Journal of Physical Education and Sport ® (JPES), Vol. 23 (issue 6), Art 171, pp. 1401 - 1406, June 2023
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Metabolic monitoring to assess the response of the body to physical loads

ANDREW MARTUSEVICH [1], IVAN BOCHARIN[2], MAXIM GURYANOV[3], ELENA ROMANOVA[4], MIKHAIL KOLOKOLTSEV[5], YURII VYAZOVICHENKO[6], RAISA LOBASTOVA[7], SERGEY SMIRNOV[8], NATALYA BALASHKEVICH[9], ELENA REDI[10]
[1,2,3] Privolzhsky Research Medical University, Nizhny Novgorod, RUSSIA
[1,2] Nizhny Novgorod State Agricultural Academy, Nizhny Novgorod, RUSSIA
[1]National Research Lobachevsky State University names after Lobachevsky of Nizhni Novgorod, RUSSIA
[4]Altai State University, Barnaul, RUSSIA
[5]Irkutsk National Research Technical University, Irkutsk, RUSSIA
[6]Institute of Public Health named after F.F.Erisman, I.M. Sechenov First Moscow State Medical University (Sechenov University) , RUSSIA
[7]Altai State Pedagogical University, Barnaul, RUSSIA
[8]Siberian Federal University, Krasnoyarsk, RUSSIA
[9]Semey Medical University, Non-Commercial Joint-Stock Company, KAZAKHSTAN
[10]Reshetnev Siberian State University of Science and Technology, Krasnoyarsk, RUSSIA

Published online: June 30, 2023
(Accepted for publication June 15, 2023)
DOI:10.7752/jpes.2023.06171

Abstract:
Studying the issues of metabolic monitoring of the body's reactivity to a standard physical load seems to be an urgent task. Early detection of changes in metabolic parameters in the body of students under the influence of dosed physical activity allows to increase the efficiency of the process of physical education. *Research aim*. For the individualization of physical education of students, to assess the intensity of free-radical oxidation and the activity of the antioxidant system as markers of the body's reactivity to the impact of standard physical activity. *Materials and methods.* The study involved 75 male students (in 18-21-years-old). As a load test, we used running 100 meters at maximum speed and pulling up from the hang on the bar until the maximum possible number of repetitions was reached. The parameters of oxidative metabolism (intensity of free radical oxidation, total antioxidant activity of blood plasma, concentration of malondialdehyde in blood plasma and erythrocytes) were studied at rest and after each of these physical exercises. *Resalts.* It has been established that the standard load used contributes to an increase in the intensity of free radical oxidation and a moderate inhibition of the activity of the antioxidant system. In addition, there is an increase in the concentration of malondialdehyde in plasma and erythrocytes after exposure to stress testing. At the same time, the depth of metabolic shifts is of an individual nature, reflecting the current level of adaptive potential. *Conclusions*. Running 100 meters at maximum speed and pulling up from the hang on the bar can act as a stress factor for testing not only the functional state of the body, but also in monitoring the oxidative metabolism of the body of people performing physical activity, which allows you to individualize the educational process of physical education.
Key words: physical loads, physical activity, oxidative metabolism, oxidative stress, physical education

Introduction

Despite the important role of using physical training to preserve and strengthen human health (Momot et al., 2020; Mozolev, 2020), the intensity of the loads performed is of fundamental importance. To control the volume and intensity of physical activity performed, the method of monitoring the heart rate is most often used (Christiani et al., 2021). This method is based on the registration and analysis of the linear dependence of the pulse rate on the intensity of physical activity (Zaitsev, & Sheinin, 2021). Biochemical methods are used to determine the volume and intensity of loads. There is information in the literature demonstrating the relationship between the intensity of physical activity for the body and oxidative stress (Ji, & Leichtweis, 1997; Polidori et al., 2000).

It is theoretically known that during exercise loads, the free radical's generation can increase because of increased oxygen consumption by the body due to activation of the mitochondrial respiratory chain functioning in tissue respiration (Pingitore et al., 2015; Hargreaves, Spriet, 2020; Papadopoulou, 2020). At the same time, it is important to emphasize that under physiological conditions, a certain amount of reactive oxygen species is generated in the body in a concentration that can be effectively utilized by the antioxidant system. However, it is known that during physical loads, oxygen consumption increases by 10-20 times, and its absorption by skeletal muscles by 100-200 times (Angela Mastaloudis et al., 2001). Hyperproduction of reactive oxygen species with insufficient ability of the antioxidant system to utilize them can lead to oxidative stress and maladaptation of the

Corresponding Author: ELENA ROMANOVA, E-mail: romanovaev.2007@mail.ru

body, as well as damage to nucleic acids and proteins (Nikitina et al., 2022; Margaritelis et al., 2018). A large oxidative stress that can occur in an athlete during prolonged aerobic exercise can cause damage to muscle tissue, fatigue development and a decrease in physical performance. Therefore, metabolic monitoring of the athlete's body reactivity state by the oxidative stress level seems to be an urgent and necessary condition for the successful implementation of educational, training and competitive loads. It has been established that primary (diene, triene conjugates), secondary (malondialdehyde) and tertiary (Schiff bases) lipoperoxidation products are informative markers of oxidative stress (Sen, Packer, 2000). Taking into account the laboratory diagnostic technologies development for assessing the state of tissues, organs and systems at the cellular and molecular levels, monitoring oxidative metabolism parameters is becoming more accessible and informative (Shamitova et al., 2018; Kovalev et al., 2022). In particular, biochemiluminescent analysis of biological fluids makes it possible to assess free radical oxidation intensity, and spectrophotometric studies make it possible to clarify the activity of enzymes of the antioxidant system.

It should be noted that biochemical tests illustrating the patterns and personalized peculiarities of oxidative metabolism (Ashkinazi et al., 2016) have been used for a relatively long time. However, the addition of existing scientific knowledge, in particular, about the body's response to the impact of the Russian physical culture and sports complex «Ready for Work and Defense» (RWD-GTO) as a unified physical activity test (Bocharin et al., 2022), is relevant today.

We believe that the use of the results of assessing the metabolic process intensity for standard physical activity will allow us to personify the educational process of students' physical education in a timely manner. This is due to the possibility of early detection of changes in metabolic parameters in each student when exposed to standard physical activity, which makes it possible to make adjustments to the process of physical education at different stages of training.

Research aim. To individualize students' physical education, our aim is to evaluate the intensity of free radical oxidation and the antioxidant system activity as markers of the body's reactivity to the effects of standard physical activity.

Material & methods

75 male students aged 18-21 took part in the research. All students at the University of Nizhny Novgorod (Russia) according to the results of periodic medical examination had no contraindications for physical education. The subjects signed a voluntary informed consent to participate in the research and the biomaterial collection, which fully complies with the Helsinki Declaration of 2008. According to our previous results (Bocharin et al., 2022), speed-strength physical exercises were used as load testing: running 100 meters at maximum speed and pulling up from the hang on the crossbar until the maximum possible number of repetitions was reached. The research control was the state of the students' body before the start of the load tests.

Blood samples (2 ml) were obtained from the ulnar vein in the morning on an empty stomach and after performing the above mentioned physical exercises. To study the intensity of lipid peroxidation, a biochemiluminometer BHL-07 (Russia) was used, which allows recording and analyzing the kinetic curves of bio- and chemiluminescence presented in Figure 1 (Martusevich et al., 2019). The measurement time was 30 seconds.

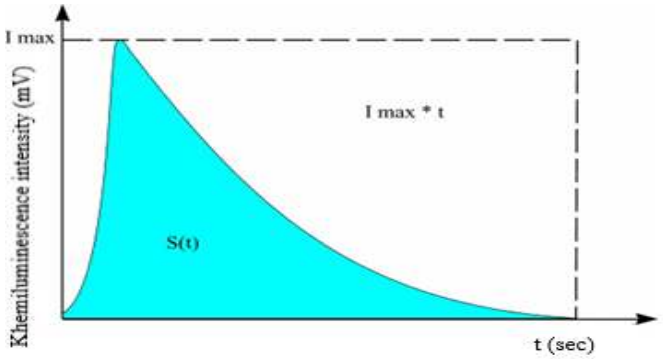


Fig. 1. Diagram of the biochemiluminescence curve and estimated indicators

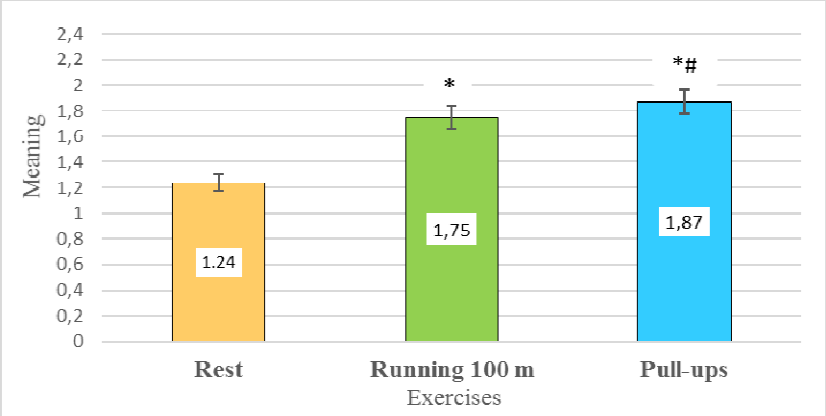
This method of investigation allows us to determine the maximum intensity of luminescence (Imax) and the indicator inverse to the light sum of biochemiluminescence (1/S). A secondary product of lipoperoxidation in plasma and erythrocytes, malondialdehyde (MDA), was also determined. It was determined by reaction with thiobarbituric acid and with subsequent spectrophotometric evaluation of the reaction result by optical density at a wavelength of 532 nm. The samples were incubated for 30 minutes, then centrifuged for 10 minutes at 3000 rpm. Distilled water was used as a control. During the reaction, a pink trimethine complex was formed, the

amount of which corresponds to the reacted MDA. To determine its concentration in biological fluid (in erythrocytes and blood plasma), a PE-5300 VI spectrophotometer (Russia) was used.

The obtained data were statistically processed in the Excel for Windows 2016 and Statistica 10.1 software package. The normality of the data distribution in the samples was checked by determining the Kolmogorov-Smirnov criterion with the Lilliefors correction. For each sample, the mean value (M) and the standard error of the mean (m) were calculated. To determine statistically significant differences in the parameters relative to the state of rest and after exposure to exercise, a variance analysis was used for repeated observations. The differences were considered statistically significant at $p<0.05$.

Results

It is known that the free radical processes intensity is associated with the peculiarities of human physical activity, the power of the load and the degree of the body adaptation to them. From these positions, we evaluated the intensity of the free radical oxidation process by Fe-induced biochemiluminescence, Figure 2.

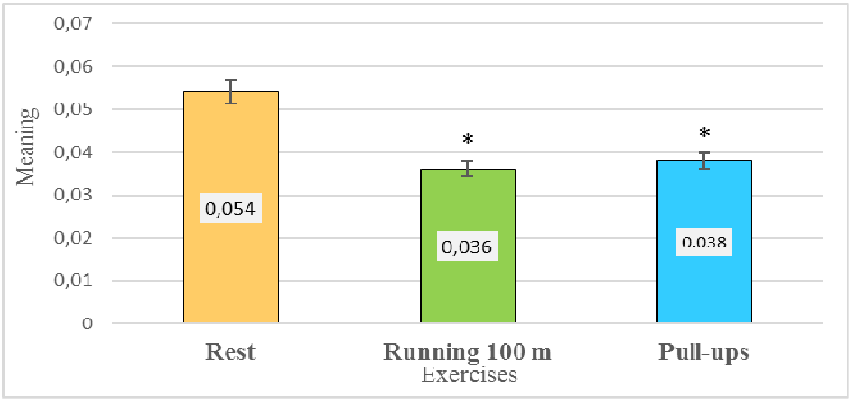


Note. *- p <0.05 in relation to the state of rest, # - p <0.05 in relation to running 100 meters

Fig. 2. Intensity of free radical oxidation at rest and after exposure to physical activity

It was found that after the physical loading completion, there is an increase in the generation of reactive oxygen species, the severity of which depended on the type of exercise. After 100 meters running, there was an increase in the value of the indicator by 29.4%, and after pulling up from the hang on the crossbar - by 33.8% compared to the state of physiological rest ($p <0.05$ for all parameters). This fact indicates the stimulation of free radical oxidation processes in the studied samples of biological fluid, depending on the type and power of the proposed load.

To assess the state of the students' body antioxidant system during stress tests, an analysis of the indicator inverse to the total light sum of biochemiluminescence was performed. This parameter, which can be considered as a criterion of the overall antioxidant activity of the biological environment, statistically significantly decreased after exercise, Figure 3.

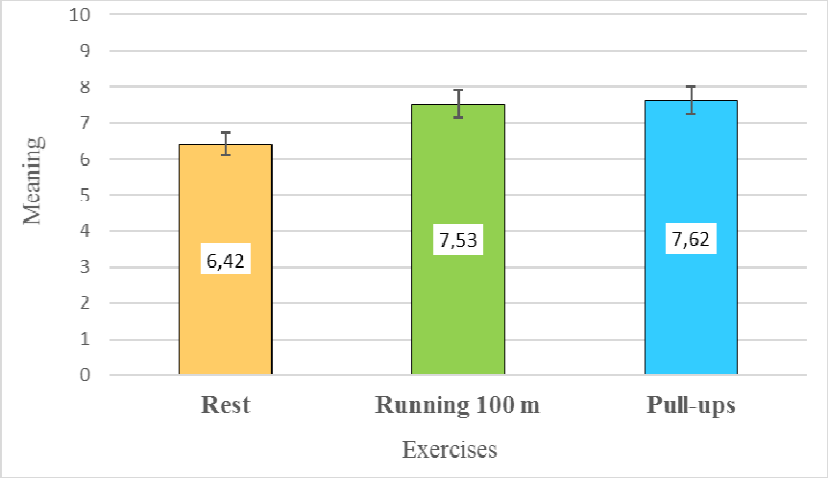


*Note. *- p <0.05 in relation to the state of rest*

Fig. 3. Total antioxidant activity of blood plasma at rest and after exposure to physical activity

After running load, the antioxidant activity of blood plasma decreased by 32.3%, and after pulling up by 30.5% ($p < 0.05$ relative to the resting state). It characterizes an increase in the ability of the substrate to oxidize by the concentration of accumulated hydroperoxides, the recorded light sum and further calculation of the parameter 1/S. Thus, the intensification of the reactive oxygen species generation manifests itself in a change in the balance of «free radical oxidation – antioxidant system», which gives an idea of the characteristics of the students' body reaction to physical exercises.

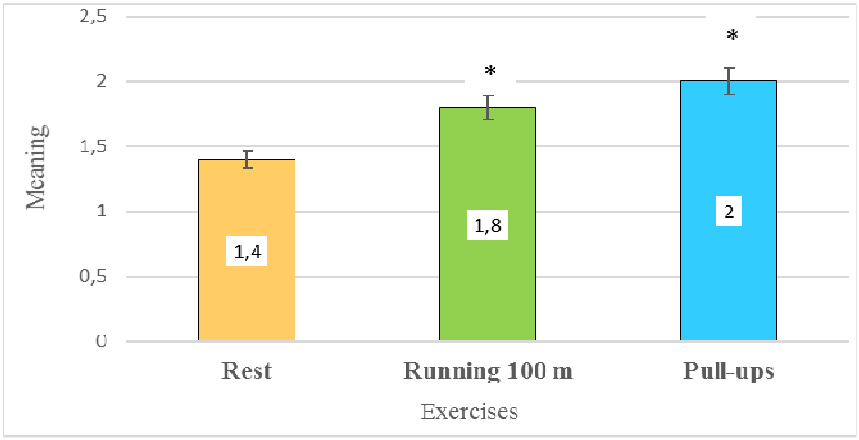
The data obtained based on the assessment of Fe-induced biochemiluminescence of the students' blood plasma were comparable with the results of monitoring the concentration of malondialdehyde in erythrocytes and blood plasma, Figures 4 and 5.



Note. *- $p < 0.05$ in relation to the state of rest

Fig. 4. Malondialdehyde concentration in erythrocytes at rest and after exposure to physical activity

It was found that after running, there is an increase in the level of MDA in erythrocytes by 14.8% relative to the resting state, after pulling up by 15.5%, $p < 0.05$ for both loads; Figure 4. We evaluated its dynamics of MDA in blood plasma under the influence of exercise.



Note. *- $p < 0.05$ in relation to the state of rest

Fig. 5. Malondialdehyde level in the students' blood plasma at rest and after exposure to physical activity

It was found that there was a statistically significant increase in the concentration of MDA by 21.2% after the first exercise of the exercise complex, and by 28.7% after the second exercise used, $p < 0.05$ relative to the state of physiological rest for all parameters; Figure 5.

Dicussion

It is known that the «free radical oxidation – antioxidant system» balance provides a wide range of the body homeostatic parameters. It is sensitive to various endogenous and exogenous factors (Elessar et al., 2022; Droge, 2002; Martusevich et al., 2022). By disrupting physiological homeostasis, factors are able to shift this

equilibrium both towards pro-oxidants, inducing the development and progression of oxidative stress, and excessively activate enzyme and non-enzyme antioxidants. It inhibits cell membrane renewal, shifts in intercellular signaling, etc. (Gomes et al., 2017). Malonic dialdehyde, being a secondary product of lipid peroxidation, is formed when polyunsaturated fatty acids are destroyed by radicals, provokes the formation of potentially toxic lipid-protein complexes (Droge W., 2002). This indicator is currently considered as one of the key markers of oxidative stress. We found that the observed students after running 100 m had an increase in the level of malondialdehyde in erythrocytes by 14.8%, and after pulling up by 15.5%. It indicates the occurrence of oxidative stress in students after performing stress tests.

At the same time, a number of impacts have a «training» effect on oxidative metabolism, increasing the antioxidant potential of systems utilizing free radicals in blood and tissues. These include physical training. However, the nature of the effect under consideration depends on the intensity of the loads and the current level of individual fitness (Bocharin et al., 2023; Hargreaves, Spriet, 2020). Therefore, it is of interest to search and study the diagnostic information content of methods for assessing physical performance, which can be based on standard sets of exercises (Enns et al., 2018). In Russia, such is the complex «Ready for Work and Defense» (RWD- GTO), therefore its components were used in this research work.

Our research allowed us to show that the physical exercises used have a fairly significant effect on the functional status of the body, which leads to an increase in the intensification of the free radicals formation and is accompanied by a moderate inhibition of the ntioxidant system activity (according to the indicators of biochemiluminescence). These trends are fully manifested in the dynamics of the classical indicator of the oxidative metabolism state – malondialdehyde. This secondary product shows a distinct tendency to increase in both blood plasma and in red blood cells.

At the same time, the degree of severity of the shifts indicated individual variability, which creates a platform for creating a technology for personifying the recommended level of physical activity. In the future, the study of enzymes of the antioxidant system that have a selective effect on reactive oxygen species (superoxide radical and hydrogen peroxide), namely superoxide dismutase and catalase, will also be of interest when using stress testing of physical fitness of young people.

Conclusions

It was found that standard physical exercises in the form of a running load for 100 meters at maximum speed and pulling up from the hang on the crossbar contribute to an increase in the free radical oxidation intensity and moderate inhibition of the antioxidant system activity. In addition, there is an increase in the concentration of malondialdehyde in blood plasma and erythrocytes after exposure to a stress test.

At the same time, the depth of metabolic shifts is individual in nature, reflecting the current level of adaptive potential of the human body. Thus, these physical exercises can act as a stress factor for testing the functional state of the body and monitoring oxidative metabolism, which will allow to personalize the physical education of students.

This study was partially supported by Lobachevsky University (Priority 2030 program).

Conflicts of interest. The authors declare no conflict of interest.

References:

Angela Mastaloudis, Scott W. Leonard, & Maret G. Traber (2001). Oxidative stress in athletes during extreme endurance exercise. *Free radical biology and medicine*, *31(7*), 911-922. DOI:10.1016/S0891-5849(01)00667-0.

Ashkinazi, S.M., Accusantsev, A.A., Bavykin, E.A., & Taymazov A.B. (2016). Results of an experimental study of the methodology for the development of special physical qualities of athletes engaged in mixed martial arts. *Actual problems of physical and special training of power structures*, *1*, 118-128 (in Russian)

Bocharin, I., Martusevich, A., Guryanov, M., Apoyan, S., Kolokoltsev, M., Melnichuk, A., Vorozheikin, A., & Romanova, E. (2022). Young men's body hemodynamics variability in different states of motor activity. *Journal of physical education and sport*, *22(3*), 562-569. DOI:10.7752/jpes.2022.03070

Bocharin, I., Guryanov, M., Martusevich, A., Kolokoltsev, M., Bolotin, A., Limarenko, A., Torchinsky, N., Mungalov, A., & Aganov, S. (2023). Swimming as a way to correct vegetative disorders in students. *Journal of physical education and sport, 23(2*), 385-390. DOI:10.7752/jpes.2023.02046

Christiani, M., Grosicki, G., & Flatt, A. (2021). Cardiac-autonomic and hemodynamic responses to a hypertonic, sugar-sweetened sports beverage in physically active men. *Appl Physiol Nutr Metab*, *24,* 1-7. DOI:10.1139/apnm-2021-0138

Droge, W. (2002). Free radicals in the physiological control of cell function. *Physiol. Rev.,* 82, 47-95. DOI:10.1152/physrev.00018.2001.

El Assar M., Álvarez-Bustos A., Sosa P., Angulo J., & Rodríguez-Mañas L. (2022). Effect of Physical Activity/Exercise on Oxidative Stress and Inflammation in Muscle and Vascular Aging. *Int J Mol Sci*, 23(15), 8713. DOI: 10.3390/ijms23158713

Enns, A., Eldridge, G.D., Montgomery, C., & Gonzalez, V.M. (2018). Perceived stress, coping strategies, and emotional intelligence: A cross-sectional study of university students in helping disciplines. *Nurse Educ Today*, *68*, 226-231. DOI: 10.1016/j.nedt.2018.06.012.

Gomes, M.J., Martinez, P.F., Pagan, L.U., Damatto, R.L., Cezar, M.D.M., Lima, A.R.R., Okoshi, K., & Okoshi, M.P. (2017). Skeletal muscle aging: influence of oxidative stress and physical exercise. *Oncotarget*, *8(12),* 20428-20440. DOI: 10.18632/oncotarget.14670.

Hargreaves, M., & Spriet, L.L. (2020). Skeletal muscle energy metabolism during exercise. *Nat Metab*, *2(9),* 817-828. DOI: 10.1038/s42255-020-0251-4.

Ji, L.L., & Leichtweis, S. (1997). Exercise and oxidative stress: sources of free radicals and their impact on antioxidant system. *Age*, 20, 91-106. DOI: 10.1007/S11357-997-0009-X.

Margaritelis, N.V., Paschalis, V., Theodorou, A.A., Kyparos, A., & Nikolaidis, M.G. (2018). Antioxidants in personalized nutrition and exercise. *Adv Nutr*, *9(6),* 813-823. DOI: 10.1093/advances/nmy052

Martusevich, A.K., Solov'eva, A.G., Galka, A.G., Kozlova, L.A., & Yanin, D.V. (2019). Effects of helium cold plasma on erythrocyte metabolism. *Bull Exp Biol Med*, *167(2*), 198-200. DOI:10.1007/s10517-019-04490-4.

Martusevich, A.K., Surovegina, A.V., Bocharin, I.V., Nazarov, V.V., Minenko, I.A., & Artamonov, M.Yu. (2022). Cold argon athmospheric plasma for biomedicine: biological effects, applications and possibilities. *Antioxidants.* 11 (7), 1262. DOI: 10.3390/antiox11071262

Momot, O., Diachenko-Bohun, M., Hrytsai, N., Grygus, I., Stankiewicz, B., Skaliy, A., Hagner-Derengowska, M., Napierała, M., Muszkieta, R. Ostrowska, M., & Zukow, W. (2020). Creation of a healthcare environment at a higher educational institution. *Journal of Physical Education and Sport*, *Vol 20* (Supplement issue 2), Art 138, pp 975 – 981. DOI:10.7752/jpes.2020.s2138

Mozolev, O., Kravchuk, L., Ostrovska, N., Nahorna, O., Polishchuk, O., & Khmara, M. (2020). Checking the effectiveness of the method of conducting physical education classes with 17-19 -year-old female students of special medical group. *Journal of Physical Education and Sport*, *Vol.20 (2*), Art 124, pp. 870 – 876. DOI:10.7752/jpes.2020.02124

Nikitina, O.A., Darenskaya, M.A., Semenova, N.V., & Kolesnikova, L.I. (2022). System of antioxidant protection: regulation of metabolic processes, genetic determinants, methods of determination. *Siberian Scientific Medical Journal,* Vol. 42(3), 4-17. DOI: 10.18699/SSMJ20220301

Papadopoulou, S.K. (2020). Rehabilitation nutrition for injury recovery of athletes: The role of macronutrient intake. *Nutrient*s, *12(8),* 2449. DOI: 10.3390/nu12082449

Pingitore, A., Lima, G.P., Mastorci, F., Quinones, A., Iervasi, G., & Vassalle, C. (2015). Exercise and oxidative stress: potential effects of antioxidant dietary strategies in sports. *Nutrition, 31(7-8*), 916-22. DOI:10.1016/j.nut.2015.02.005

Polidori, M.C., Mecocci, P., Cherubini, A., & Senin, U. (2000). Physical activity and oxidative stress during aging. *Int J Sports Med, 21(3),* 154-7. DOI: 10.1055/s-2000-8881

Shamitova, E.N., Alexandrova, N.L., & Mikhailova, K.N. (2018). Biochemical control of the body's reaction to increased physical activity. *Scientific Review. Biological sciences, 2,* 27-31. 85

Sen, C.K., & Packer, L. (2000). Thiol homeostasis and supplements in physical exercise. *American Journal of Clinical Nutrition, 72*, 653S-669S. DOI: 10.1093/ajcn/72.2.653S.

Kovalev, A.A., Shusharina, N.N., Sapunov, V.V., & Zaitsev, A.A. (2022). Management of motor activity based on digital data. Actual problems of improving the system of physical education. Materials of the All-Russian scientific-practical conference with international participation. Kaliningrad, pp. 77-82.

Zaitsev, A.A., & Sheinin, A.A. (2021). Features of human motor activity control using rank analysis of heart rate. East - Russia - West. Physical culture, sports and a healthy lifestyle in the XXI century. Proceedings of the XXII International Symposium. Kaliningrad, 2021, pp. 33-38.