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THE USE OF HYPERCAPNIC EFFECT FOR OPTIMIZING ORGANISM'S PERFORMANCE IN THE MODE OF EDUCATIONAL ACTIVITY

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Key words: hypercapnia, regulated control of breathing, oxy-pause, functional state of students, motor activity culture, distance learning.

Annotation. This study demonstrates how functioning of organism systems depends on the level of CO_2 in blood. Various methods of influencing this level, which are used internationally, were examined. The specific attention was given to the issue of health problems of students and searching a way for solutions, which could be easily adapted and used during the learning process. The use of oxy-pause is the most suitable way to solve this task. Results of the experiment on implementation of the given method within the "Physical culture and sports" subject are presented in this study.

Introduction. Physiology of human breathing is constructed in a way that the regulation of this process is made through the respiratory centre, which is a combination of nerve cells in various segments of the central nervous system. It is important to note that nerve receptors, which cause activity in the centre, which is the respiratory reflex, response to the level of carbon dioxide in blood, while oxygen concentration does not affect it in any way. During hypercapnia (increased carbon dioxide), there is an extension of vessels and impact on autoregulation, which allows to reduce rises of blood pressure. Antioxidative activity gets stronger and the level of acid-base balance is being controlled. Moreover, increase of CO_2 in blood and decrease of level of O_2, which is related to the first process, contribute to the creation of VEGFxxx isoforms, which are responsible for the creation of new blood vessels. It is also important to note that without carbon dioxide, oxygen cannot separate from hemoglobin, which indivertibly leads to the appearance of tissue hypoxia, in some cases – to anemia [1, 4, 11]. All these facts demonstrate the degree of impact of CO_2 in blood on various systems of vital activity of a human. Maintaining this level within normal values could contribute to the improvement of functioning of an organism, which is the reason why we give special consideration to it.

Table 1

Gas composition of atmosphere, alveolar and expiratory air, % (mm of Mercury)

Air gas composition	Atmosphere air	Alveolar air (P_{ET})	Expiratory air
O_2	20,85 (160)	13,5 (104)	15,5 (120)
CO_2	0,03 (0,2)	5,3 (40)	3,7 (27)
N_2	78,62 (596)	74,9 (569)	74,6 (566)
H_2O	0,5 (3,8)	6,3 (47)	6,2 (47)
Total	100,0 (760)	100,0 (760)	100,0 (760)

Carbon dioxide content in atmosphere air is 0,03% (Table 1). If this percentage value was increased to 5-7% during inhale, rebreathing or using special training devices, this would be the reason for the increase of lung ventilation approximately 6 times, which increases CO_2 content in alveolar air by 1% [9]. As a standard, partial pressure of carbon dioxide in alveolar air ($P_{ET}CO_2$) is 1-3 mm of Mercury lower than pressure in arterial blood (P_ACO_2). Values of P_ACO_2 acceptable for vital activity, are 3,6-7,5%, with the further increase, the possibility of oxygen uptake begins to decrease, and, as a result, the hypercapnic coma (loss of consciousness, rapid decrease in blood pressure, cyanosis) happens. Decreased CO_2 content could lead to apnea (complete respiratory arrest) due to cerebral hypoxia, because the respiratory centre reports the need to inhale only on certain level of carbon dioxide, oxygen deficit does not serve as a signal to it. Deep and hurried breathing, which is also called hyperventilation, leads to this state. It also serves as the reason for alkalosis – decrease of hydrogen ions [H+] and consequent increase in pH in direction to the alkali area (>7,45), which decreases the content of calcium ions in blood, and human will experience such symptoms as tingling, numbness, muscle spasms and even cardiac arrest [1, 4, 8]. Understanding acceptable boundaries and knowing the symptoms, which appear due to their violation, human is able to consciously control the level of carbon dioxide in blood, which could help them to normalize and improve, if needed, the work of main systems of an organism.

Control over the level of carbon dioxide in blood is represented in two tasks: not allowing critical states to happen and normalizing your state or develop it to the level of increased endurance in case of having health problems (Table 2). There are several ways to control the increase of CO_2. One of them is a process of physical hypercapnia – natural increase in the level of carbon dioxide in blood during physical loads. The statement that aerobic training (running on long distances, rowing, swimming, running in place, ice-skating etc., all types of activity, which are

performed on low or average tempo) contributes to the development of endurance, has already become self-evident. Thus, for example, running on 10 km distance with average speed of 10 km/h would contribute to the increase of the breakage of oxyhemoglobin into oxygen and hemoglobin approximately 2-3 times [7]. The given feature, as the number of others, has already been noticed and actively used in the training process of athletes. However, it is typical for science to improve the given results, which encouraged scientists to search other ways leading to hypercapnia.

Table 2

Dependence of the human condition on the level of CO_2 in arterial blood

P_ACO_2	Stage of state	Reason	Consequence
> 8,6%	Death	Critical increase of CO_2 in inspiratory air	Hypercapnic coma
7,6-8,5%	Critical		O_2 uptake decreases, acidosis, cyanosis, impaired judgment and loss of consciousness
6,1-7,5%	Super-endurance	Hypercapnic training	Increased O_2 uptake, improved autoregulation, blood pressure normalizing, blood flow improvement, stress reduction
4,6-5,0%	Norm		
3,6-4,5%	Having health problems	Снижение уровня физической активности, возрастные изменения	O_2 uptake decreases, increased vascular tone (blood flow increase), stress increase
2,1-3,5%	Critical	Hyperventilation	Cerebral hypoxia, alkalosis, loss of consciousness
< 2%	Death		Apnea, cardiac arrest, brain death

One of those solutions was the K.P. Butejko's suggestion concerning the breathing process. The yogi practice of reducing lung ventilation at rest was used as the basis of his method. He tracked the connection between the human critical state and frequency of their breathing, suggesting that with the obligatory control of inhale and exhale duration, diseases could be cured. This suggestion was developed into the "Voluntary Elimination of Deep Breathing Method" (VEDBM), in the basis of which was the principle of control of external respiration due to delays of breathing after exhale and the increase of exhale duration. With the use of this method, content of carbon dioxide in blood was normalized, by which the main reason of many functional disorders was eliminated, which is the tissue hypoxia [2, 3]. However, despite the scientifically based effectiveness, this method is not suitable for everyone. The reason for that is the course's duration and increased emphasis on

conations of an individual, which was not always achievable due to various psychological features of people.

It became possible to completely avoid or to decrease the effect of the volitional factor to the minimum thanks to the use of hypercapnic respiratory training devices. Their principle was mainly based on the obstruction of inhale and exhale due to the closure of the lumina, through which air comes in and out. Moreover, the methods of inhalation and invasive CO_2 intake during treatment of various diseases gained wide use [5]. However, even though the use of training devices and the method of artificial intake of carbon dioxide demonstrated its effectiveness, it still could not solve the problem and make the use available for everyone. First, a specific training device was needed, which is required not only to buy, but also to understand how to use it. Therefore, with a shortage of funds and the absence of an instructor, the person does not have the opportunity to use it. Second, conditions of an in-patient facility were needed, in which, for obvious reasons, it is not possible to place everyone, who needs a correction of the CO_2 level in blood. Our task was to find a method, which could be used for everyone, for example within the educational activity in the university.

The need for searching such method exactly for students of the university is defined by a certain degree of abnormalities in the state of health of students, which can be traced through the annual analysis of the health groups of applicants [10]. Such tendency could be the reason of the increasing role of computer technologies in human's life. The process of learning, working and even resting is related to spending time with a computer, which, in most cases, could be the reason for sedentary lifestyle and cause the number of accompanying diseases. The problem of the imbalance in functional indicators of health is extremely relevant, especially during the pandemic, when the incidence rate is especially high. The role of the "physical culture" subject in such conditions is also increases. The teacher should contribute to the formation of the motor activity culture in students, i.e., they should try and give knowledge and foster abilities about health and capabilities of an organism, which could be demanded by students in real life. We have decided to draw their attention to the respiratory process and make an emphasis on the method of a regulated control of breathing or the oxy-pause, which was simple in adaptation for distance working and is, in fact, a simplified version of the Butejko's method. We decided to decrease the time of intervals of the hypercapnic training, which, by contrast with the VEDBM, required a lot less conations, which means that it was suitable for most students. Moreover, this method was available, since it did not require special conditions or additional training devices, which is why using it during classes was the most promising, which was the determining factor in its choice.

The purpose of this study is to give evidence that using hypercapnic training during the learning process is able to normalize and improve indicators of the functional state of students.

Methods and organization. 149 female students of the 1-3 year aged 17 to 23 years, who have chosen Pilates as the elective course of physical culture and sports, participated in the experiment. The study was carried out during autumn semester of 2020 in the Moscow City University. It is important to note that all classes were carried out remotely in Microsoft Teams. Before the beginning of the experiment and at the end of it, the questionnaire was given to students and their functional indicators were registered (vital capacity, heart rate at rest and under loads, level of blood pressure). During the initial questionnaire, we asked students to state their full name, age, sleep duration, average time spent on a computer every day, and also specify their approximate level of physical activity in hours per week. Physical activity was divided into two types: passive (walking) and intense (training, outdoor activities). Moreover, students were required to state their health complaints and medical diagnoses, if there were any. During the final questionnaire, students gave feedback on their well-being after the experiment.

Results and discussion. Implementation of oxy-pause in classes was carried out in two stages. At the first stage, the students were given information about the physiology of breathing; special attention was given to the dependency of the functional state on degree of the carbon dioxide level in blood. Various methods of influencing the respiratory process, which could increase or decrease the CO_2 level, were examined. Only after that, the oxy-pause method was explained. The point of this method was in splitting time of classes into segments in order to eliminate the fatigue effect from the informational supersaturation. Duration of these segments was 20-25 minutes, oxy-pause served as a delimitative barrier. Students were required to make a continuous inhale for 15 seconds, then hold their breath for 30 seconds and make a gradual exhale with small “hissing” for 15 seconds, leaning their tongue against the upper palate. It allowed creating the effect of the “limiting valve”, which did not allow releasing all air at once. The duration of one exercise was 1 minute; one oxy-pause should last up to 5 minutes. Special emphasis was made on posture during breathing exercises: students were required to straighten their back and sit comfortably. The attention should be paid to breathing and the state of comfort and relaxation, which helped to release stress and “reload” consciousness. Students were recommended to perform the oxy-pause outside classes of physical culture in case of first symptoms of fatigue or loss of concentration, registering the number of pauses per day.

During the analysis of the initial questionnaire (Fig. 1), it was revealed that every third student had officially determined medical diagnoses, in accordance to

which they were included in the physical culture group with reduced exercise load or special group. 31% of interviewed students spent less than 1 hour a week on physical activity, 32% spent 1 to 2 hours. This data demonstrated that every third of all interviewed students spent time on physical activity higher than the recommended minimum level equal to 2 hours a week and only every sixth exceeded the limit of 3 hours.

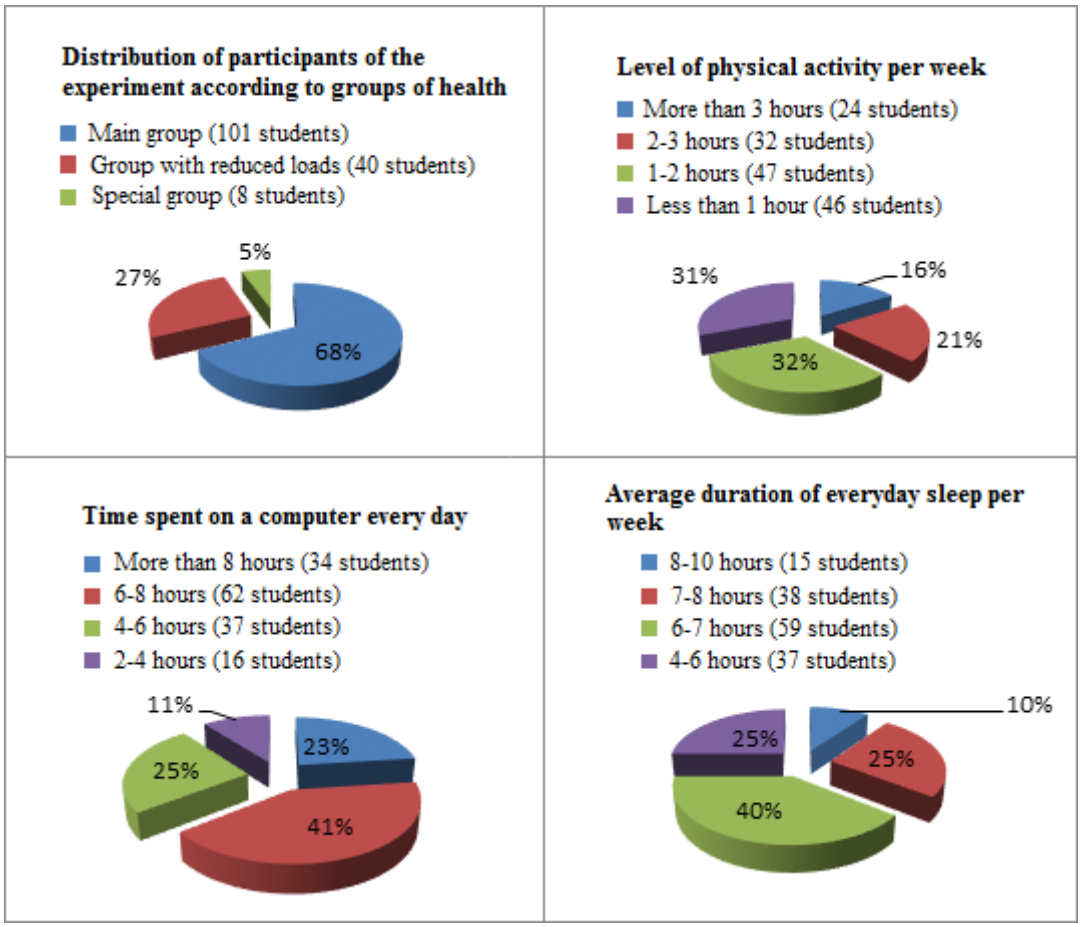

Fig. 1.Results of the initial questionnaire

Moreover, it is important to pay attention to the fact that 64% of the experimental group spent time on a computer every day for more than 6 hours, and most often this time was not divided by breaks, i.e. it was spent in one go. 90% of students in average spent less than 8 hours on sleep. This data cannot be considered as positive, most indicators were different from the norm adopted to determine healthy lifestyle, which was approved by numerous complaints from students about their health (Fig. 2).

Complaints mainly included recurrent headaches, loss of sleep, pain in the back, neck and knee joints, the students were also concerned about the increased level of stress, which worsened due to the pandemic and mandatory quarantine.

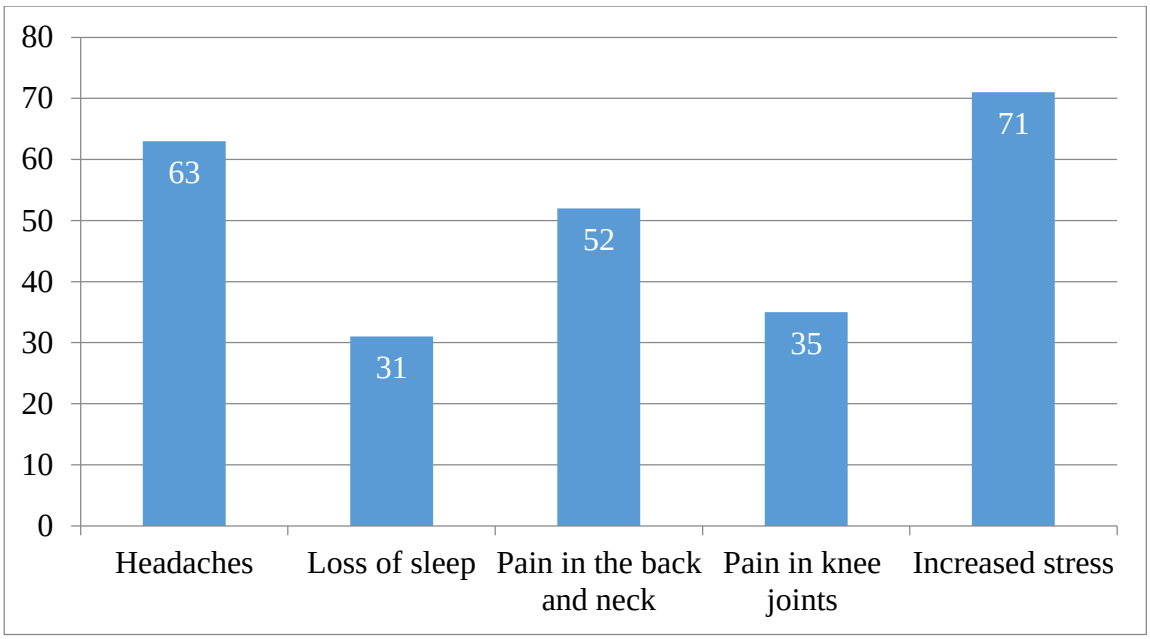

Fig. 2. The most frequent symptoms and complaints, which were stated by the students during the initial questionnaire (number of students)

Taking these facts into consideration, the implementation of hypercapnic training into the educational process was more than justified. The use of the oxy-pause method by students during classes and independently contributed to the improvement of their functional indicators. The vital capacity in average was increased from 2,5 l to 3 l. Positive dynamics were registered in all participants of the experimental group with the insignificant margin of error. The heart rate at rest and under loads was also decreased. If before the beginning of the experiment, average indicators were 75 beats/min and 135 beats/min at rest and under loads, then after the end they were 70 beats/min и 120 beats/min respectively. Stabilizing the level of blood pressure was also typical. During the first measurement, the average indicator was 123/81 (range of 123/81 to 134/87), during the measurement at the end of the experiment is was at the level of 115/70, moreover, the range between the lowest and the highest value was also decreased and it was from 105/63 to 125/80. Aside from functional indicators, which were compared by us, answers of students in the final questionnaire also give evidence on the oxy-pause effect. Students stated an improvement of the quality of sleep, stabilizing of the psychoemotional state, and improvement of general state of their organism, despite numerous external irritants.

More of the positive moments of the oxy-pause implementation into the educational process was the increase of attention of students to their health. Participants of the experiment became more aware of the signals sent by their organism, and, most importantly, started to understand them. It all contributed to the development of the motor activity culture among students and became a motivator for those who know them, who started to show interest to such activity and new knowledge, which is applicable to life and their own health. Questions about both

the method and health protection technologies in whole began to come from students of other elective courses, who learned about the oxy-pause from participants of the experimental group. The impact of the educational function should be noted, because the task of any learning process is a maximum distribution of knowledge and motivating the biggest number of people to get this knowledge. With this approach, only the effect of the implemented method could be not one-time and local, but extended and widespread, which is why in our case more attention was paid to the explanation of the effect of carbon dioxide on an organism. Only by trying to show students how to understand the point of the process the maximum effect could be achieved, because in this case the students are able to distribute useful knowledge by themselves and contribute to the development of not only their motor activity culture, but also the motor activity culture of those, who know them.

Conclusion. The use of hypercapnic effect showed its effectiveness both for therapeutic and health-improving purposes. Understanding principles of relationship between the carbon dioxide level in blood and functioning of main systems of an organism could help to increase the level of health of an individual if the approach to its regulation is conscious. Thanks to the implementation of the oxy-pause into the educational process of the "physical culture and sports" subject, results on optimizing organisms of students in the mode of their educational activity were achieved. The given method did not require additional training devices or special conditions, which allowed adapting it even for distance learning. The method of regulated breathing control has all evidence to become one of the basic keys to solve issues on the formation of the motor activity culture of the society, which could be achieved through the distribution of its use beyond the scope of one specific subject.

References

1. Agadzhanyan N.A. Physiological role of carbon dioxide and human's performance / N.A. Agadzhanyan, N.P. Krasnikov, I.N. Polunin // Moscow-Astrakhan'-Nal'chik: Publishing House "Volga". – 1995. – 188 p.

2. Butejko K.P. Manual for using the VEDB method (Voluntary Elimination of Deep Breathing) / K.P. Butejko // Novosibirsk. – 1988. – 47 p.

3. Volkova A.M The effect of technology of using measures of the cold water treatment and breathing exercises / A.M. Volkova, V.A. Shalabodina // Bulletin of the Moscow City University. Natural Sciences Series. – 2020. – № 3 (39). – P. 50-59.

4. Gridin L.A. Modern views on physiological, therapeutic, and preventive effects of hypoxia and hypercapnia / L.A. Gridin // Medicine. – 2016. – Vol. 4. – № 3 (15). – P. 45-68.

5. Drogovoz S.M. Carboxytherapy is an alternative for traditional drug therapy / S.M. Drogovoz, S.Yu. Shtrygol', M.V. Zupanets, A.V. Kononenko, E.V. Levinskaya // Clinical Pharmacy. – 2016. – № 1. – P. 12-17.

6. Mishchenko V.P. Human physiology. Module 2: Physiology of visceral systems. Context module 10: "The respiratory system" / V.P. Mishchenko, V.N. Sokolenko, M.Yu. Zhukova // Poltava. – 2006. – 48 p.

7. Senin I.P. Hypercapnic training as a mean to eliminate the tissue hypoxia / I.P. Senin, Yu.N. Mishustin // Journal of the GrSMU. – 2006. – №1 (13). – P. 81-83.

8. Solopov I.N. Physiological effect of methods of targeted exposure to the human's respiratory function. A monograph. / I.N. Solopov // Volgograd. – 2004.

9. Drogovoz S.M. Physiological qualities of CO2 – justification of carboxytherapy's relevance / S.M. Drogovoz, S.Yu. Shtrygol', M.V. Zupanets, A.V. Kononenko// Medical and clinical chemistry. – 2016. – Vol. 18. – № 1. – P. 112-116.

10. Shalabodina V.A. Physical culture of students of higher education establishments in conditions of total informational support: tendencies, risks, prospects / V.A. Shalabodina, A.E. Stradze // Bulletin of the Moscow City University. Natural Sciences Series. – 2020. – № 3 (39). – P. 68-79.

11. Shtabnitskij V.A. Disturbance in carbon dioxide metabolism special features of the pathogenesis and diagnostics / V.A. Shtabnitskij // Consilium Medicum. – 2016. – Vol. 18. – № 12. – P. 88-91.

Spisok literatury

1. Agadzhanyan N.A. Fiziologicheskaya rol' uglekisloty i rabotosposobnost' cheloveka / N.A. Agadzhanyan, N.P. Krasnikov, I.N. Polunin // Moskva-Astrakhan'-Nal'chik: Izdatel'stvo "Volga". – 1995. – 188 s.

2. Butejko K.P. Instruktsiya po primeneniyu metoda VLGD (Volevoj likvidatsii glubokogo dykhaniya) / K.P. Butejko // Novosibirsk. – 1988. – 47 s.

3. Volkova A.M. Vliyanie tekhnologii primeneniya sredstv zakalivaniya i dykhatel'nykh uprazhnenij na funktsional'nye pokazateli plovtsov podrostkovogo vozrasta / A.M. Volkova, V.A. Shalabodina // Vestnik Moskovskogo gorodskogo pedagogicheskogo universiteta. Seriya: Estestvennye nauki. –2020. – № 3 (39). – S. 50-59.

4. Gridin L.A. Sovremennye predstavleniya o fiziologicheskikh i lechebno-profilakticheskikh effektakh dejstviya gipoksii i giperkapnii / L.A. Gridin // Meditsina. – 2016. – T. 4. – № 3 (15). – S. 45-68.

5. Drogovoz S.M. Karboksiterapiya – al'ternativa traditsionnoj farmakoterapii / S.M. Drogovoz, S.Yu. Shtrygol', M.V. Zupanets, A.V. Kononenko, E.V. Levinskaya // Klinichna farmatsiya. – 2016. – № 1. – S. 12-17.

6. Mishchenko V.P. Fiziologiya cheloveka. Modul' 2: Fiziologiya vistseral'nykh sistem. Kontekstnyj modul' 10: «Sistema dykhaniya» / V.P. Mishchenko, V.N. Sokolenko, M.Yu. Zhukova // Poltava. – 2006. – 48 s.

7. Senin I.P. Giperkapnicheskaya trenirovka kak sredstvo ustraneniya tkanevoj gipoksii / I.P. Senin, Yu.N. Mishustin // Zhurnal GrGMU. – 2006. – №1 (13). – S. 81-83.

8. Solopov I.N. Fiziologicheskie effekty metodov napravlennogo vozdejstviya na dykhatel'nuyu funktsiyu cheloveka. Monografiya. / I.N. Solopov // Volgograd. – 2004.

9. Drogovoz S.M. Fiziologicheskie svojstva SO2 – obosnovanie unikal'nosti karboksiterapii / S.M. Drogovoz, S.Yu. Shtrygol', M.V. Zupanets, A.V. Kononenko// Medichna ta klinichna khimiya. – 2016. – T. 18. – № 1. – S. 112-116.

10. Shalabodina V.A. Fizicheskaya kul'tura obuchayushchikhsya vysshej shkoly v usloviyakh total'noj informatizatsii: tendentsii, riski, perspektivy / V.A. Shalabodina, A.E. Stradze // Vestnik Moskovskogo gorodskogo pedagogicheskogo universiteta. Seriya: Estestvennye nauki. – 2020. – № 3 (39). – S. 68-79.

11. Shtabnitskij V.A. Narushenie obmena uglekislogo gaza: osobennosti patogeneza i diagnostiki / V.A. Shtabnitskij // Consilium Medicum. – 2016. – T. 18. – № 12. – S. 88-91.

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