The Impact of Radiation Pollution of Environment on Students' Physical Development and Health

Wpływ zanieczyszczenia środowiska promieniowaniem na rozwój fizyczny i zdrowie studentów

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SUMMARY

Aim: To study the impact of small doses of radiation pollution of environment on the physical development and health of students from different areas of residence.

Materials and Methods: The study was conducted at Polissya National University (Zhytomyr, Ukraine) during 2012-2020. 647 students of different specialties in the age of 17-23 were interviewed about the use of preventive measures to eliminate the consequences of the Chernobyl Nuclear Power Plant (CNPP) accident in 1986 and other factors of radiation pollution of environment. In addition, 127 students who were born, lived for some time or periodically lived in the area of low doses of radioactive contamination (58 males and 69 females) and 238 students who lived in the clean area from radioactive contamination (113 males and 125 females) were interviewed to compare the samples.

Results: The comparative analysis of the students' physical development from different areas of residence showed that the students from the clean area have better indicators of average body height, body weight, Erisman index with no significant differences ($P>0.05$). Significant differences were revealed in the indicators of the circumference of the chest and the dynamometry of the hand ($P<0.05$-0.01).

Conclusions: It was established that long-term residence in the area with low doses of radioactive contamination has a negative impact on the physical development and health of the students. The students who have lived for a long time in the area of radioactive contamination more often suffer from a disease, miss classes and get tired faster during physical education sessions. It was clarified that the majority of the students are not involved in health preservation activities, but only in cases when they face significant health problems associated with the need to see a doctor, disability, etc.

Key words: radiation pollution, physical development, health, students

Słowa kluczowe: zanieczyszczenie radiacyjne, rozwój fizyczny, zdrowie, studenci

INTRODUCTION

The life-sustaining activities of the human body is in a continuous dynamic relationship with environmental factors. Such interaction should not disrupt the adaptive mechanisms of the human body. Inborn and acquired reflexes are created in the human's body under the influence of various stimuli of the internal and external environment, which determine the maintenance of dynamic balance based on metabolism and energy exchange between the body and the environment. Environmental factors must effectively influence health and ensure the normal flow of all human life processes.

As a result of the Chernobyl Nuclear Power Plant (CNPP) disaster and other sources of radioactive impact, the environment of certain areas of Ukraine is contaminated with radionuclides such as strontium-90, iodine-129, radium-226, cesium-137, plutonium-239. The accident was unique worldwide in terms of the number of radionuclides released into the atmosphere, the area of contaminated territories, the collective human

radiation exposure, and the large "iodine shock", millions of people affected by small doses of radiation. In this situation, a significant part of the population of Ukraine is forced to consume water and food products with a certain content of radioactive substances, which leads to the accumulation of radionuclides and causes chronic internal exposure of the body [1-3].

The scientists have identified a number of features of the biological action of small doses of radiation, namely: 1) small doses of radiation actively affect human metabolism; 2) low-intensity radiation is more effective than acute one within certain dose intervals; 3) the dependence of the effect on the radiation dose may be nonlinear, non-monotonic, polymodal in nature; 4) the doses with observed extreme values depend on the power (intensity) of radiation and decrease with its reduction; 5)radiation in small doses leads to changes (in most cases to the increase) in the sensitivity to the action of damaging factors [4, 5].

Air, soil, vegetation, water in open reservoirs, agricultural products, etc. are polluted as a result of the fallout of radioactive substances. Radioactive particles are partially dissolved in water, and some of them gravitate to the bottom, infecting water bodies to the full depth. The greatest radioactive contamination is experienced by lakes, ponds, slow-flowing rivers, rainwater and melt water. Radionuclides get into food raw materials of plant origin through root systems and leaves and into the human body – through air, water and through the consumption of fruits, vegetables and grain varieties, meat of animals, poultry, fish grown on contaminated lands [6, 7]. The shortest ways for radionuclides to enter the human body are the use of radioactively contaminated drinking water and the inhalation of atmospheric air with radioactive dust. The analysis of scientific research [8, 9] shows that more than 90% of all radioactive substances that enter the human body from the environment are contained in food, 5-9% – in drinking water, less than 1% – in air. The gastrointestinal tract is the main route of radionuclides entry into the human body. Radioactive elements behave as corresponding stable ones. The principle of selective absorption is justified in such a way that when the body is provided with the necessary substances, the probability of absorption of radioactive substances by cells decreases. Depending on this, there are isotopes that: 1) are accumulated in the bones: strontium, barium, radium, calcium; 2) are concentrated in the liver and skeleton: lanthanum, cerium, promethium; 3) are evenly distributed: tritium, carbon, iron, polonium; 4)are accumulated in the muscles: potassium, cesium, rubidium; 5)are concentrated in the spleen and lymph nodes: ruthenium, niobium; 6)are accumulated in the thyroid gland: iodine [10, 11].

The degree of danger of radionuclide contamination depends on the frequency of consumption of products contaminated with radioactive substances, as well as on the rate of their excretion from the body. If the radionuclides that enter the body are the same as the elements consumed by humans with food (sodium, potassium, chlorine, calcium, iron, manganese, iodine and others), they are quickly excreted with them. Radioactive isotopes are accumulated in the tissues of various organs and become a source of long-term radiation. The concentration of radionuclides in an organ can be many times higher than in the human body as a whole. Therefore, the absorbed doses accumulated in one of the organs can cause adverse effects, although the total isotope content in the body is small [12].

According to the scientific research [13], the vast majority of schoolchildren and students living in the areas of radioactive contamination is characterised by a decrease in mental and physical performance, psychomotor tone, the level of psychosocial activity, as well by a tendency to proneness to conflict and deterioration of their emotional state. Therefore, it is necessary to modify the content, methods and organizational forms of teaching and education in terms of working with high schoolers and students living in the contaminated area.

Therefore, it is necessary to take into account the degree of influence of environmental factors on the body of students, especially the effects of radiation pollution during the training sessions on physical education and physical culture as well as fitness and health recreation events. In particular, high-risk areas should be identified, the level of mutagenic background and mutational variability should be assessed, and the sources of mutagens entering the environment should be clarified in order to avoid pathology of a genetic nature.

AIM

The aim of this article is to study the impact of small doses of radiation pollution of environment on the physical development and health of students from different areas of residence.

MATERIALS AND METHODS

The study was conducted at Polissya National University (Zhytomyr, Ukraine) during 2012-2020. 647 students of different specialties in the age of 17-23 were interviewed about the use of preventive measures to eliminate the consequences of the CNPP accident and other factors of radiation pollution of environment. In addition, 127 students who were born, lived for some time or periodically lived in the area of low doses of radioactive contamination (58 males and 69 females) and 238 students who lived in the clean area from radioactive contamination (113 males and 125 females) were interviewed to compare the samples. The survey was conducted using the author's questionnaires. A questionnaire was used for the survey in accordance with the requirements of the Codes of Ethics of Polissya National University. The questionnaire was assessed by the experts in this field (6 professors and 8 associate professors) and was approved by the Academic Council of Polissya National University (Protocol No. 2 dated 15.09.2012). Consent to voluntary participation in the survey was obtained from all the students involved in the study.

The research methods: theoretical (analysis and generalization of literature sources (26 sources on the topic of the article from the scientometric databases PubMed, Scopus, Web of Science Core Collection and others were analyzed), study and analysis of clinical records of the students); empirical

(pedagogical observations, questionnaires, surveys, testing); methods of mathematical statistics.

This study complies with the ethical standards of the Act of Ukraine "On Higher Education" No. 1556-VII dated 01.07.2014 and the Letter from the Ministry of Education and Science of Ukraine "On the Academic Plagiarism Prevention" No. 1/11-8681 dated 15.08.2018. Also, this study followed the regulations of the World Medical Association Declaration of Helsinki – ethical principles for medical research involving human subjects. Informed consent was received from all individuals who took part in this research.

RESULTS

The impact of negative environmental factors on the body of students during their intense physical activities is even more harmful because it is associated with greater consumption of polluted air, food products, water and the intensity of all functional systems and the body as a whole. Therefore, the construction of sports facilities, the choice of grounds for training and conditioning exercises, leisure-time activities and outdoor recreation, swimming in open water should take into account the impact of radioactive contamination of the environment on the health of students. Each student must understand the ways in which radionuclides enter the body and predict the consequences they may lead to.

We have studied the ways in which radionuclides enter the human body. Included in the cycle of substances, radionuclides enter the human body with food products, water and air, moving through the food chain. The first chain is air – man. The second chain is soil – plant food – man. The third chain is soil – vegetation – cows, goats, sheep – milk – man. The fourth chain is soil – vegetation – graminivorous domestic and wild animals, poultry and wild birds – man. The fifth chain is 1)water – man; 2)sea and river water – phytoplankton – fish – man; 3)sea and river water – zooplankton – crayfish, crabs, mollusks, algae (seaweed) – man; 4)sea and river water – waterfowland wild birds – man.

The state of health of students depends on the social, economic and spiritual development of society, the state of the environment, waste disposal, the availability of sufficient amount of wholesome and safe food, clean water, fresh air and certain scientific and educational knowledge about environmental behaviour and the use of its natural resources. At the same time, morbidity reflects the degree of students' adaptation to environmental conditions, and the structure of morbidity i.e. the proportion of each disease in their total number. The analysis of the causes of morbidity and environmental conditions, in which students live, provides grounds for the protection of each individual from the influence of negative environmental factors.

The study of measures to preserve students' own health in connection with environment pollution due to the CNNP accident and other natural factors showed that 57.9% of the students do not pay attention to this situation and do not take any preventive measures. Only a small proportion of students – 15.3% (usually those who already have health problems) undertake examination in diagnostic centres, 7.6% – additionally engage in exercise to improve health, 11.1% – visitsauna, 8.9% – consume pure products of radioprotective action, 5.1% – use chemicals of radioprotective action prescribed by a doctor (Table 1). In general, the surveys have shown that the majority of the students are not involved in health preservation activities, but only in cases when they face significant health problems associated with the need to see a doctor, disability and sick leave.

Our in-depth surveys of the students who were born and lived for a long time in the areas of high radionuclide contamination showed that 63.8% of those surveyed complained of general weakness, frequent headaches, rapid fatigue, increased irritability, sweating, sleep disorders, dizziness, memory impairment, frequent respiratory diseases, pains in joints, muscles, bones during physical activity and without it (Table 2). The students often sought medical help (2-5 times a year) for respiratory diseases, sore throats, tooth decay, osteochondrosis, etc. The comparison of the indicators of the students' subjective assessment of their own health status living in the area of radioactive contamination and clean area of residence indicates a significant difference between the comparison groups (34.5-9.3%). The data confirm the statistics that the area with low doses of radioactive radiation has a negative impact on the health of young people.

It is established that inflammatory processes, pneumosclerosis, and tumours develop due to the biological activity of alpha radiation when radionuclides are inhaled into the lungs. Active radicals are formed in the body, which have high biological activity and quickly damage molecules in the process of ionizing radiation. The analysis of the survey results of the students from different areas of residence confirms the trend that the long-term effects of radiation have a negative impact on the students' health (Table 3). The results of the analysis of the causes of complaints about the disease of students from different areas of residence showed that from 1.7 to 15.4% of the students from the area of radioactive contamination seek more help from a doctor. Thus, 24.7% of the students visited the doctor with respiratory diseases, 22.1% – with sore throat, 11.0% – with thyroid gland, 14.2% – with joint pain, 24.4% – with tooth decay, 20.5% – with cardiovascular system. At the same time, the students from the clean area visited the doctor not that often with similar diseases, in particular with respiratory diseases – 10.5%, sore throat – 6.7%, thyroid gland – 0.8%, joint pain – 2.9%, tooth decay – 8.8%, cardiovascular system – 7.6%. Accordingly, the students who have lived for a long time in the area of radioactive contamination more often suffer from a disease, miss classes and get tired faster during physical education sessions.

Our surveys of the students of Polissya National University showed that their height is in the range of 160.7-191.2 cm, weight – 54.3-97.8 kg, respectively, chest circumference – 78.7-105.6 cm, Erisman index – 3.21-6.2 cm, hand dynamometry – 28.7-56.8 kg, which indicates large individual differences in the students' physical development. The comparative analysis of the students' physical development from different areas of residence showed that the students from the clean area have better indicators of average body height, body weight, chest circumference, Erisman index with no significant differences

Table 1. Preventive activities undertaken by the students to preserve their own health in connection with the consequences of the Chernobyl accident (%, n=647)

Activities	Gender	Study year				Total percent
		1st	2nd	3d	4th	
No activities undertaken	male	70.5	70.3	54.3	47.1	64.7
	female	65.9	47.1	64.7	51.8	54.0
	total	68.4	52.9	60.5	50.4	57.9
Students undertake the following activities and other	male	29.6	29.7	45.7	52.9	35.3
	female	34.1	52.9	35.3	48.2	46.0
	total	31.6	47.1	39.5	49.6	42.1
General medical examination in the clinic	male	25.7	7.8	37.1	38.2	28.6
	female	28.0	30.4	17.6	24.7	27.1
	total	26.7	28.6	25.6	28.6	27.7
Examination in diagnostic centres	male	15.2	10.9	14.3	14.7	13.9
	female	9.8	15.2	17.6	23.5	16.1
	total	12.8	14.1	16.3	21.0	15.3
Additional physical exercises	male	6.7	6.3	14.3	14.7	8.8
	female	7.3	5.2	2.0	12.9	6.8
	total	7.0	5.5	7.0	13.4	7.6
Visiting bath-house or sauna	male	10.5	14.1	17.1	23.5	14.3
	female	9.8	7.3	15.7	9.4	9.3
	total	10.2	9.0	16.3	13.4	11.1
Consumption of pure radioprotective products	male	5.7	12.5	5.7	8.8	8.0
	female	9.8	10.5	13.7	4.7	9.5
	total	7.5	11.0	10.5	5.9	8.9
Consumption of radioprotective chemicals	male	3.8	1.6	5.7	5.9	3.8
	female	6.1	4.7	5.9	8.2	5.9
	total	4.8	3.9	5.8	7.6	5.1

Table 2. Indicators of long-term impact of small doses of radioactive contamination on the health of students from different areas of residence (%)

Students' subjective assessment of their own health	Students from the area of radioactive contamination (n=127)	Students from the clean r esidence area (n=238)	Difference
General weakness	48.0	13.5	34.5
Rapid fatigue	41.7	24.0	17.7
Frequent headache	21.3	7.6	13.7
Dizziness	26.0	13.5	12.5
Frequent respiratory diseases	40.2	28.9	11.3
Pain in joints, muscles, bones during exercise	32.3	12.2	20.1
Increased irritability	18.1	8.8	9.3
Sweating	50.4	26.5	23.9
Sleep disorders	26.0	11.3	14.7
Memory impairment	14.2	3.8	10.4

– P>0.05 (Table 4). Significant differences were revealed only in the indicators of the circumference of the chest – 2.2 cm and the dynamometry of the hand – 3.6 kg (P<0.05).

The indicators of height in female students are in the range of 150.4-182.8 cm, weight – 41.9-80.3kg, respectively, chest circumference – 62.5-90.2 cm, Erisman index – 2.4-4.9 cm, hand dynamometry – 23.8-39.6 kg, which indicates large individual differences in the physical development of female students of the same age. The comparative analysis of the female students' indicators from different areas of residence also has no significantly better indicators of body height, body weight, Erisman index (P>0.05) in the female students from the clean areas of residence. At the same time, the female students from the clean areas of residence showed significantly better indicators in the circumference of the chest – 2.7 cm (P<0.05) and and dynamometry – 5.4 kg (P<0.01) (Table 5).

Based on the above, it can be stated that long-term residence in the area with low doses of radioactive contamination has a negative impact on the students' physical development.

Table 3. Seeking medical advice by the students from different areas of residence during the academic year

Reason for treatment (complaints of illness)	Students from the area of radioactive contamination (n=127)		Students from the clean r esidence area (n=238)		Difference, %
	n	%	n	%	
Respiratory diseases	31	24.4	25	10.5	13.9
Angina	28	22.1	16	6.7	15.4
Thyroid gland	14	11.0	2	0.8	10.2
Headache	13	10.2	6	2.5	7.7
Joint pain	18	14.2	7	2.9	11.3
Tooth decay	31	24.4	21	8.8	15.6
Osteochondrosis	11	8.7	7	2.9	5.8
Sense of vision	12	9.5	13	5.5	4.0
Cardiovascular system	26	20.5	18	7.6	12.9
Gastrointestinal tract	8	6.3	4	1.7	4.6
Genitourinary and endocrine systems	11	8.7	13	5.5	3.2
Respiratory system	8	6.3	11	4.6	1.7
Nervous system and sense organs	7	5.5	6	2.5	2.5
Congenital anomalies	1	0.8	3	1.3	0.5
Other causes of diseases	16	12.6	23	9.7	2.9
Total	15.7	12.4	11.7	4.9	7.5

Table 4. The level of physical development of the students from different areas of residence (males, X±m)

Indicators of physical development	Students from the area of radioactive contamination (n=58)	Students from the clean residence area (n=113)	The level of significance	
			t	P
Body length, cm	174.6±1.12	176.3±1.09	1.09	>0.05
Body weight, kg	69.3±0.94	71.6±0.88	1.79	>0.05
Chest circumference, cm	90.2±0.73	92.4±0.65	2.25	<0.05
Erisman index, cm	4.47±0.51	5.58±0.57	1.45	>0.05
Hand dynamometry, kg	36.2±1.04	39.8±0.96	2.54	<0.05

Table 5. The level of physical development of the students from different areas of residence (females, X±m)

Indicators of physical development	Students from the area of radioactive contamination (n=69)	Students from the clean residence area (n=125)	The level of significance	
			t	P
Body length, cm	164.7±1.14	165.8±1.18	0.67	>0.05
Body weight, kg	56.8±1.91	57.7±1.48	0.37	>0.05
Chest circumference, cm	80.2±0.57	82.9±1.03	2.29	<0.05
Erisman index, cm	2.8±0.49	3.2±0.53	0.55	>0.05
Hand dynamometry, kg	28.2±1.13	33.6±0.97	3.63	<0.01

DISCUSSION

It is established that the radiological situation in the inhabited localities of the north of Zhytomyr oblast has changed for the better in the remote period after the Chernobyl accident, but there are still some critical areas that are radiation-hazardous to the population. The radionuclides of cesium and strontium, having similar chemical properties, respectively, to potassium and calcium, are often easily included in biogenic migration through the trophic chain and are accumulated in food products [6, 8]. Consumption of products contaminated with cesium and strontium by the population leads to additional internal exposure of the human body.

The studies of the researchers [10, 13] have shown that children living in the areas with the same contamination density differed significantly in the level of incorporated cesium-137. The examined children revealed direct dependence of the state of arterial blood pressure (hypertension) on the level of incorporated radionuclides, which indicates a certain role of ionizing radiation in the pathogenesis of the detected changes in terms of cardiovascular disorders. The radiation factor indirectly affects the tissues, organs and systems of the body through the central nervous system in people living in the area contaminated with radionuclides. Incorporated radiocaesium is one of the important ethnological factors of the syndrome of

vegetative-vascular dystonia, which is quite common among children and adults living in contaminated areas.

The following peculiarities have been identified when studying the effect of radiation on the human body: 1) even a small amount of absorbed radiation energy causes profound biological changes in the body; 2) the presence of a latent (incubation) period of ionizing irradiation; 3) radiation has a genetic effect; 4) the organs of a living organism have different sensitivity to radiation; 5) individual organisms react differently to radiation; 6) radiation depends on the frequency. Occasional radiation in a large dose causes deeper changes than small doses of radiation [14, 15].

It has been experimentally proven that there is no safe dose of radiation. A wide range of minimum doses of radionuclides, when there are various pathological disorders in the human body (general weakness, drowsiness, apathy, etc.), confirms the unequal sensitivity of organs and tissues to ionizing radiation [16]. It is also recognized that the relationship between low doses of radiation and disease in the population is linear, as it is most fully consistent with existing experimental data and clinical observations [17].

The ecological approach to physical education classes as well as physical culture and sports activities in the environment contaminated with radioactive substances takes a different perspective and brings the student's worldview from a narrow subject area to the field of universal human sphere i. e. health saving one. As a result, the students develop global thinking, an important element of which is the ecological and humanistic understanding of the world, the restructuring of their thinking and certain premonitions about maintaining their own health.

The organization and conduct of the educational process on physical education, fitness and health recreation events as well as sports activities with students who were born, live or lived a certain period of their lives in the environment contaminated with radioactive substances, require special attention to the formation of environmental and physical education. The reason for this is: 1) lack of environmental knowledge of teachers of physical education; 2) inadequate material and technical resources for conducting recreational and health-improving as well as preventive physical exercises; 3) inadequate medical examination, control over the students' health and the environment; 4) no control over physical development, mental and physical performance; 5) lack of scientific recommendations for physical activities in conditions of small doses of ionizing radiation; 6) violation of food rules in the conditions of radionuclide contamination; 7) violation of sanitary and hygienic conditions for sports as well as physical culture and health activities, leisure and recreation events, etc. Our research is confirmed by the work of other scientists [18-26].

CONCLUSIONS

1. A high frequency of diseases of the respiratory system, musculoskeletal system, cardiovascular system, endocrine, nervous systems, vision in modern students who have lived for a long time in the areas affected by small doses of radionuclide contamination has been determined.
2. Physical development of students is one of the important integral indicators of their health, adaptation to environmental factors, living conditions, learning and at the same time an indicator of the state of the living environment. The physical development of the students of Polissya National University corresponds to the general laws of its formation, but also has its own peculiarities, which are primarily related to the contamination of the environment with radionuclides, in which the students have lived or live for a long time. The comparative analysis of the students' physical development from different areas of residence showed that the students from the clean area have better indicators of average body height, body weight, and Erisman index with no significant differences ($P>0.05$). Significant differences were revealed in the indicators of the circumference of the chest and the dynamometry of the hand ($P<0.05$-0.01).
3. It has been established that long-term residence in the area with low doses of radioactive contamination has a negative impact on the physical development and health of students. The students who have lived for a long time in the area of radioactive contamination more often suffer from a disease, miss classes and get tired faster during physical education sessions. At the same time, the majority of the students are not involved in health preservation activities, but only in cases when they face significant health problems associated with the need to see a doctor, disability, etc.

Prospects for further research are to analyse the functional state and physical fitness of students who lived in the area of radiation pollution.

References

1. Hatch M, Ron E, Bouville A, Zablotska L, Howe G. The Chernobyl disaster: cancer following the accident at the Chernobyl nuclear power plant. Epidemiol Rev. 2005; 27:56-66. doi:10.1093/epirev/mxi012.
2. Wakeford R. Chernobyl-20 years on. J Radiol Prot. 2006;26(2):125-126. doi:10.1088/0952-4746/26/2/E02.
3. Fushiki S. Radiation hazards in children - lessons from Chernobyl, Three Mile Island and Fukushima. Brain Dev. 2013; 35 (3): 220-227. doi:10.1016/j.braindev.2012.09.004.
4. Furdichko OI., Kuchma M D. Reabilitatsiya – strategichniy napryam upravlinnya radioaktivno zabrudnenimi teritoriyami [Rehabilitation is a strategic direction of radioactively contaminated areas management]. Agroekologichniy zhurnal. 2008;1:5-12 (In Ukrainian).
5. United Nations Scientific Committee on the Effects of Atomic Radiation UNSCEAR Sources and Effects of Ionizing Radiation: Report to the General Assembly, with Scientific Annexes (United Nations Scientific Committee on the Effects of Atomic Radiation). New York. 2000.
6. Alexakhin RM, Sanzharova NI, Fesenko SV et al. Chernobyl radionuclide distribution, migration, and environmental and agricultural impacts. Health Phys. 2007;93(5): 418-426. doi:10.1097/01.HP.0000285093.63814.b7.
7. Hinton TG, Alexakhin R, Balonov M et al. Radiation-induced effects on plants and animals: findings of the United Nations Chernobyl Forum. Health Phys. 2007;93(5):427-440. doi:10.1097/01.HP.0000281179.03443.2e.
8. Hohenemser C, Deicher M, Hofsäss H et al. Agricultural impact of Chernobyl: a warning. Nature. 1986; 321(6073):817. doi:10.1038/321817a0.

9. Geras'kin SA, Fesenko SV, Alexakhin RM. Effects of non-human species irradiation after the Chernobyl NPP accident. Environ Int. 2008;34(6):880-897. doi:10.1016/j.envint.2007.12.012.
10. Beresford NA, Fesenko S, Konoplev A et al. Thirty years after the Chernobyl accident: What lessons have we learnt?. J Environ Radioact. 2016;157:77-89. doi:10.1016/j.jenvrad.2016.02.003.
11. Angelevska B, Atanasova V, Andreevski I. Urban air quality guidance based on measures categorization in road transport. Civil Engineering Journal. 2021;2(7):253-267. https://doi.org/10.28991/cej-2021-03091651.
12. Krasnoselskyi MV, Pushkar ES, Simonova-Pushkar LI, Myroshnychenko MS. Nitric oxide metabolism features under conditions of experimental infected radiation-induced skin injuries development and their treatment with photodynamic therapy. Wiad. Lek. 2020;73(8), 1655-1658. doi:10.36740/WLek202008112.
13. Morris JA. After effects of the Chernobyl accident. Br Vet J. 1988;144(2):179-186. doi:10.1016/0007-1935(88)90051-6.
14. Nykolaichuk RP, Fedoruk OS, Vizniuk VV. Impact of environmental factors on male reproductive health. Wiad. Lek. 2020;73(5):1011-1015. doi:10.36740/WLek202005132.
15. Ren X, Wang J, Zhong Q et al. Radionuclide and trace metal accumulation in a variety of mosses used as bioindicators for atmospheric deposition [published online ahead of print, 2021 Jul 22]. Sci Total Environ. 2021;797:149224. doi:10.1016/j.scitotenv.2021.149224.
16. Ruano-Ravina A, Varela Lema L, García Talavera M et al. Lung cancer mortality attributable to residential radon exposure in Spain and its regions. Environ Res. 2021; 199:111372. doi:10.1016/j.envres.2021.111372.
17. Birioukov A, Meurer M, Peter RU et al. Male reproductive system in patients exposed to ionizing irradiation in the Chernobyl accident. Arch Androl. 1993;30:99-104.
18. Griban G, Filatova O, Bosenko A et al. Water in students' life and its impact on their health. Acta Balneol. 2021;2(164):99-104. doi:10.36740/ABAL202102104.
19. Prontenko K, Bublei T, Marushchak M, Bondar T. A computer program for evaluation of children's fitness at football classes. Information Technologies and Learning Tools. 2020;77(3): 0-100. doi: https://doi.org/10.33407/itlt.v77i3.3277.
20. Prysiazhniuk S, Oleniev D, Tiazhyna A et al. Formation of heath preserving competence of students of higher educational institutions of information technologies specialties. Inter J Appl Exer Physiol. 2019; 8(3):283-292. doi:10.26655/IJAEP.2019.10.1.
21. Prontenko K, Griban G, Medvedeva I et al. Interrelation of students' motivation for physical education and their physical fitness level. Inter J Appl Exer Physiol. 2019;8(2): 815-824. doi:https://doi.org/10.30472/ijaep.v8i2.1.566.
22. Griban G, Prontenko K, Yavorska T et al. Non-traditional means of physical training in middle school physical education classes. Inter J Appl Exer Physiol. 2019;8(3): 224-232. doi:10.26655/IJAEP.2019.10.1.
23. Tymoshenko O, Arefiev V, Griban G et al. Characteristics of the motivational value-based attitude of students towards physical education. Revista Dilemas Contemporáneos: Educación, Política y Valores. 2019. https://www.dilemascontemporaneoseducacionpoliticayvalores.com/index.php/dilemas/article/view/1880/1391.
24. Prontenko K, Griban G, Bloshchynskyi I et al. Development of power qualities of cadets of Ukrainian higher military educational institutions during kettlebell lifting training. Baltic Journal of Health and Physical Activity. 2019;11(3):27-38. doi:10.29359/BJHPA.11.3.04.
25. Arefiev V, Tymoshenko O, Malechko T et al. Methodology of differentiation of health-improving classes in physical education for primary school students. Inter J Appl Exer Physiol. 2020;9(7):134-143.
26. Griban G, Smiianov V, Lyakhova N et al. The impact of nutritional quality on the students' health. Acta Balneol. 2021;1(163):43-54. doi:10.36740/ABAL202101107.

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