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Influence of radioecological pollution on heart rate variability in young men of different somatotypes

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Monitoring of the influence of radioactive contamination as a result of the accident at the Chernobyl nuclear power plant was carried out using morphophysiological and statistical research methods. The sources of the data are our own research, the data of Bryanskstat, Rostekhnadzor, Rospotrebnadzor. Groups of normosthenics, asthenics and hypersthenics were raced and identified among young men permanently residing in the areas with different levels of radioactive contamination. Different frequency of somatotypes occurrence, depending on the area of residence, was stated. Normally clean territories are dominated by normosthenics. In the areas with an increased level of radioactive contamination the number of asthenics and hypersthenics is growing. As for normostenics, moderate autonomic and moderate central mechanisms of heart rate regulation dominate. Asthenics are characterized by increase in the pronounced central mechanism of regulation. As for hypersthenics, the influence of a pronounced autonomous mechanism of regulation of the heart rate prevails. The pronounced dominance of the central circuit of heart rate regulation in asthenics and the autonomous circuit of heart rate regulation in hypersthenics is a consequence of tension, and in some representatives of depletion of the reserve capabilities of the systems under study in conditions of prolonged exposure to low doses of radiation. The identified variants of autonomic regulation of the heart rate are largely genetically determined, but at the same time, they are finally formed under the influence of external (radiation load on the environment) and internal (constitutional) factors. The data obtained make it possible to identify groups of persons susceptible to maladjustment phenomena and to use the heart rate variability results for physical rehabilitation of young people in extreme living conditions.

Keywords: age, radiation, somatotype, heart rate, type of regulation.

УДК 574.24

Влияние радиоэкологического загрязнения на вариабельность сердечного ритма у юношей разных соматотипов

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Проведены мониторинговые исследования влияния радиоактивного загрязнения на механизмы регуляции сердечного ритма у юношей в результате аварии на Чернобыльской АЭС с использованием морфофизиологических и статистических методов исследования. Выделены группы нормостеников, астеников и гиперстеников среди юношей,

постоянно проживающих в районах с разным уровнем радиоактивного загрязнения. Обнаружена разная частота встречаемости соматотипов в зависимости от территории проживания. На условно чистых территориях преобладают нормостеники. В районах с повышенным уровнем радиоактивного загрязнения растёт представительство астеников и гиперстеников. У нормостеников доминирует умеренный автономный и умеренный центральный механизмы регуляции сердечного ритма. Для астеников характерно усиление выраженного центрального механизма регуляции, а в группах гиперстеников преобладает влияние выраженного автономного механизма регуляции сердечного ритма. Выраженное доминирование центрального у астеников и автономного контура регуляции сердечного ритма у гиперстеников является следствием напряжения, а у отдельных представителей – истощения резервных возможностей исследуемых систем в условиях длительного воздействия на организм малых доз радиации. Полученные данные позволяют осуществлять выделение групп лиц, подверженных явлениям дезадаптации и использовать результаты вариабельности сердечного ритма для физической реабилитации молодых людей в экстремальных условиях среды проживания.

Ключевые слова: возраст, радиация, соматотип, сердечный ритм, тип регуляции.

The population of radiation-polluted territories in south-western districts (SWD) of the Bryansk region which were to suffer the most as a result of an accident at the Chernobyl nuclear power plant (CNPP) is 316 thousand people living in 749 settlements [1]. Radio-ecological monitoring showed that density of soil contamination with ^{137}Cs and ^{90}Sr in SWD dozens of times exceeds the set limits (to 2116 kBq/m^2 for ^{137}Cs and to 60 kBq/m^2 for ^{90}Sr) [1, 2]; average accumulated effective radiation dozes, to which the population is exposed to, vary from just a few to hundreds mSv [2–4]. ^{137}Cs и ^{90}Sr contained in the fertile soil layer are included in the biosphere matter cycle and have a radiation effect on man. Up to the present moment polymorphism of post-radiation reactions in case of low-dose exposure has been a matter of debate [5]. Sustainability of an organism to damaging factors of the environment is determined by one's somatotype and genetics, as well as by the original functional status of an organism, mostly, of its regulator systems, such as: CNS, hypothalamic-pituitary-adrenal system, and immune system [6–8]. Neurohumoral mechanisms of heart rate regulation have been recently researched both in ecology and physiology [9, 10]. Heart rate reflects the fundamental correlation in functioning not only of a cardio-vascular system, but also of a whole organism. Gradual decrease in adaptation abilities of an organism is one of the reasons of one's gradual shift from a healthy state to getting ill. A human somatotype, as well as peculiar features of a bodily structure, reflects the peculiarities of one's psychic activity, metabolism and functioning of the autonomic nervous system, one's adaptative, compensatory, and pathological reactions. Research of recent time has shown that certain somatotypes are firmly connected with parameters of the heart function, the respiratory system, and functional characteristics of the gastrointestinal tract, nervous system, etc. [11–13]. It is known that morphological features of the somatotype reflect harmoniousness, physical fitness, and the state of health. Thus people of different somatotypes can have some physiological peculiarities of heart rate regulation, which is considered in our research paper.

The aim of our research is to investigate the peculiar features of heart rate autonomic regulation of young men aged 17–25 of different somatotypes residing in the ecologically polluted areas of the Bryansk region.

Objects and methods of research

The research was made in one of higher educational institutions of Bryansk from 2017 to 2020. We tested 380 male students from radio-ecologically polluted regions (REPR) and 812 male students from radio-ecologically appropriate regions (REAR) of the SWD of the Bryansk region aged 17–25. The REPR group includes students from Novozybkovskiy, Gordeyevskiy, Krasnoogorskiy, Klintsovskiy, Zlynkovskiy, and Klimovskiy districts, the level of pollution with ^{137}Cs there exceeded the regulated norm 4–11 times (129.4–427.1 kBq/m^2). In 2017 the minimal doses of pollution were stated in Klimovskiy district: 129.4 ^{137}Cs and 5.9 ^{90}Sr, and maximal doses – in Novozybkovskiy district: 427.1 ^{137}Cs and 7.7 ^{90}Sr. The REAR group included students from Suzemskiy, Brasoskiy, Zhukovskiy, Navlinskiy, Komarichskiy, Dubrovskiy, Karachevskiy. Sevskiy, and Kletnyanskiy districts, the level of radioecological pollution varied from the maximum of 25.1 kBq/m^2, as for ^{137}Cs, and 0.9 kBq/m^2, as for ^{90}Sr in Komarichskiy district to the minimum of 5.0 kBq/m^2, as for ^{137}Cs, and 0.4 kBq/m^2, as for ^{90}Sr in Kletnyanskiy district [14]. Only the students who are accepted to lessons of Physical Training and who have no serious health problems took part in the experiment, it was the main criterion of the research. We used traditional ways of taking the basic somatometric indices, such as body weight, height, sitting height, and chest circumference.

The indices we used in calculating Pignet index (PI, relative units), it characterizes somatotype. Three somatotypes were indicated, according to Chernorutskiy scheme: asthenics (26 < PI < 35 and more), normosthenics (10 < PI < 25), and hypersthenics (PI < 10).

Cardiointervalogramm was made with the help of the special device "Varikard 2.51" OOO "IVNMT "Ramena" (Ryazan). The type of autonomic heart rate regulation was calculated according to the classification of N.I. Shlyk [15]. Such indices were taken into account: MxDMn – the difference between maximum and minimum RR intervals, or variation range, ms; TP – the total spectral power, the power of RR intervals temporal meaning range, ms^2; VLF – spectral power of very low frequency oscillations 0.04–0.015 ms^2; SI – stress-index – the index of stress of regulatory systems, relative units. Four types of heart rate variability (HRV) are based on these indices: moderate (I type) and significant (II type) predominance of central regulation mechanism; predominance of moderate (III type) and significant (IV type) autonomic regulation mechanism. To interpret the data acquired we took into account other HRV indices as well: SDNN – standard deviation of full array of RR cardio-intervals, ms; RMSSD – a square root of the sum of differentials of RR intervals sequence, ms; Mo – mode, ms; AMo – amplitide mode, ms; spectrums of high frequency HF waves (0.4–0.15 hz), of low frequence LF waves (0.15–0.04 hz).

The data acquired are processed with the use of *t*-criterion of Student. In checking statistic hypotheses, the significance level was $p < 0.05$.

Results and discussion

Irrespective of their place of residence, the somatometric research showed that young men had three somatotypes, they were either normostenics, or asthenics, or hypersthenics. We noticed some connection between the somatotype and the place of residence. Asthenic somatotype was more characteristic for young men from the REPR (44%), nomosthenic somatotype was less frequent (36%), as well as hypersthenic sometotype (20%). In the population of young men from REAR the shares of hypersthenics and normosthenics are almost equal (33% and 38% consequently), and the share of asthenics is lowered to 29%. Morphological research has shown sustainability of the normosthenic spmatotype of young men from the areas which are different as for the degree of their radioeclogical safety. In the REPR the amount of asthenics increases 1.6 times, and the amount of hypersthenics decreases 1.9 times ($p < 0.05$). Asthenics increase in number and normosthenics decrease in number in the populations residing in extreme environmental conditions [16].

We studied the distribution of types of autonomic heart rate regulation in different somatotypes, depending on the place of permanent residence. The hypothesis was that, as neurodynamic processes are closely connected with the somatotype, the features of one's physique are reflected in heart rate regulation mechanisms. Nowadays, irrespective of the research already made, the functional indices of somatotypes are still studied not enough, especially in the population of people who reside in the areas which are radiation-polluted due to the accident at the Chernobyl nuclear power plant. Normosthenic young men who have been living in the radiation-polluted areas are characterized by increased centralization of heart rate control, which means, according to some researchers, that, on the whole, stress in regulatory systems increases. Comparative analysis of frequency of occurrence of the types under research showed that, as for young men from the REPR, the frequency of occurrence of the I type of HRV (heart rate variability) increased 1.2 times, and that of the II type – 1.6 times.

Taking into account the functional antagonism principle, the growth of activity of the VNS sympathetic part sopited the work of the parasympathetic part of the VNS, and in the REPR the number of young men of the III type of VHR decreased 1.1 times, and of VHR with the IV type decreased by 1.3 times.

The dynamics of HRV types distribution of asthenics remains almost similar to that of normosthenics, it reflects growth of frequency of occurrence of moderate and significant central heart rate regulation mechanism, at the same time the activity of the autonomous regulation mechanism decreases.

The II type of HRV changed more than others, this type is 1.5 times more frequent in young men from the REPR, at the same time the number of young men with the I type of HRV decreased 1.2 times. It is also notable that in the REPR young men with the autonomous type the III type of regulation were met 1.2 times more seldom, and, on the contrary, young men with the IV type were met 1.3 times more often.

Comparative analysis of hypersthenics frequency in various regions of residence showed that the most considerable variability concerned young men with the autonomous mechanism of regulation. Among hypersthenics who constantly reside in the radiation polluted areas the number of young men with the VI type of HRV increased 3.2

times, and the number of those with the III type of HVR decreased 1.4 times. As for young men with the central mechanism of regulation residing in the REPR, the number of those with the I type of HRV increased by 1.1 times, and of those with the II type of HRV it decreased 1.3 times.

Thus it was stated that the III type of HRV prevailed in young men, irrespective of their region of residing and their somatotype; we consider this type the most favourable variant of vegetative regulation [17].

We assessed the markers serving as the ground for HRV typology according to the region of residence. Normosthenics from the REPR of the I and II type are characterized by statistically steady decrease in activity of the parasympathetic part of the autonomic nervous system (ANC), as compared with those from the PEAR (Table 1).

In particular, as for young men with the I type, their indices of MxDMn, TP, and VLF decreased by 25, 29, 34% accordingly, and SI index grew by 43% (in all cases $p < 0.05$). Changing for the II type was accompanied by growth of tension of the central regulation mechanism, the indexes of MxDMn and TP lowered by 40 and 54% accordingly, SI grew by 88% ($p < 0.05$). Thus young men with domination of the central regulation mechanism reacted to changes of the quality of the environment by growth of tension of the systems of heart rate control. Autonomous mechanism dominated in normosthenics from the REPR, the analysis of the indices under study showed tendency to their lowering, though there was no statistically significant difference with young men from the REAR. Quite different dynamics in indices was characteristic of the young residents of the REPR with the IV type of HRV. The research showed a spike in growth of the indices of MxDMn, TP, and VLF by 24, 81, and 97% accordingly, the index of SI lowered by 34% (in all cases $p < 0.05$).

"The paradox feature" of the IV type consisted in the fact that the average indices in question got way beyond the norm, 560 ms for MxDMn, < 10000 for TP, and < 500 for VLF: according to [15], it is considered to be a pathological type. Presumably, stress increase of the regulation systems of the II and IV type may be connected with the increased level of disease rate of the inhabitants of the radiation-contaminated areas [18, 19]. Thus, in 2008–2017 in the polluted areas of the SWR of the Bryansk region the primary disease incidence, as for all the disease classes, in the child population

Table 1

Heart rate variability indices in students with normosthenic physique ($M \pm m$)

Index	Region	Normostenics			
		I	II	III	IV
MxDMn, ms	REAR	316.2±16.4	314.1±13.7	368.1±16.6	518.9±14.1
	REPR	238.0±11.7*	187.9±9.5*	394.7±14.0	644.9±36.1*
TP, ms^2	REAR	3791.0±216.8	2963.9±180.5	6781.1±454.8	9469.0±1080.1
	REPR	2704.1±162.1*	1366.0±145.2*	6489.3±478.9	17146.4±1419.2*
VLF, ms^2	REAR	780.6±102.5	212.9±40.8	904.1±177.8	2542.3±454.6
	REPR	512.6±79.7*	186.1±18.2	1079.2±204.0	4998.4±1106.8*
SI, n.u.	REAR	117.7±10.5	121.8±14.2	68.2±6.2	18.7±2.5
	REPR	168.3±17.0*	228.6±44.6*	57.0±5.5	12.3±1.2*

Note: I, II, III, IV – types of HRV; MxDMn – variation range, TP – total spectral power, VLF – spectral power of very low frequency oscillations, SI – stress index. Asterisk denotes statistically significant ($p < 0.05$) difference between REAR and REPR.

Table 2

HRV indices in students with asthenic physique ($M \pm m$)

Index	Region	Asthenics			
		I	II	III	IV
MxDMn, ms	REAR	182.2±13.0	149.2±8.1	414.0±27.1	490.8±29.1
	REPR	134.3±10.5*	111.2±10.3*	359.2±18.9	404.6±15.3*
TP, ms^2	REAR	2878.9±311.0	2603.9±261.5	5247.5±278.9	14255.4±2031.0
	REPR	1508.9±187.2*	1181.6±100.0*	3586.9±215.6*	10448.3±1192.3
VLF, ms^2	REAR	597.3±52.5	218.1±29.2	747.5±140.9	2658.1±354.0
	REPR	421.2±46.4*	152.4±13.3*	567.3±80.9	1055.0±159.8*
SI, n.u.	REAR	216.9±27.9	251.6±34.4	51.7±5.1	19.8±2.3
	REPR	344.2±41.7*	396.8±47.1*	76.9±7.8*	33.9±4.1*

Note: see Table 1.

Table 3

HRV indices in students with hypersthenic physique ($M \pm m$)

Index	Region	Hypersthenics			
		I	II	III	IV
MxDMn, ms	REAR	265.4±10.0	241.0±10.3	383.8±41.8	633.4±52.2
	REPR	228.0±8.6*	205.4±7.4*	380.8±26.0	483.2±23.5*
TP, ms^2	REAR	2344.8±179.8	1836.5±152.3	5666.8±389.0	10105.7±1402.9
	REPR	2261.2±260.9	1015.4±121.8*	5431.2±310.2	7921.0±450.1*
VLF, ms^2	REAR	585.1±68.1	207.5±33.6	762.3±100.5	1701.6±202.5
	REPR	408.3±52.1*	141.9±12.9*	833.5±87.2	1233.8±133.3*
SI, n.u.	REAR	128.5±13.0	144.0±20.4	63.7±7.8	15.6±2.0
	REPR	179.1±19.6	225.3±32.4*	48.6±4.3	20.7±1.5*

Note: see Table 1.

varied from 1370 to 1885 (average 1501) per 10000. On the whole, the level of primary disease incidence of the child population in ecologically clean, acceptable territories was less by 62% ($p = 0.001$), as compared with the radiation polluted areas [14].

Change from the REAR to the REPR caused total decrease of all the indices under study of asthenics with all the HRV types. Young men from the REPR with the I and II regulation type were characterized by decrease of the indices within about the same interest interval of change (Table 2).

As for the I type, the indices MxDMn, TP, and VLF lowered by 26, 48 and 30% (in all cases $p < 0.05$), in the II type the indices of MxDMn, TP and VLF lowered by 25, 55, and 30% accordingly (in all cases $p < 0.05$). Stress index of the I type grew by 59%, of the II type – by 58% ($p < 0.05$). It was stated that there was a tendency to increasing central heart rate control by the autonomic homeostasis, the sympathetic system got more active, and the influence of the ANS parasympathetic system on the sinoatrial node decreased. Decrease of the indices MxDMn, TP, and VLF was conditioned by stress of the regulatory systems at different location levels, including the level of control. As for young men from the REPR with the III type of HRV and with predomination of the autonomous mechanism of regulation, the index of TP decreased by 32% and SI grew by 48% ($p < 0.05$). As for the IV type, the index of MxDMn decreased by 18%, VLF – by 60%, and SI grew by 70% (in all cases $p < 0.05$).

MxDMn of hypersthenics with the I type from the REPR decreased by 14% ($p < 0.05$). Increase of the number of isochronous cardiac cycles is connected with growth of activity of the sympathetic part of the ANS. In these conditions energy potential of an organism lowered, as the index of VLF decreased by 30% ($p < 0.05$) (Table 3). Centralization of heart rate control increased in young men from the REPR with the II type, according to certain markers, it changed firmly. In particular, the average index of MxDMn, TP, and VLF lowered by 15, 45, and 32 % accordingly (in all cases $p < 0.05$). Sudden increase in activity of the central heart rate control in the young men from the REPR shows decline in the functional state of the regulatory systems.

According to Table 3, the index SI increased by 56% ($p < 0.05$). Hypersthenics with the III type of regulation were characterized by increased "resistance" to small doses of radiation. The level of changes of the average numbers of HRV markers was not beyond random fluctuations. This fact reflected autonomic balance in mechanisms of heart rate regulation. In the group of hypersthenics with the IV type of HRV the indices of MxDMn, TP. and VLF lowered by 24, 22, and 27% (in all cases $p < 0.05$), at the same time the index SI grew by 33%, which means increase of activity of the sympathetic system. It is a negative prognostic sign and it suggests that young men from the REPR are apparently starting to get some health problems. The research results acquired by us correspond with the results of other researchers [19].

Conclusion

The unity of somatic, physiological, and biochemical compartments forms the body type, each of the compartments takes part in forming the biological individuality of a human being, Unity and interpenetration of the somatic and the physiological in a human body type, human physique, help the organism to keep together in conditions of the changing environment. The variants of vegetative heart rate regulation which were found out are to a large extent determined genetically. But at the same time thay get finally formed under the influence of external (radiation load on the environment) and internal somatotype factors, as this research shows. The data acquired reflect strengthening of central mechanisms of heart rate

regulation in conditions of lessening of activity of the autonomus heart rate regulation mechanism. The data allow distinguishing certain groups of people who are exposed to misadaptation and using the results of heart rate variability analysis in the process of physical rehabilitation of young men in extreme living conditions.

References

1. Bruk G.Ya., Shutov V.N., Balonov M.I., Basalaeva L.N., Kislov M.V. Dynamics of ^{137}Cs content in agricultural food products produced in regions of Russia contaminated after the Chernobyl accident // Radiat. Prot. Dosimetry. 1998. V. 76. No. 3. P. 169–178 (in Russian).

2. Burlakova E.B., Goloshchapov A.N., Gorbunova N.V., Gurevich S.M., Zhizhina G.P., Kozachenko A.I., Konradov A.A., Korman D.B., Molochkina E.M., Nagler L.G., Ozerova I.B., Skalatskaya S.I., Smotryaeva M.A., Tarasenko O.A., Treshchenkova Yu.A., Shevchenko V.A. Research activities about the radiological consequences of the Chernobyl NPS accident and social activities to assist the sufferers by the accident / Ed. T. Imanaka. Research Reactor Institute. Japan: Kyoto University, 1998. P. 223–234.

3. Brechignac F., Oughton D., Mays C., Barnthouse L., Beasley J.C., Bonisoli-Alquati A., Bradshaw C., Brown J., Dray S., Geras'kin S., Glenn T., Higley K., Ishida K., Kapustka L., Kautsky U., Kuhne W., Lynch M., Mappes T., Mihok S., Moller A.P., Mothersill C., Mousseau T.A., Otaki J., Pryakhin E., Rhodes O.E., Salbu B., Strand P., Tsukada H. Addressing ecological effects of radiation on populations and ecosystems to improve protection of the environment against radiation: Agreed statements from a Consensus Symposium // Journal of Environmental Radioactivity. 2016. V. 158. P. 21–29. doi: 10.1016/j.jenvrad.2016.03.021

4. Data on radioactive contamination of the territory of settlements of the Russian Federation with cesium-137, strontium-90 and plutonium-239 + 240 / Ed. C.M. Vakulovsky. Obninsk: Federal state budgetary institution research and production association "Typhoon", 2015. 225 p. (in Russian).

5. Torre L.A., Siegel R.L., Ward E.M., Jemal A. Global cancer incidence and mortality rates and trends-an update // Cancer Epidemiol Biomarkers Prev. 2016. V. 25. No. 1. P. 16–27. doi: 10.1158/1055-9965.EPI-15-0578

6. Volodin V.V., Vetosheva V.I., Volodina S.O. Correction of adaptive reactions of the cardiovascular system using the ecdysteroid-containing remedy Adasten during intensive physical work in the North // Theoretical and Applied Ecology. 2021. No. 1. P. 227–234 (in Russian). doi: 10.25750/1995-4301-2021-1-227-234

7. Cohen L.E. Endocrine late effects of cancer treatment // Endocrinol Metab Clin North Am. 2005. V. 34. No. 3. P. 769–789. doi: 10.1016/j.ecl.2005.04.008

8. Tuschl H., Steger F., Kovac R. Occupational exposure and its effect on some immune parameters // Health Physics. 1995. V. 68. No. 1. P. 59–66. doi: 10.1097/00004032-199501000-00007

9. Averyanova I.V., Maksimov A.L. Indicators of the cardiovascular system and cardiac rhythm in young men from Magadan with different types of constitution // Bulletin of the Mordovian University. 2017. V. 27. No. 3. P. 397–409 (in Russian). doi: 10.15507/0236-2910.027.201703.397-409

10. Baevsky R.M., Ivanov G.G. Heart rate variability: theoretical aspects and possibilities of clinical application // New methods of electrocardiography / Eds. S.V. Gracheva, A.L. Syrkin. Moskva: Technosphere, 2007. P. 474–496 (in Russian).

11. Schmitt L., Regnard J., Desmarets M., Schmitt L., Regnard J., Desmarets M., Mauny F., Mourot L., Fouillot J.P., Coulmy N., Millet G. Fatigue shifts and scatters heart rate variability in elite endurance athletes // PLoS One. 2012. V. 8. No. 8. Article No. e71588. doi: 10.1371/journal.pone.0071588

12. Britton D.M., Kavanagh E.J., Polman R.C. Validating a self-report measure of student athletes' perceived stress reactivity: associations with heart-rate variability and stress appraisals // J Front Psychol. 2019. V. 10. Article No. 1083. doi: 10.3389/fpsyg.2019.01083

13. Shankin A.A., Shankina G.I. Ecological, morpho-functional and medical-pedagogical aspects of the evolutionary constitution of a person: monograph. Saransk: Mordovian State Pedagogical Institute, 2014. 310 p. (in Russian).

14. Korsakov A.V., Geger E.V., Lagerev D.G., Pugach L.I., Mousseau T.A. *De novo* congenital malformation frequencies in children from the Bryansk region following the Chernobyl disaster (2000–2017) // Heliyon. 2020. V. 6. No. 8. Article No. e04616. doi: 10.1016/j.heliyon.2020.e04616

15. Shlyk N.I. Standards of heart rate variability indices at rest and orthostasis at different ranges of MxDMn values and their change in biathletes in the training process // Chelovek. Sport. The medicine. 2020. V. 20. No. 4. P. 5–24 (in Russian). doi: 10.14529/hsm200401

16. Maksimov A.L., Sukhanova I.V., Vdovenko S.I. Features of the functional state of young men of the city of Magadan, depending on the type of constitution // Human Ecology. 2012. No. 12. P. 25–30 (in Russian).

17. Mylnikova I.V., Efimova N.V. Informative value of heart rate variability indicators for revealing the unfavorable influence of environmental factors on the health of girls // Hygiene and Sanitation. 2015. No. 1. P. 121–124 (in Russian).

18. Yablokov A.V. On the concept of "population cargo" (review) // Hygiene and sanitation. 2015. No. 6. P. 11–15 (in Russian).

19. Konstantinova D.E., Maslakova T.A., Shalaumova Yu.V., Varaksin A.N., Zhivoderov A.A. Radiation contamination of the territory and the adaptive response of the human body // Human Ecology. 2019. No. 2. P. 4–11 (in Russian). doi: 10.33396/1728-0869-2019-2-4-11