Вестник РУДН. Серия: МЕДИЦИНА
RUDN Journal of MEDICINE
2021;25(2):127—135
http://journals.rudn.ru/medicine

DOI 10.22363/2313-0245-2021-25-2-127-135
UDC 612.13

RESEARCH ARTICLE

Heart rate variability analysis of students with different motor activity levels

A.S. Emelyanova[1], L.A. Simonyan[2], E.E. Stepura[2*]

[1]Ryazan State Agrotechnological University, *Ryazan, Russian Federation*
[2]State Social and Humanitarian University, *Kolomna, Russian Federation*
*Correspondihg author: chimik89@mail.ru

Annotation. *Relevance*. Assessment of the functional state of the body is one of the leading tasks of physiology. The article deals with the analysis of the initial vegetative status of students with different levels of motor activity. *Materials and Methods*. Registration and analysis of the heart rate variability was carried out with the help of a modern complex electrophysiological laboratory «CONAN – 4.5». The heart activity of students engaged in physical culture within the educational process was evaluated on the basis of heart rate variability analysis. *Results and Discussion*. It was revealed that among the entire studied array of students (with the differentiation of the initial vegetative status calculated according to muscle tension index), «normotonics» are characterized by an optimal ratio between the parasympathetic and sympathetic divisions of the autonomic nervous system. At the same time, the value of the coefficient of physical activity in the studied group was determined at the level of 1.73±0.1. *Conclusion*. For vagotonics, the value of the triangular index was 2.5±0.2 conventional units (CU), which confirms the idea of an increase in the influence on the autonomic nervous system. The value for normotonics is 2.2±0.1 CU. This group was characterized by the balance between the sympathetic and parasympathetic parts of the autonomic nervous system. In sympathicotonics – 1.9±0.5 CU, which confirms the idea of increasing the influence of the sympathetic division of the autonomic nervous system. In hypersympathicotonics-1.1±0.4 CU. To ensure adequate functioning of the cardiovascular system and for normal adaptation to physical exertion in students, it is necessary to form a level of motor activity that quantitatively corresponds to a coefficient of physical activity of at least 1.75.

Key words: electrocardiogram, cardiovascular system, stress index, initial vegetative tone, physical activity coefficient

Author contributions: concept and design of the study, discussion of the results – A.S. Emelyanova; planning and execution of the experimental part of the study – E.E. Stepura; discussion of the results, design of the introduction and formulation of the conclusion – L.A. Simonyan.

Conflict of interest statement. The authors stated that there was no conflict of interest.

Received 26.01.2021. Accepted 11.02.2021.

For citation: Emelyanova AS, Simonyan LA, Stepura EE. Heart rate variability analysis of students with different motor activity levels. *RUDN Journal of Medicine*. 2021;25(2):127—135. doi: 10.22363/2313-0245-2021-25-2-127-135

Анализ электрокардиограммы студентов с разным уровнем двигательной активности

А.С. Емельянова[1], Л.А. Симонян[2], Е.Е Степура[2*]

[1]Рязанский государственный агротехнологический университет им. П.А. Костычева, *г. Рязань, Российская Федерация*
[2]Государственный социально-гуманитарный университет, *г. Коломна, Российская Федерация*
*chimik89@mail.ru

Аннотация. *Актуальность*. Оценка функционального состояния организма является одной из ведущих задач физиологии. В статье рассматривается анализ исходного вегетативного статуса студентов с разным уровнем двигательной активности. *Материалы и методы.* Регистрация и анализ вариабельности сердечного ритма проведен с помощью современной комплексной электрофизиологической лаборатории «CONAN – 4.5». Оценена сердечная деятельность студентов, занимающихся физической культурой в рамках образовательного процесса на основе анализа вариабельности сердечного ритма. *Результаты и обсуждение.* Выявлено, что среди всего изученного массива студентов (при дифференцировании исходного вегетативного статуса, рассчитанного по индексу напряжения) «нормотоники» характеризуются оптимальным соотношением между парасимпатическим и симпатическим отделами вегетативной нервной системы. При этом значение коэффициента физической активности у исследованных данной группы определялся на уровне значений 1,73±0,1. *Выводы*. Для ваготоников значение триангулярного индекса составляло 2,5±0,2 у.е., что подтверждает представление о повышении влияния парасимпатического отдела вегетативной нервной системы. Значение у нормотоников – 2,2±0,1 у.е. Данная группа характеризовалась равновесием между симпатическим и парасимпатическим отделами вегетативной нервной системы. У симпатикотоников – 1,9±0,5 у.е., что подтверждает представление о повышении влияния симпатического отдела вегетативной нервной системы. У гиперсимпатикотоников – 1,1±0,4 у.е. Для обеспечения адекватного функционирования сердечно-сосудистой системы и для нормальной адаптации к физическим нагрузкам у студентов необходимо формировать уровень двигательной активности, количественно соответствующий коэффициенту физической активности не ниже 1,75.

Ключевые слова: электрокардиограмма, сердечно-сосудистая система, индекс напряжения, исходный вегетативный тонус, коэффициент физической активности

Вклад авторов: Емельянова А.С.– концепция и дизайн исследования, обсуждение результатов. Степура Е.Е.– планирование и выполнение экспериментальной части исследования. Симонян Л.А.– обсуждение результатов, оформление введения и формулировка заключения.

Информация о конфликте интересов. Авторы заявили об отсутствии конфликта интересов.

Поступила 26.01.2021. Принята 11.02.2021.

Для цитирования: *Емельянова А.С., Симонян Л.А., Степура Е.Е.* Анализ электрокардиограммы студентов с разным уровнем двигательной активности // Вестник Российского университета дружбы народов. Серия: Медицина. 2021. Т. 25. № 2. С. 127—134. doi: 10.22363/2313-0245-2021-25-2-127-134

Introduction

The body's functional reserves are developing and adapting during physical exertion, and the level of physical activity determines their quantitative equivalent [1—7]. According to the investigation of Dorontsev A.V. and Kozlyatnikova O.A. there is a relationship between such indicators as physical development and physical fitness of the body [8—12]. During physical exertion, there is a change in functional systems, a change in adaptive-regulatory systems, predetermining the further course of adaptation of the organism. The functional reserves of the body are

influenced not only by training activity, but also by the training load, which makes increased demands on the state of health of students [13—19].

The purpose of the scientific work is to analyze the heart rate variability (HRV) among students, taking into account the level of physical activity.

The objectives of this work are:

1) to conduct ECG registration of students with different coefficient of physical activity (CPA); 2) to conduct a mathematical analysis of HRV of students with different coefficient of physical activity using the modern complex electrophysiological laboratory «CONAN – 4.5»; 3) to establish the initial vegetative tone based on the stress index in students with different CPA; 4) to analyze the obtained numerical values of the primary indicators of HRV – mode, mode amplitude and variation range and heart rate, obtained on the basis of electrocardiogram processing; 5) to analyze the triangular HRV index of students, with different CPA; 6) to determine the relationship between CPA and HRV indicators.

Materials and methods

Heart rate and ECG were recorded at rest in an amount of 100 students (31 women and 69 men, aged from 18 to 22). All study participants received informed consent to participate in the study in accordance with the World Medical Association's Declaration of Helsinki (WMA Declaration of Helsinki – Ethical Principles for Medical Research Involving Human Subjects, 2013) and the processing of personal data.

ECG recording was carried out using the complex electrophysiological laboratory «CONAN – 4.5» with logging of heart rate variability indicators calculated from the electrocardiogram, followed by computer data processing in Microsoft Excel 2007 software package for statistical analysis Statistica10. All experiments were carried out in compliance with the principles of bioethics.

Results and discussion

The resulting electrocardiograms were mathematically analyzed. In the course of mathematical analysis, the stress index of each examined student was obtained. To divide the stress index into groups, we used the gradation of numerical values of the authors O.Yu. Shiryaev and E.I. Ivleva, they believed that under stress or any diseases, the value of the stress index increases.

The authors identified in their studies five types of the initial autonomic tone: vagotonic, normotonic, sympathicotonic, oversymaticotonic and transcendent supersymaticotonic. In our studies, all the students were healthy and the transcendental supersymaticotonic tone was not detected in any student (the value of the transcendental supersymaticotonic tone is more than 600 conventional units (CU)).

As a result of the research, the students were divided into 4 groups, each group had its own stress index and the estimated initial autonomic tone. The obtained ratios of the stress index and the estimated initial tone and the number of students under study are presented in Table 1.

Table 1

The ratio of students on the basis of the initial vegetative status (IVT)

Muscle tension index, CU	IVT by Muscle tension index	Number of subjects examined
≤30	Vagotonia	10
31—120	Normotonia	22
121—300	Sympathicotonia	63
≥301	Hypersympathicotonia	5

When analyzing the electrocardiogram using the modern complex electrophysiological laboratory «CONAN – 4.5», the heart rate was established in students with different initial vegetative status, the obtained numerical values are presented in Table 2.

Table 2

Heart rate of students with different autonomic regulation

№	Muscle tension index, CU	IVT by Muscle tension index	Heart rate, beats/min	Type of rhythm change / absence of rhythm disturbance
1	≤30	Vagotonia	65 ± 0,13	Reasonable normocarbia
2	31—120	Normotonia	70 ± 0,21	Normocarbia
3	121—300	Sympathicotonia	73 ± 0,16	Normocarbia
4	≥ 301	Hypersympathicotonia	80 ± 0,27	Tachycardia

Note: the significance of heart rate differences was evaluated between the groups using the Student's t-test, p<0.001

When analyzing Table 1, the first group of students (10 people) with the by Muscle tension index of regulatory systems up to 30 with the expected IVT – «vagotonia» – was characterized by the predominance of parasympathetic autonomic nervous system (ANS). At rest, the examined group has a heart rate of 65 ± 0.13 beats / min (p <0.001) – moderate normocardia is observed.

In the second study group of students (22 people) with different levels of physical activity with Muscle tension index from 31 to 120 conventional units. with the alleged IVT – «normotonia» – was characterized by an equilibrium state of the ANS between the parasympathetic and sympathetic divisions, which indicated the activity of the parasympathetic division of the nervous system. Heart rate was 70 ± 0.21 bpm (p <0.001) – normocardia.

The third group of students (63 people) was characterized by a predominance of sympathetic ANS with Muscle tension index from 121 to 300 CU with the supposed IVT – «sympathicotonia». The heart rate in comparison with the previous groups is 8 and 3 beats / min more vagotonia and normotonia, respectively, and amounted to 73 ± 0.16 beats / min (p <0.001) – normocardia.

The fourth group of students (5 people) is characterized by an increase in the activity index of the sympathetic ANS with Muscle tension index ≥ 301 CU, with the assumed IVT – «hypersympathicotonia». The heart rate was 80 ± 0.27 beats / min (p <0.001), the type of arrhythmia was tachycardia.

When analyzing the electrocardiogram using the modern complex electrophysiological laboratory «CONAN – 4.5», the numerical values of heart rate variability indicators in students with different initial vegetative status were obtained and analyzed, the values obtained are presented in tables 3, 4, 5.

Table 3

The value of the mode (Mo) of heart rate variability of students

№	Muscle tension index, CU	IVT by Muscle tension index	Confidence between groups	Mo, sec
1	≤ 30	Vagotonia	1—3 (p<0,001) 1—2 (p<0,001) 1—4 (p<0,001) 2—3 (p<0,001) 2—4 (p<0,001) 3—4 (p<0,01)	0,881±0,01
2	31—120	Normotonia		0,821±0,01
3	121—300	Sympathicotonia		0,792±0,01
4	≥ 301	Hypersympathicotonia		0,763±0,01

Note: the significance of the Mo differences was evaluated between the groups using the Student's t-test

Analysis of tables 3, 4, 5 showed the following physiological picture of the primary indicators of heart rate variability in students with different initial vegetative status.

Mode is the range of values for the most common R-R intervals. In hypersympathicotonics it was 0.763 ± 0.01 sec (p <0.05) – it was characterized by the lowest

value of the frequently occurring cardiointerval among the other examined groups.

In the group of vagotonics, the parasympathetic section prevails over the sympathetic section of the ANS, the value of this indicator is 0.881 ± 0.1 sec (p <0.05). The lowest value of heart rate among students is observed among the entire investigated array.

The value of this indicator in normotonics was 0.821 ± 0.1 sec (p <0.05) – they were characterized by the equilibrium state of the autonomic nervous system between the parasympathetic and sympathetic divisions, which indicated the tone of the parasympathetic division of the ANS.

The group of sympathicotonics, which was characterized by a shift in the autonomic balance towards the sympathetic autonomic nervous system – 0.792 ± 0.1 sec (p <0.05).

The number of cardiointervals that correspond to the value of the mode index characterizes the amplitude of the mode. The predominance of the autonomous control loop is indicated by low values of this parameter, while the activity of the central control loop is indicated by high values.

Table 4

The value of the amplitude mode (AMo) of the heart rate variability of students

№	Muscle tension index, CU	IVT by Muscle tension index	Confidence between groups	AMo,%
1	≤ 30	Vagotonia	1—2 (p<0,05) 1—3 (p<0,001) 1—4 (p<0,001) 2—4 (p<0,001) 3—4 (p<0,001)	40,3±1,2
2	31—120	Normotonia		45,2±2,1
3	121—300	Sympathicotonia		52,4±3,5
4	≥301	Hypersympathicotonia		89,3±8,4

Note: the significance of the AMo differences was evaluated between the groups using the Student's t-test

The data in Table 4 indicate that the highest value of this indicator is observed in hypersympathicotonics – 89.3 ± 8.4 % (p <0.01), thus, the process turns on the central circuit of regulation.

For the group of subjects with IVT vagotonia, the analyzed indicator was 40.3 ± 4.2 % (p <0.05), and in the group of subjects with IVT, normotonia and sympathicotonia – 45.2 ± 2.1 % (p <0.001) and 52, 4 ± 3.5 % (p <0.001), respectively. When analyzing the studied indicator, low ones indicate the predominance of the autonomous regulation circuit.

In the study group with IVT vagotonia, the analysis of the variation indicator – 0.651 ± 0.02 sec (p <0.05), indicates a decrease in myocardial contractile functions and the prevalence of vagotonic tone.

This value of the analyzed indicator in the group of normotonics was 0.323 ± 0.07 sec (p <0.05), which indicates the tone of the parasympathetic part of the nervous system.

In the examined groups – sympathicotonics and hypersympathicotonics, the smallest indicators of the variation range were 0.222 ± 0.04 sec (p <0.05) and 0.121 ± 0.06 sec (p <0.05), respectively. It is a consequence of the predominance of the non-respiratory component of the heart rate and the parasympathetic link. Consequently, such groups of students are characterized by a low adaptive capacity, which may be characterized by low indicators of the level of innate reserves.

Table 5

The value of the variation range (ΔX) of the heart rate variability of students with different vegetative status

№	Muscle tension index, CU	IVT by Muscle tension index	Confidence between groups	ΔX, sec
1	≤30	Vagotonia	1—2 (p<0,001) 1—3 (p<0,001) 1—4 (p<0,001) 2—3 (p<0,001) 2—4 (p<0,001) 3—4 (p<0,001)	0,651±0,02
2	31—120	Normotonia		0,323±0,07
3	121—300	Sympathicotonia		0,222±0,04
4	≥301	Hypersympathicotonia		0,121±0,06

Note: the significance of the differences in ΔX was evaluated between the groups using the Student's t-test

When analyzing the electrocardiogram using the modern complex electrophysiological laboratory «CONAN – 4.5», the values of the triangular index (TiNN) of heart rate variability were obtained and analyzed in students with different initial vegetative status, the numerical values of this indicator are presented in Table 6.

Table 6

Indicators of the triangular index (TiNN) of heart rate variability of students with different vegetative status

№	Muscle tension index, CU	IVT by Muscle tension index	Confidence between groups	TiNN, y. e.
1	≤ 30	Vagotonia	1—2 (p<0,05) 1—3 (p<0,05) 1—4 (p<0,001) 2—4 (p<0,05)	2,5±0,1
2	31—120	Normotonia		2,2±0,1
3	121—300	Sympathicotonia		1,9±0,2
4	≥ 301	Hypersympathicotonia		1,1±0,4

Note: The significance of TiNN differences was evaluated between the groups using the Student's t-test

For vagotonics, in which the parasympathetic division prevails over the sympathetic division of the ANS, the value of the triangular index was 2.5 ± 0.1 CU ($p < 0.05$), the number of heart contractions decreases in comparison with normotonics, sympathicotonics and hypersympathicotonics. This confirms the idea of an increase in the influence of the parasympathetic division of the autonomic nervous system.

The triangular index value in normotonics was 2.2 ± 0.1 CU ($p < 0.05$). This group was characterized by an equilibrium state of the autonomic nervous system between the parasympathetic and sympathetic divisions, which indicated the tone of the parasympathetic division of the nervous system.

In sympathicotonics, which were characterized by a predominance of the sympathetic division of the autonomic nervous system, the indicator of this value was 1.9 ± 0.2 a.u. ($p < 0.05$). This confirms the idea of an increase in the influence of the sympathetic division of the autonomic nervous system.

In hypersympathicotonics, the triangular index was 1.1 ± 0.4 CU ($p < 0.05$). This group of students is characterized by a decrease in the most frequent cardiointerval among the entire array.

The students were offered a test to determine the coefficient of physical activity. The coefficient of physical activity is the ratio of a person's average daily energy expenditure to energy expenditure at rest, to the so-called basal metabolic rate.

Table 7 shows the values of the coefficient of physical activity among students with different initial vegetative tone.

Table 7

Indicators of the coefficient of physical activity (CPA) in students with different vegetative status

№	Muscle tension index, CU	IVT by Muscle tension index	Confidence between groups	CPA, points
1	≤ 30	Vagotonia	1—2 (p<0,05) 1—3 (p<0,001) 1—4 (p<0,001) 2—3 (p<0,001) 2—4 (p<0,001) 3—4 (p<0,001)	1,41±0,1
2	31—120	Normotonia		1,73±0,1
3	121—300	Sympathicotonia		2,01±0,1
4	≥ 301	Hypersympathicotonia		2,42±0,2

Note: The significance of the CPA differences was evaluated between the groups using the Student's t-test

The first group included students with Muscle tension index up to 30. with the original vegetative tone «vagotonia». This group was characterized by a predominance of the parasympathetic autonomic nervous system. The coefficient of physical activity was 1.41 ± 0.1 points.

The second group with a muscle tension index from 31 to 120 CU with the expected initial vegetative

tone «normotonia». Such a group was characterized by an equilibrium state of the autonomic nervous system between the parasympathetic and sympathetic divisions. The coefficient of physical activity in this group of students was 1.73 ± 0.1 points.

The third group was characterized by a predominance of the sympathetic autonomic nervous system with a stress index from 121 to 300 CU with the initial vegetative tone «sympathicotonia». For this group, the coefficient of physical activity was 2.01 ± 0.1 points.

The fourth group was characterized by a significant increase in the indicators of the activity of the sympathetic autonomic nervous system with a stress index of more than 301 CU, with an initial autonomic tone of «hypersympathicotonia». The coefficient of physical activity was 2.42 ± 0.2 points.

It was revealed that among the entire study group of students (when differentiating the initial vegetative tone, calculated by the stress index), «normotonics» were characterized by the optimal ratio between the parasympathetic and sympathetic divisions of the autonomic nervous system. At the same time, the value of the coefficient of physical activity in the studied group was determined at the level of values 1.73 ± 0.1 points.

Thus, to ensure adequate functioning of the cardiovascular system and for normal adaptation to physical activity in students, it is necessary to form the level of physical activity, quantitatively corresponding to the coefficient of physical activity not lower than 1.75 points.

Conclusion

In the course of registration and mathematical analysis of heart rate variability among students using the modern complex electrophysiological laboratory «CONAN – 4.5», we came to the following conclusions.

1. As a result of the research, the tested students were divided into four subgroups: the first subgroup with an initial vegetative tone – vagotonia included 10 people, the second with an assumed initial vegetative tone – normotonia – 22 students, the third subgroup with an initial vegetative tone – sympathicotonia – 63 students, and in the fourth with the initial vegetative tone – hypersympathicotonia – 5 people.

2. The value of fashion in hypersympathicotonics is 0.76 ± 0.01 sec. For vagotonics, in which the parasympathetic department predominates, the value was 0.88 ± 0.1 sec. In normotonics it was 0.82 ± 0.1 sec – there is an equilibrium in the autonomic status of the ANS. In sympathicotonics – 0.79 ± 0.1 sec.

3. The highest value of the AMo index is typical for the study group – hypersympathicotonics – 89.3 ± 8.4 %. The smallest value for vagotonics was 40.3 ± 4.2 %, and intermediate values were in the groups of normotonics and sympathicotonics – 45.2 ± 2.1 % and 52.4 ± 3.5 %, respectively.

4. In the studied group of vagotonic patients the variation range is 0.651 ± 0.02 sec, vagotonic tone prevails. Normotonics – 0.323 ± 0.07 sec, which indicates the tone of the ANS and the predominance of respiratory changes in the heart rate. In groups – sympathicotonics and hypersympathicotonics it was 0.222 ± 0.04 sec and 0.121 ± 0.06 sec, respectively.

5. For vagotonics, the value of the triangular index was 2.5 ± 0.2 CU, which confirms the idea of an increase in the influence of parasympathetic nervous system. The value for normotonics is 2.2 ± 0.1 CU. This group is characterized by a balance between the sympathetic and parasympathetic divisions of the autonomic nervous system. In sympathicotonics – 1.9 ± 0.5 CU, which confirms the idea of an increase in the influence of the sympathetic division of the autonomic nervous system. In hypersympathicotonics – 1.1 ± 0.4 CU.

6. To ensure adequate functioning of the cardiovascular system and for normal adaptation to physical activity in students, it is necessary to form the level of physical activity, quantitatively corresponding to the coefficient of physical activity not lower than 1.75.

References

1. Agadzhanyan NA, Baevsky RM, Berseneva AP. *Problems of adaptation and the doctrine of health*. Moscow. Publishing house RUDN. 2006;281-290. (In Russ).

2. Baevsky RM, Ivanov GG. Heart rate variability: theoretical aspects and clinical application possibilities. *Ultrasound and functional diagnostics*. 2015;2:108. (In Russ).

3. Baevsky RM. Analysis of heart rate variability: history and philosophy, theory and practice. *Clinical Informatics and telemedicine*. 2004;1:54–64. (In Russ).

4. Baevsky RM, Ivanov GG, Chireikin IV. Analysis of heart rate variability in the use of various electrocardiological systems. *Bulletin of Arrhythmology*. 2001;24: 15-20. (In Russ).

5. Bondarev SA. Cloud technologies of ECG registration in the training cycle and prevention of sudden death of an athlete. *Materials of the III All-Russian Scientific and Practical Conference with International Participation*. 2016;24-25. (In Russ).

6. Bondarev SA. Application of cloud technologies for ECG registration for monitoring the cardiac activity of athletes. *Health - the basis of human potential: problems and ways to solve them*. 2016;11(2):517-519. (In Russ).

7. Kulaichev AP. *Methods and means of complex data analysis*. M. 2007;640. (In Russ).

8. Makarov LM, Komolyatova VN, Kiseleva II. Features of ECG in young athletes of the highest sports skill level. *Applied sports science*. 2015;2:108-114. (In Russ).

9. Sudakov KV. Information principle in physiology: analysis from the standpoint of the general theory of functional systems. *Advances in physiological sciences*. 1995;26(4):3-27. (In Russ).

10. Bockeria LA, Golukhova EZ, Ivanitsky AV. *Functional diagnostics in cardiology*. M.: Bakulev them. A. N. After Bakulev RAMS. 2005;700.

11. Golukhova EZ. *Non-invasive Arrhythmology.* M.: Bakulev Them. RAMS. 2002. 200. (In Russ).

12. Akselrod S, Gordon D, Ubel FA. Power spectrum analysis of heart rate fluctuation: A quantitative probe of beat-to-beat cardiovascular control. *Science*. 1999;213:220–222.

13. Algra A, Tijssen JG, Roelandt JR. Contribution of the 24 hour electrocardiogram to the prediction of sudden coronary death. *Br. Heart J*. 2003;70:421–427.

14. Algra A, Tijssen JG, Roelandt JR. Heart rate variability from 24-hour electrocardiography and the 2-year risk for sudden death. *Circulation.* 1998;88(1): 180–185.

15. Barutcu I, Esen AM, Kaya D. Cigarette smoking and heart rate variability: Dynamic influence of parasympathetic and sympathetic maneuvers. *Ann. Noninvasive Electrocardiol.* 2005;10:324–329.

16. Berger RD, Saul JP, Cohen RJ. Assessment of autonomic response by broad-band respiration. *Trans. Biomed. Eng.* 1999;36:1061–1065.

17. Bigger JT, Fleiss JL, Steinman RC. RR variability in healthy, middle-aged persons compared with patients with chronic coronary heart disease or recent acute myocardial infarction. *Circulation.* 1995;91:1936–1943.

18. Bigger JT, Fleiss JL, Kleiger R. The Multicenter Postinfarction Research Group: The relationship among ventricular arrhythmias, left ventricular dysfunction, and mortality in 2 years after myocardial infarction. Ibid. 1984;69: 250-257.

19. Bigger JT, Fleiss JL, Rolnitzky LM. Stability over time of heart period variability in patients with previous myocardial infarction and ventricular arrhythmias. *The CAPS and ESVEM investigators. Am. J. Cardiol.* 1992;69:718–723.

Библиографический список

1. *Агаджанян Н.А., Баевский Р.М., Берсенева А.П.* Проблемы адаптации и учение о здоровье. М.: РУДН, 2006. С. 281-290.

2. *Баевский Р.М., Иванов Г.Г.* Вариабельность сердечного ритма: теоретические аспекты и возможности клинического применения // Ультразвуковая и функциональная диагностика. 2015. № 2. С. 108.

3. *Баевский Р.М.* Анализ вариабельности сердечного ритма: история и философия, теория и практика // Клиническая информатика и телемедицина. 2004. № 1. С. 54–64.

4. *Баевский Р.М., Иванов Г.Г., Чирейкин И.В.* Анализ вариабельности сердечного ритма при использовании различных электрокардиологических систем // Вестник аритмологии. 2001. № 24. С. 15–20.

5. *Бондарев С.А.* Облачные технологии регистрации ЭКГ в тренировочном цикле и профилактике внезапной смерти спортсмена // Материалы III Всероссийской научно-практической конференции с международным участием. 2016. С. 24-25.

6. *Бондарев С.А.* Применение облачных технологий регистрации ЭКГ для контроля сердечной деятельности спортсменов // Здоровье – основа человеческого потенциала: проблемы и пути их решения. 2016. Т. 11. № 2. С. 517–519.

7. *Кулаичев А.П.* Методы и средства комплексного анализа данных. М., 2007. 640 с.

8. *Макаров Л.М., Комолятова В.Н., Киселева И.И.* Особенности ЭКГ у молодых спортсменов уровня высшего спортивного мастерства // Прикладная спортивная наука. 2015. № 2. С. 108–114.

9. *Судаков К.В.* Информационный принцип в физиологии: анализ с позиций общей теории функциональных систем // Успехи физиологических наук. 1995. Т. 26 № 4. С. 3–27.

10. *Бокерия Л.А., Голухова Е.З., Иваницкий А.В.* Функциональная диагностика в кардиологии. М.: НЦССХ им. А.Н. Бакулева РАМН, 2005. С. 700.

11. *Голухова Е.З.* Неинвазивная аритмология. М.: НЦССХ им. А. Н. Бакулева РАМН, 2002. С. 200.

12. *Akselrod S., Gordon D., Ubel F.A.* Power spectrum analysis of heart rate fluctuation: A quantitative probe of beat-to-beat cardiovascular control // Science. 1999. Vol. 213. P. 220–222.

13. *Algra A., Tijssen J.G., Roelandt J.R.* Contribution of the 24 hour electrocardiogram to the prediction of sudden coronary death // Br. Heart J 2003. Vol. 70. P. 421–427.

14. *Algra A., Tijssen J.G., Roelandt J.R.* Heart rate variability from 24-hour electrocardiography and the 2-year risk for sudden death // Circulation. 1998. Vol. 88. № 1. P. 180–185.

15. *Barutcu I., Esen A.M., Kaya D.* Cigarette smoking and heart rate variability: Dynamic influence of parasympathetic and sympathetic maneuvers // Ann. Noninvasive Electrocardiol. 2005. Vol. 10. P. 324–329.

16. *Berger R.D., Saul J.P., Cohen R.J.* Assessment of autonomic response by broad-band respiration // Trans. Biomed. Eng. 1999. Vol. 36. P. 1061–1065.

17. *Bigger J.T., Fleiss J.L., Steinman R.C.* RR variability in healthy, middle-aged persons compared with patients with chronic coronary heart disease or recent acute myocardial infarction // Circulation. 1995. Vol. 91. P. 1936–1943.

18. *Bigger J.T., Fleiss J.L., Kleiger R.* The Multicenter Postinfarction Research Group: The relationship among ventricular arrhythmias, left ventricular dysfunction, and mortality in 2 years after myocardial infarction // Ibid. 1984. Vol. 69. P. 250-257.

19. *Bigger J.T., Fleiss J.L., Rolnitzky L.M.* Stability over time of heart period variability in patients with previous myocardial infarction and ventricular arrhythmias // Cardiol. 1992. Vol. 69. P. 718–723.

Corresponding author: Stepura Evgeny Evgenievich – PhD of Biological Sciences, Associate Professor of the Department of Medical and Biological Disciplines State Educational Institution of Higher Education of the Moscow Region «State Social and Humanitarian University», 140411, Zelenaya str., 30, Kolomna, Russia. E-mail: chimik89@mail.ru

Emelyanova A. S. ORCID: 0000–0002–0622–8626

Simonyan L. A.: ORCID: 0000–0002–5596–294X

Stepura E. E. SPIN: ORCID: 0000–0002–0554–6331

Ответственный за переписку: Степура Евгений Евгеньевич – кандидат биологических наук, доцент кафедры медико-биологических дисциплин Государственное образовательное учреждение высшего образования Московской области «Государственный социально-гуманитарный университет», Россия, 140411, г. Коломна, ул. Зеленая, д. 30. E-mail: chimik89@mail.ru

Емельянова А. С. SPIN: 3024–8527; ORCID: 0000–0002–0622–8626

Симонян Л. А.: SPIN: 3343–9019; ORCID: 0000–0002–5596–294X

Степура Е. Е. SPIN: 2786–1539; ORCID: 0000–0002–0554–6331