

Parameters of lipid and oxidative-antioxidant status in persons aged 18-23 from radiation-contaminated areas under conditions of moderate physical activity

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation.

Abstract

Purpose: There is a significant amount of data on the stressful effects of exercise, which contain conflicting results. Some publications testify to the adaptive processes and the benefits of optimized exercise for various physiological systems, some deny such an effect. Much controversial is the question of combination the physical exercises of different intensity with other stressors. The purpose of the study: to analyze the parameters of lipid metabolism and oxidative-antioxidant system in persons aged 18-23 who lived in territories with different radioecological status, under conditions of moderate physical activity during exercise.

Material: There were examined 50 students from relatively ecologically clean areas (control group) and 50 students from the IV radiation zone (experimental group). The radiation zone is selected by the dosimetry of soil contamination with ¹³⁷Cs isotopes after the Chernobyl catastrophe. Age of the examined is 18-23 years. Within the framework of the experimental group there were formed two subgroups: the main group for physical training classes (without signs of morphological-functional disorders) and the group for therapeutic physical training classes (TPTC, persons with signs of vegetative-vascular dystonia syndrome). For the control and experimental main group, classes contained all the planned exercises due to the standard curriculum. The program included a combination of aerobic and strength exercises of moderate intensity. For students with signs of vegetative-vascular dystonia, teachers used specially designed therapeutic exercise complexes. The first analysis of parameters was carried out the day before physical training classes, the second one – immediately after the class.

Results: Higher levels of total cholesterol and its lipoprotein fractions (LDL-C and HDL-C), triglycerides, oxidative stress index are detected in the experimental group compared to the control group. At the same time lower levels of sulfhydryl groups (SH) were marked. The absence of statistically significant changes in the analyzed parameters in the control group and the experimental therapeutic group after physical exercises is shown in the study. There were evident tendencies of ceruloplasmin level increase in the control along with the absence of such trends in persons with signs of vegetative-vascular dystonia syndrome. This led to the formation of a significant difference between groups for this antioxidant. There is a significant increase in cortisol level and oxidative stress index in the main group of students from radiation contaminated areas.

Conclusions: Potentiation of various stress factors in persons who experienced the prolonged exposure to Chernobyl accident reduces the adaptive potential of homeostatic systems. This eliminates the optimization of lipid metabolism and oxidative-antioxidant system through moderate exercise. Exercise therapy does not cause a pronounced stress effect.

Keywords: physical training, Chernobyl accident, adaptive reactions, malondialdehyde, oxidative stress index

Glossary

Adaptive reactions are body reactions to the change of environmental conditions. They are especially expressed at extreme influences of environmental factors and controlled by homeostasis systems.

Aerobic exercise is a type of physical activity characterized by the aerobic nature of energy supply (walking, running, swimming, etc.). Usually aerobic exercises are cyclic and performed for a relatively long time. Aerobic exercise is considered an effective type of health-improving physical activity.

Antioxidants are biologically active protein and low-molecular components. They can prevent or slow down the oxidation processes in the cell by interacting with free radicals and prooxidants.

Chernobyl accident is a radiation catastrophe at the Chernobyl nuclear power plant in 1986 caused a number

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of fundamental and applied radiobiological problems in the areas of radionuclide contamination.

High-density lipoprotein cholesterol (HDL-C) is a transport form of cholesterol that carries it back to the liver. It is a high-molecular easily soluble form that does not precipitate. HDL-C plays a protective role against lipid deposition in atherosclerotic plaques

Hypercortisolemia is a condition of elevated cortisol level due to stressful situation.

Low-density lipoprotein cholesterol (LDL-C) is a transport form of cholesterol and desaturated fatty acids from the liver to organs and tissues. LDL-C is poorly soluble and prone to the formation of atherosclerotic plaques in blood vessels, due to the increased ability to lose cholesterol during transportation.

Malondialdehyde (MDA) is a product of lipid peroxidation, a marker of oxidative stress, widely used in the assessment of oxidative status in various biological

samples.

Oxidative stress (OS) is oxidative processes mobilization, qualitatively different from spontaneous cellular processes. It is characterized by ROS production or inactivation imbalance, as well as oxidants/antioxidants imbalance (in favor of oxidants). Oxidative stress can cause destructive and pathogenic effects in the body.

Oxidative-antioxidant status is the balance between complexes of oxidants and antioxidants in the body.

Physical training is a system of physical exercises increasing the general physical activity of different social groups that is the factor of good health and physical condition maintenance.

Reactive oxygen species (ROS) are free radical components, oxygen ions and peroxides. Their sources are mitochondrial, microsomal, phagocytic electron transport chains of oxidation, etc. They have a high reactivity and a short life span. ROS levels may increase in response to certain endogenous and exogenous factors.

Stress is any change in the homeostasis due to the action of real or potentially dangerous factors characterized by activation of the axis «hypothalamus-pituitary-adrenal». The phase of physiological parameters recovery to homeostatic values is an important component of a normal response to stress. Stress exposure when regulatory systems are unable to restore indicators to optimal values, is called an allostatic load.

Therapeutic physical training classes (TPTC) are a set of strictly dosed physical exercise specially created for treating diseases and injuries, preventing disease recurrence or complications, restoring the health and working ability of patients or disabled people.

Triglycerides are the main lipid component of ultra-low density lipoproteins containing little cholesterol. It is a leading transporter of cholesterol from the liver to the blood.

Vegetative-vascular dystonia is a complex multifactorial syndrome. Its development is caused mostly by genetic factors. It is characterized by impaired neurohumoral and endocrine regulation of tone, mainly at the level of the cardiovascular system.

Introduction

Proper physical activity is considered an important factor in maintaining optimal health of the human. It affects the intensity of aging, development and progression of chronic diseases associated with age [1, 2]. Regular exercise can reduce the destructive manifestations of aging in the elderly at the level of immune status. It can indirectly reduce the impact of negative psychosocial factors and prevent the formation of depressive states [3, 4]. The mechanisms of the following effect at the molecular level are still being discussed. Perhaps the leading factor is adaptive response in the form of metabolic changes focused on forming a new dynamic balance in the body [5]. The result may be influenced by other factors of individual life: diet, smoking, alcohol and medication. It is believed that an important factor of exercise positive effect is inducing changes in the level of cholesterol, low-

density lipoprotein cholesterol (LDL-C) and high-density lipoprotein cholesterol (HDL-C), triglycerides. In other words the effect is manifested in the lipid and lipoprotein metabolism and catabolism. Although a similar result can be obtained through the normal physical work, the value of special training in maintaining a proper lipid profile is more important [6, 7]. The question of the exercise expedience, duration, intensity, frequency in the implementation of the mechanisms of dynamics of the lipids and lipoproteins level always attracted the attention of scientists [8, 9]. Here it is recommended to take into consideration the difference between the concepts of “physical activity” and “physical exercise”. Also we should mind the lack of clear recommendations for the selection of exercises to improve lipid status [10].

Previous research suggests that physical activity has a positive effect on metabolic status not only by increasing energy expenditure. It also alleviates the psychosocial stress caused by metabolic syndrome and obesity. On the other hand, exercise itself is a stressor. Chronic activation of the hypothalamus-pituitary-adrenal axis, associated with stress, forms a state of hypercortisolemia [11]. Increased stress reactivity may be a prerequisite for the formation of metabolic syndrome [12].

One of the possible factors of physical activity influence on age-related changes in the body is the intensification of oxidative processes. They can cause the destruction of muscle fibers and the suppression of the antioxidant defense [13, 14]. On the one hand, it is believed that the positive effects of exercise are mostly realized due to the active forms of oxygen. Active forms of oxygen are required for mitochondrial biogenesis and effective muscle contraction [15]. On the other hand, an increase in the concentration of reactive oxygen species is a sign of the oxidative processes mobilization. They, in turn, are realized by lipid peroxidation, in other words, it is the manifestation of oxidative stress [16].

Oxidative stress (OS), in particular during intense physical activity, is characterized by an imbalance between the production/inactivation of reactive oxygen. There is an imbalance between oxidants and antioxidants (in favor of oxidants). This can cause destructive and pathogenic effects in the body [5, 17]. Oxidative stress manifestations vary depending on the type of exercise. High-intensity exercise increases oxidative stress, and medium-intensity exercise is usually associated with decreased OS level [18]. Accordingly, the exercise intensity can be considered the factor of health benefits [19].

However, there were described the cases when long-term exposure to medium-intensity aerobic exercise has led to increased levels of malondialdehyde (MDA, a marker of oxidative stress) in laboratory animals [20]. Periodic increase in training load with weight reduced lipid peroxidation and, accordingly, had a positive effect on the development of oxidative stress [21].

In previous years, a significant amount of data has been accumulated on the stressful effects of physical activity with rather contradictory results. Some studies propose the hypothesis of adaptation to cross-stress. It

finds the benefits of optimized exercise for the formation of adaptive processes to strong social stressors. Other researches deny this effect. Many publications indicate that the positive or negative effect of training exercise on the human body depends on the various factors. It includes the type, intensity, frequency and duration of exercise, the rate of body parameters returning to its original level. The conclusions could be influenced by the methodological difference of conducting experiments that indicates the need to continue the scientific research in this direction [4, 11, 22].

It should be taken into account that a strongly pronounced increase in the level of reactive oxygen species (ROS) with subsequent cell damage is observed in conditions of environmental pollution of varying nature [17]. In our previous studies, we have found an increase in oxidative stress in people who have lived for a long time in radiation-contaminated areas. Also the signs of lipid status disorders were discovered [23-25]. However, in the same cohort, dosed physical exercise during physical training classes led to short-term changes in the immune system within the homeostatic norm. It indicated a low level of physical stress and effective recovery [26].

Purpose of study: to analyze the parameters of lipid metabolism and oxidative-antioxidant system in persons aged 18-23 who lived in areas with various radioecological status, under conditions of moderate physical activity during exercise.

Materials and methods

Participants.

The control group includes 50 students of Bohdan Khmelnytsky National University of Cherkasy (Ukraine) from radiation-free areas, without signs of acute or chronic diseases. The experimental group includes 50 students from the territory of enhanced radioecological control (zone IV, the status was granted by dosimetric assessment after the Chernobyl accident in 1986). Within the experimental group there are two subgroups formed: 25 healthy people (the main group) and 25 people with signs of vegetative-vascular dystonia (the therapeutic group). Age of students is 18-23 years. The conclusion about the state of health of the examined students was made by the doctors of the sanatorium "Edem" of Cherkasy National University. The study was conducted in compliance with the ethical principles of the European Convention and the Helsinki Declaration (ethics principles regarding human experimentation). It was confirmed by the Bioethics Commission of the University. Examined provided written approvals for analysis and subsequent disclosure.

Procedure.

Biomaterial collection techniques, used in the study reagents and methods for assessing the level of cortisol, lipid and oxidative-antioxidant status are described in detail in previous publications [23-25]. To assess the intensity of oxidative processes used the method developed by Korol and Myhal [27].

The research was conducted in late September, early October, after the adaptation period due to the beginning

of studies. First-year students were not involved in the research. Physical activity in physical training classes was supervised by the teachers. Class duration is 80 minutes. For the control and experimental main groups, classes contained all the planned exercises due to the standard curriculum. The aerobic and strength exercises of moderate intensity were combined [28]. For people with signs of vegetative-vascular dystonia, teachers used specially designed therapeutic exercise complexes. They include breathing exercises, stretching exercises and coordination exercises, time-limited action games [29].

The first analysis of parameters was carried out the day before physical training classes, the second one immediately after the class.

Statistical Analysis.

The calculated statistical parameters are presented in the table in the form of average values and standard error ($M \pm m$). Student's t-test was used to compare data between groups and parameters before and after exercising. In the case where the data did not show a normal distribution, the Mann-Whitney U test was used. Statistical significance of the parameter's difference is reflected in three levels ($P < 0.05$; $P < 0.01$; $P < 0.001$).

Results

It was found that in the control group the concentration of cortisol was within homeostatic norm. Physical training caused a tendency to increase in the concentration of cortisol, but the changes were not statistically significant. Examined from areas of radiation contamination (both main and therapeutic group) showed the initial concentration of cortisol significantly higher than the control values ($P < 0.001$). The index was at the upper values of the homeostatic norm. Physical training caused a tendency to increase in the therapeutic group and a significant increase in the main group ($P < 0.05$). The rate after exercise is significantly higher than the control under the same conditions ($P < 0.001$) in both groups of students from radiation-contaminated areas (Table 1).

Prior to physical training, total cholesterol concentration was shifted to the upper values of the homeostatic norm in the main group from radiation-contaminated areas. The index exceeded the upper values of the norm in the therapeutic group (with signs of vegetative-vascular dystonia) The index in both groups from radiation-contaminated areas is significantly higher than the control ($P < 0.001$). After physical activity any significant changes were not detected in either the control or experimental groups (Table 1).

Similar features were observed for triglyceride concentration and high-density lipoprotein cholesterol. In both experimental groups from radiation-contaminated areas, the rates were significantly higher than the control both before and after exercise ($P < 0.001$). Under conditions of physical activity any significant changes are absent in all the groups of examined students. Although some tendencies to increase (in average) in the level of HDL-C and decrease in the level of triglycerides were observed in all the groups (Table 1).

Table 1. Physical activity influence caused by physical training lessons on cortisol parameters, lipid profile and oxidative-antioxidant status of the examined (M ± m)

Components	Control, n=50		The main group, n=25		The therapeutic group, n=25	
	before exercise	after exercise	before exercise	after exercise	before exercise	after exercise
Cortisol, nmol /l	349.1±10.12	387±18.44	627.2±21.10 ***	693.1±15.9 *** #	620.2±24.31 ***	641.1±19.02 *** §
Total cholesterol, mmol /l	3.06±0.28	2.81±0.16	5.35±0.51 ***	5.32±0.85 **	6.68±0.84 ***	6.65±0.61 ***
Triglycerides, mmol /l	0.52±0.08	0.50±0.07	0.93±0.08 ***	0.90±0.06 ***	0.97±0.04 ***	0.96±0.06 ***
High density lipoprotein cholesterol, mmol /l	1.07±0.07	1.16±0.07	1.64±0.09 ***	1.69±0.08 ***	1.47±0.07 ***	1.56±0.07 ***
Low density lipoprotein cholesterol, mmol /l	1.82±0.11	2.05±0.13	3.15±0.41 **	2.92±0.40 *	4.92±0.58 *** §	4.25±0.39 *** §
Malondialdehyde, mmol /l	125.4±27.51	132.1±23.14	130.3±10.01	142.2±10.99	141.2±9.99	143.1±8.11
Ceruloplasmin, g /l	0.24±0.02	0.28±0.02	0.22±0.01	0.26±0.02	0.21±0.02	0.21±0.02 **
Transferrin, cond. un.	5.33±1.01	5.36±1.08	4.52±0.63	4.63±0.87	4.25±0.85	4.32±0.96
SH-groups, mmol /l	2.52±0.03	2.62±0.05	1.84±0.04 ***	1.99±0.06 ***	1.63±0.06 *** \$\$	1.67±0.04 *** \$\$\$
Oxidative stress index, un.	1.03±0.04	1.05±0.06	1.37±0.04 ***	1.52±0.05 *** #	1.43±0.05 ***	1.44±0.05 ***

Notes: * – P < 0.05; ** – P < 0.01; *** – P < 0.001 compared to the control under the same conditions; # – P < 0.05 compared to the index before exercise; § – P < 0.05; \$\$ – P < 0.01; \$\$\$ – P < 0.001 compared to the index in the main group under the same conditions

Before physical activity a significantly higher rate of low-density lipoprotein cholesterol was found compared to the control. The effect is marked in both main (P < 0.01) and therapeutic (P < 0.001) groups of students from radiation-contaminated areas. In the therapeutic group the rate is significantly higher than in the main group (P < 0.05). There are no statistically significant changes under conditions of physical exercise in all the groups. However, students from radiation-contaminated areas, especially in the therapeutic group, have a tendency to the rate decrease. After exercise, the rate in the main group is significantly higher than in the control under the same conditions (P < 0.05). In the therapeutic group it is significantly higher than in the control (P < 0.001) and in the main group (P < 0.05) (Table 1).

There are no significant differences between the analyzed groups before physical exercise in the concentration of malondialdehyde, ceruloplasmin and transferrin. There are no significant changes in exercise conditions as well (Table 1). There are pronounced trends to increase in ceruloplasmin concentration on the average

value in the control group. The same trends are absent in the group of people with the signs of vegetative-vascular dystonia. This led to the fact that the rate became significantly lower in the therapeutic group than in the control group after exercise (P < 0.01) (Table 1).

Before exercise, SH-groups concentration in the examined from the main group was significantly lower than in the control (P < 0.001). In the therapeutic group it is lower than both in the control (P < 0.001) and in the main group (P < 0.01). No significant changes were found for all the groups. After exercise, there was a significant difference in the rate compared to the control. The effect was marked both in the main group of students from contaminated areas (P < 0.001) and in the therapeutic group (P < 0.001). In the therapeutic group index remained significantly lower than in the main group (P < 0.001) (Table 1).

The oxidative stress index was significantly higher in both experimental groups than the control, both before and after exercise (P < 0.001). Under conditions of physical activity, the rate significantly increased only in the main

group of students from radiation-contaminated areas ($P < 0.05$) (Table 1).

Discussion

Cortisol level remains the leading biomarker of the hypothalamus-pituitary-adrenal activity and the reactions of the physiological response of the body to acute or prolonged stress [30]. Increased cortisol level in the examined from radiation-contaminated areas before exercise indicated the chronic stress. Ionizing radiation is a stressor for the human body. Moreover, it acts both as a physical and psychological factor, in particular, with a long-term awareness of the constant potential health risk [31-33]. Under conditions of physical activity during physical training lessons, cortisol level significantly increased only in the main group of students from the IV radiation zone (Table 1). However, cortisol rate did not reach such high values as in the period of intensified psycho-emotional load caused by the examination session. This effect, when cortisol level also increased in the control group, was observed in our previous studies [24, 25]. Thus, we can distinguish the lack of the evident stress effect of physical activity. Cortisol level increase in the main group of students could be a sign of potentiation of previous chronic radiation exposure and exercise. The important factor is no increase in cortisol levels in the therapeutic group. The positive aspects of this effect can be assessed in comparison with the analysis of other analyzed parameters.

Hypercortisolemia is associated with metabolic syndrome, accumulation of total cholesterol and low-density lipoprotein cholesterol, as well as decrease in the level of high-density lipoprotein cholesterol [34, 35]. Lipoprotein lipase (LPL) activity increases that, in turn, leads to an increase in triglycerides. Such processes are mobilized in individuals with dysregulated or hyperactive stress response [11, 36, 37]. Correction of elevated cortisol level usually improves the state of hyperlipidemia [38]. Our previous studies have shown associative relations between cortisol level and lipid profile in individuals from the areas of enhanced radioecological control. Strongly pronounced lipid parameters imbalance was observed in persons with signs of vegetative-vascular dystonia and dysfunctions of thyroid status [23].

Taking into consideration the initial elevated level of cortisol in the experimental groups, its further increase during physical exercise could be characterized as an unfavorable factor. However, it is necessary to take into account the possible positive effect of exercise on the lipid profile. There are studies conducted for Australian farmers who have experienced severe emotional stress and were inclined to metabolic disorders. It was shown that a set of physical exercises caused a significant reduction in obesity. However, it had little effect on cortisol concentrations, anxiety, depression and stress [39].

There are data indicating on elevated levels of total cholesterol and LDL-C in individuals of different sexes who had a high level of physical activity during the life

[40]. However, a significant number of publications indicate a positive effect of exercise on the lipoprotein profile of examined. It applies to people of different ages, starting from childhood and ending with the old age [41, 42]. Usually, the ratio of low and high density lipoproteins cholesterol, as well as the level of triglycerides, is analyzed when assessing the lipid profile. Elevated LDL-C indicates an excess of lipids in the blood. Along with triglyceride excess, it causes a risk of cardiovascular dysfunction. In particular, it is a marker of atherosclerotic diseases [10, 43, 44]. In contrast, HDL-C, transporting lipids to the liver for further utilization is considered to be protective for cardiovascular system. However, a significant increase in this parameter can also create the preconditions for the pathologies development [45, 46]. Hypertriglyceridemia has received less attention in clinical practice, although it is clearly associated with diabetic conditions and pancreatitis [47, 48].

Thus, in our case, a group of people with signs of vegetative-vascular dystonia can be considered a risk group. This is the risk of metabolic syndrome formation and the development of cardiovascular disorders complications. They are caused by a significantly elevated LDL-C level. Under conditions of physical activity, no statistically significant changes in the lipid profile parameters of the examined were detected. However, there are signs of positive effect of physical exercises, especially pronounced in people from the therapeutic group. Here belong the tendency to decrease in the level of LDL-C against the background of LDL-C increase and triglycerides decrease. (Table 1).

Lipid profile changes during exercise can be influenced by several factors. First of all, it's exercise intensity.

Analysis of publications shows that low and medium intensity aerobic exercises lead to a significant reduction in the level of LDL-C. It is believed such exercises determine the effective use of lipids as a source of energy, supporting the activity of the cardiovascular system [49, 50]. Moderate-intensity exercises keep the level of LDL-C and triglycerides lower than high-intensity exercises. Under the same conditions HDL-C level is contrarily higher. At the same time no difference in the level of total cholesterol between the groups of physical activity of different intensity may be observed. Such tendencies are representative not only for aerobic, but also for strength training [10, 51].

The second effectiveness factor is exercise type. Aerobic exercises (running, cycling) are considered more favorable for lipid profile improving. However, the result is mostly determined by the intensity [10, 52]. The combination of aerobic and strength exercises usually gives a result similar to individual aerobic. Moreover, the statistical significance of lipid profile changes is noted for the elderly people. In young ones there were only trends in the same direction [53].

The next effectiveness factor is the age of the examined, although the results are contradictory in this regard. There are reports of the absence of a clear correlation between physical activity and lipoprotein profile in the elderly

[42]. At the same time, a study of college students with the signs of obesity or overweight showed certain trends. An increase in HDL-C and decrease in triglyceride level during regular fitness is observed. It is especially evident in females [54]. Fitness also improved the lipid profile of obese adult women [55].

Another important factor is previous physical form. Usually the concentrations of total cholesterol and LDL-C are significantly higher in groups that did not have regular exercise. The concentration of high-density lipoprotein cholesterol is higher in the group of trained individuals [56]. It was reported that untrained young males showed the ratio of low/high density lipoproteins higher than in the trained group. The effect appeared both before and after exercise. However, cortisol level (also elevated) in this group was optimized after exercise [57]. In general, people previously having low physical activity, showed a correlation of its growth with an improvement in triglycerides and HDL-C. Moreover, taking into account the data variability, the main effect of exercise is suggested to be an increase in HDL-C [10].

The duration of the physical training course should not be neglected either. In particular, a significant decrease in the level of low-density lipoprotein cholesterol was observed after 2-6 months of training [42, 55, 58]. There are data on a certain racial and gender variability of the lipid profile response to exercise [59].

Metabolic changes being formed in the body of athletes during intense physical and emotional load are characterized by specific features. On the one hand, physical activity helps to increase overall physical efficiency, energy supply, optimization of maximum oxygen consumption [60]. On the other hand it leads to the body deconditioning and the oxidative stress formation. There is evidence that at the beginning of the training period the level of malondialdehyde in the group of athletes is higher than in the control group [56]. The rate increased even more by the end of the training period that indicates the body deconditioning and the oxidative stress formation. In the middle of the training period, the rate declining tendency was observed, that was characterized as the oxidative processes hierarchy change [61, 62]. Intensification of lipid peroxidation was observed in middle-aged and elderly men during long training with combined strength and exercise tolerance circuit. This gave the reason to talk about the importance of the time factor in the response of oxidative and antioxidant systems to physical stress [63]. However, even short-term intense exercise (running, swimming) can cause the MDA level increase and the effect lasts at least 24 hours [64, 65]. In particular, the MDA concentration increase after intense exercise was found in young people of different sexes in the postpubertal period. This indicates the mobilization of oxidative stress [66]. Intensification of oxidative processes in trained individuals during exercise was less pronounced than in untrained group [67]. There are data demonstrating the absence of pronounced changes in the level of malondialdehyde during 12-week training [68].

Malondialdehyde (MDA), as a product of lipid

peroxidation, is its reliable marker. It is widely used in the assessment of oxidative status in various biological samples [16, 69, 70]. The MDA level assessment under conditions of exogenous influences should be performed in combination with the antioxidant status assessment. However, even in this case, contradictory results are often obtained. Some studies have described the absence of a significant increase in the level of MDA, in others its presence is marked [71, 72]. Obviously, in addition to the time factor, the training intensity is essential for the effect manifestation. This is confirmed by the positive correlations between exercise intensity, antioxidant and malondialdehyde concentration [56].

There is comparison of the groups of students who had standard training and balanced physical therapy classes. It showed no difference in the level of MDA both at the beginning of the 8-week training period and at the end. Moreover, at the beginning of the training period there was a tendency to the MDA level increase after classes. At the end of training period a fairly stable level was marked. There was a tendency to gradually reduce the level of MDA during the training period [73].

There is an analysis of 8-week classes of various types in a group of men aged 60-80 years. Aerobic, strength or combined classes three times a week for 1 hour. We marked a decrease in the level of MDA, regardless of the type of exercise. The effect was characterized as the oxidative stress reduction. Antioxidant protection parameters also improved, however, the value depended on the type of exercise performed. This indicated the variability of the antioxidant protection mechanisms depending on the type of exercise [4]. In patients with insulin-independent diabetes, 12-week aerobic exercise caused a tendency to the MDA level decrease. There was physical and mental condition improvement [74].

Ceruloplasmin, transferrin and sulfhydryl groups are recognized antioxidants [75-77]. Particular attention is paid to ceruloplasmin. It is a regulator of copper and iron ions homeostasis in the body and free radicals formation protector [78]. Antioxidant status is usually higher in trained individuals before exercise and it was improved in untrained individuals after exercise [57]. In our studies, there is no significant difference between the analyzed groups in the initial concentration of malondialdehyde. It relates to the most parameters of antioxidant status. Only SH-groups concentration in the main group of students from radiation-contaminated areas is significantly lower than in the control. In the therapeutic group it is significantly lower than in the other two groups (Table 1). After physical training, there were no significant changes in the parameters. However, different tendencies led to a significant increase in the index of oxidative stress in the examined of the main experimental group (Table 1). Thus, they showed a tendency of increase in the levels of ceruloplasmin and sulfhydryl groups that did not compensate the tendencies of increase in the levels of malondialdehyde. In general, the oxidative stress index is significantly higher in all experimental groups than the control both before and after exercise. It is clear that in

conditions of environmental pollution of various nature, the level of ROS increases [17]. Obviously, the effect is caused by long-term living in the territories of the IV radiation zone. It happened in the periods of ontogenesis that is important for the formation of physiological homeostatic systems. As a result, it created the tension of the antioxidant system with the following specific response to exogenous influence. On the other hand, there is the lack of the oxidative stress index increase in the therapeutic group. It indicates the optimal selection of exercises for therapeutic training course.

Vegetative-vascular dystonia syndrome is a complex of dysfunctions at the level of autonomic regulation and vascular insufficiency. This requires careful physiotherapeutic rehabilitation, in particular, through exercise [79]. Regular exercise is considered an important physiological stimulus for adaptive responses. They improve the regulation of vascular tone and, consequently, vascular endothelial function [80]. In addition, there are data on the associated nature of neurodegenerative diseases with increased oxidative stress. Under such conditions regular exercise can increase the activity of antioxidant system and the system of oxidative damage repair [81, 82].

When assessing any stress response as the cause of allostatic load, it is recommended to take into consideration various parameters. They are the value (intensity) of stress, its frequency, duration, rate of parameters' return to the initial level, etc. [11]. ROS are the important signal molecules for adaptive response. Detoxification and normalization of ROS parameters due to exercise depends on various factors. These are age, sex, level of physical activity, environmental conditions, genetic characteristics of the individual, lifestyle, nutrition quality. Increased as a result of metabolic processes, ROS production leads to oxidative damage. However, it also stimulates the antioxidant protection that eliminates much of the damage [83].

Thus, we considered the age of the examined, the lack of trained individuals, low and medium intensity of the exercise. Accordingly, we expected more pronounced changes in lipid status and improved parameters of antioxidant status. Perhaps a significant factor was the study period. The analysis was performed almost at the beginning of the semester. Any significant changes could be expected at the end of the school year.

It is believed the benefit of regular short-term exercise is connected with the stimulation of oxidative processes.

ROS level increase continues to the values causing significant but acceptable damage. This, in turn, stimulates adaptive responses. According to the theory of hormesis, they protect against stress effects of greater intensity or strength. The following effect, being realized at the molecular level, can serve as a protective factor against diseases associated with ROS. In particular, age-related changes [18, 84]. However, the examined from radiation-contaminated areas have some specifics. The adaptive reactions realization could be affected by failures in the regulation of lipid and oxidative-antioxidant profile. The failure probability is described in our previous publications [23-25]. When selecting exercise for this cohort, it is important to consider the risk of all stressors' potentiation. A special attention should be paid to the social anxiety as a factor of significant hypercortisolemia [85].

Conclusions

Students from the control group did show statistically significant changes of the analyzed parameters during physical activity. The group of exercise therapy was formed by the people from radiation-contaminated areas with signs of vegetative-vascular dystonia syndrome. There are no significant changes in lipid metabolism and oxidative-antioxidant status in the group. This indicates the absence of a pronounced stress effect of specially selected exercises. People from the radiation-contaminated areas performed the standard set of aerobic and strength exercises. There is a significant increase in cortisol level and oxidative stress index in the group. This effect may indicate the potentiation of various stressors. The group from the IV radiation zone has the lack of positive dynamics of the analyzed parameters after physical education. This may be a sign of a short period of training and failure of adaptive homeostatic systems.

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Conflict of interest

The authors state that there is no conflict of interest.

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