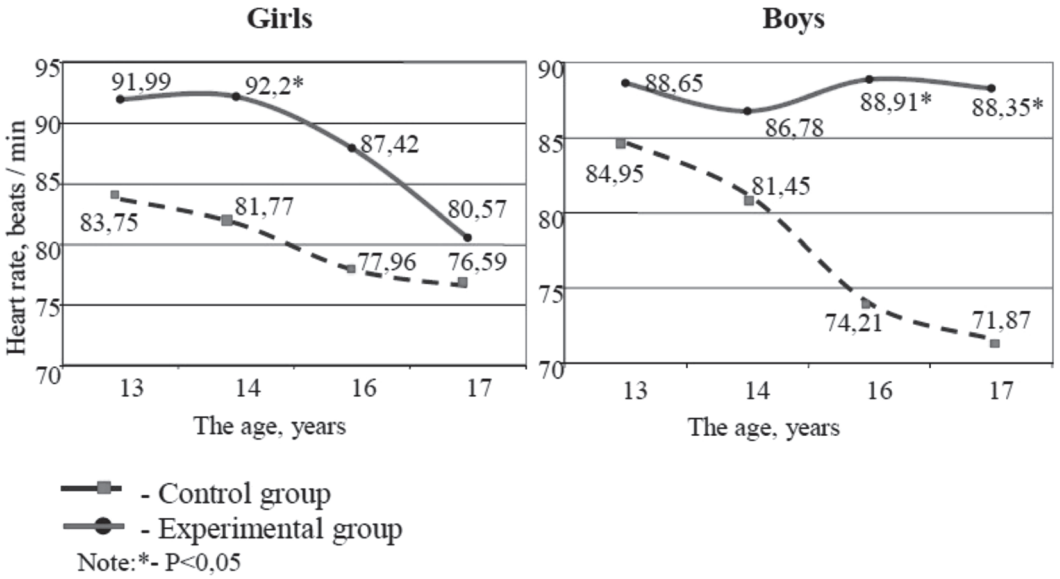

Fig. 1. Age dynamics of heart rate in boys and girls living in different ecological regions

According to data obtained from girls aged 13 to 14 and girls 17 years old, were living in conditions of the environment's chemical pollution, the standard deviation and variational range are higher compared with the girls from the control group. In boys, who were living in conditions of environmental pollution, a significantly evident increase in the variational range compared with the control group was observed at 13 and 14 years old (P<0.01-0.001). The standard deviation was observed at 13 years.

When considering the MoA indicator in girls, no significant changes were detected, however, with aging, this indicator tends to increase.

Young men aged 13 and 17, living unfavorable environmental conditions, revealed a significantly evident decrease in MoA (P<0.05) compared with those in boys of control group, which indicates the moderate activity of parasympathetic division of autonomic nervous system and the predominant influence of autonomic contour regulation on the heart rhythm.

The stress index is an indicator of total activity of central regulation loop (psycho-emotional stress, activity of the hypothalamic-pituitary system, vasomotor, and sympathetic centers of nervous system). The stress index is usually called by the name of its author R.M. Baevskij. This index most fully informs about the tension of body compensatory mechanisms. According to data from the Table 4, less than half of the girls of all studied age groups living in ecologically unfavorable region are in state of vegetative equilibrium compared to control group. Moreover, at 13 years old 29.67% of schoolgirls showed a pronounced and moderate predominance of activity of the parasympathetic department of autonomic nervous system. At 14 years old this mark was 34.09%; at 16 years – 34.09%; and at 17 years – 31.37%. That is, the influence of the autonomous regulation circuit increases with aging. On the other hand, in girls 13 and 14 years of age, there is a pronounced predominance of activity of the sympathetic part of autonomic nervous system, which may subsequently lead to pathological changes in the heart. In girls of the control group no strengthening of the central contour of heart rhythm regulation was revealed.

In boys living in a chemically contaminated area, there is a pronounced moderate predominance of activity of the parasympathetic division of autonomic nervous system in all age groups trending up, and its highest value was found in adolescents

Table 3. Heart rate variability in adolescents living in chemically contaminated area

Age, years	Control group					Experimental group				
	M	MSD, ∫	⊗X	Mo	MoA	M	MSD, ∫	⊗X	Mo	MoA
Girls										
13	724.50±19.16	64.54±7.28	392.67±32.87	672.92±18.32	36.58± 3.04	677.16±20.18	80.09± 3.03*	589.24± 35.75***	629.12±13.77	33.27±1.48
14	743.00±27.90	58.33±5.89	331.33±30.23	716.67±33.22	36.83± 3.40	673.45±17.34	76.82± 4.66*	649.70± 61.54***	647.73±18.84	36.25± 2.19
16	749.92±20.26	84.54±9.63	455.04±33.97	760.42±47.16	32.79± 2.09	723.52±27.62	79.16± 6.10	623.46± 58.93***	734.09±30.84	35.88±2.14
17	793.35±24.73	66.82±5.95	373.35±36.48	767.65±27.02	32.76± 3.51	782.98±26.05	82.00± 4.41*	556.00± 53.15**	749.02±24.84	35.88±2.14
Boys										
13	684.05±15.90	54.35±4.72	323.00±29,89	650.00±20.93	30.45± 2.87	694.71±14.06	122.99± 19.41***	521.52± 6.37***	653.05±17.01	35.04±1.45*
14	747.00±33.19	64.82±12.56	362.91±51.36	731.81±42.80	35.36± 4.19	707.67±20.46	68.99± 3.40	563.90± 31.65**	673.91±19.05	36.10±1.62
16	805.84±14.42	89.82±10.32	493.74±50.24	776.32±43.52	30.74± 2.18	752.27±37.01	73.53± 5.99	558.03±55,90	696.66±33.09	36.80±2.23
17	726.87±28.31	79.33±7.15	381.93±33.73	820.00±26.36	30.47± 2.03	691.00±19.79	81.65± 7.89	494.60± 47.59	732.50±53.81	24.30±1.85*

Note: * - P<0.05; ** - P<0.01; *** - P<0.001.

of 17 years of age – 40.00%, and the predominance of activity of the sympathetic section of autonomic nervous system is observed at 13 years of age – 7.32%, at 14 years of age – 11.60%, at 16 years of age – at 23.33%. In adolescents in the control group this trend is not observed. However, at age 16 more than half of boys in control group showed a pronounced and moderate predominance of the parasympathetic autonomic nervous system.

Discussion

According to the results of our study, it was found that chemical pollution of the environment leads to decrease in the functioning of respiratory and cardiovascular system as other authors note (Osmanov *et al.*, 2015; Kapranov and Koktyshev, 2017; Huang *et al.*, 2013; Schnell *et al*., 2013; Jian *et al*., 2017; Daley *et al.*, 2018; Juntunen *et al.*, 2017), and further to the occurrence of pathological conditions.

Moreover, by the indicator of external respiration, the vital capacity of lungs we determined that the respiratory system of male adolescents is more sensitive to chemical pollution of the environment than that of a female. Similar results were obtained by Lykov with co-authors (2006) in the Kaluga city, Russia.

The values of blood pressure and heart rate in adolescents living in a chemically contaminated area are significantly higher than in children from relatively favorable living conditions. And, as known, the values of systolic and diastolic blood pressure are predictors of the risk of cardiovascular disease. It is equally important to know and diagnose the response of blood pressure to stress factors and physical activity in predicting the development of hypertension. Analysis of gender differences showed that manifestation of eco-sensitivity in different age periods is associated with different periods of puberty. According to data obtained, girls have the highest blood pressure at 13 years of age. In boys the maximum values of blood pressure occur at 14, 17 years of age.

A significantly evident increase in the variation range in boys living in environmental pollution conditions was observed at 13 and 14 years of age, and the standard deviation – at 13 years of age. This fact indicates an increase in the activity of the autonomous circuit of vegetal regulation in these age groups. At the same time, within the boundaries of the vegetative equilibrium, there were about a third of the results on SI in adolescents living in ecologically unfavorable area. In this case, both parasympathetic and severe sympathetic reactions were observed. A significant shift in SI both in the direction of decreasing and increasing indicates an unsatisfactory adaptation. More favorable is the vegetative balance, as well as the moderate predominance of sympathetic tone over parasympathetic. The parasympathetic reaction to the heart rhythm is less fa-

Table 4. Value of the stress index in adolescents living in conditions of chemical pollution of the environment (percentage of the total number of examined adolescents)

Age, years	Stress index, conv. units									
	≤ 25 significant predominance of PNS		26-50 moderate prevalence of PNS		51-200 vegetative balance		201-500 moderate prevalence of SNS		>500 significant predominance of the SNS	
	Control	Exp.	Control	Exp.	Control	Exp.	Control	Exp.	Control	Exp.
					Girls					
13	12.50	29.67	12.50	19.78	62.50	36.26	12.50	5.50	-	8.79
14	8.33	34.09	8.33	20.45	75.00	38.64	8.33	2.27	-	4.55
16	25.00	34.09	16.67	15.91	58.33	36.36	-	13.64	-	-
17	5.89	31.37	11.76	25.50	82.35	37.25	-	5.88	-	-
					Boys					
13	5.00	23.17	20.00	26.83	65.00	41.46	10.00	7.32	-	7.32
14	9.09	24.64	27.27	33.33	54.55	30.43	9.09	11.60	-	11.60
16	31.58	26.67	21.05	20.00	36.84	30.00	10.53	23.33	-	23.33
17	6.67	30.00	40.00	35.00	53.33	35.00	-	-	-	-

Note: PNS is a parasympathetic division of the autonomic nervous system;
SNS is a sympathetic division of the autonomic nervous system

vorable, which corresponds to average adaptive stability. The inclusion of the central contour of heart rhythm regulation in some 13-14-year-old adolescents, as evidenced by the growth of SI, leads to activation of the sympathetic division of the autonomic nervous system and can cause an increase in the tone of smooth muscle cells that are part of the structure of blood vessels, which other authors note (Gubareva *et al*., 2017; Schnell *et al*., 2013). Thus, a significant increase in SI, indicating the predominance of sympathetic tone on the activity of the heart, can be considered as a risk factor in the occurrence of heart pathology.

Conclusions

Chemical pollution of the environment leads to decrease in the functional capabilities of the respiratory and cardiovascular systems and can cause a limitation on the ability to perform physical activity. The dynamics of the shifts of violations revealed by us depend on sex and ontogenesis period. Stronger changes in the level of adaptive capabilities were detected in children at the peak of puberty, with the most severe changes observed in boys. According to preliminary data, chemical environmental pollution leads to a change in the functioning of the endocrine and nervous systems. This will be the future perspective of our research. At the same time, there is a growing need to find ways to reduce such an anthropogenic load that is excessive for a child's body.

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