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Original Article

Polyfunctional express-evaluation criteria of the sportsman organism state

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Abstract:
After examining 1930 male athletes, which included three consecutive two-minute measurements using the SACR, followed by an analysis of individual components of the spectral power of the heart rate variability (HRV), variability of systolic blood pressure (SBPV) and diastolic blood pressure variability (DBPV), and spontaneous respiration (SR)and controlled respiration (CR) together with designed centennial tables, the ranges of which differ significantly, the spectrum of normative values of heart rate variability indicators, systolic and diastolic blood pressure, breathing at random and controlled respiration were determined. While conducting tests on CR compared with SR, it is found out that CR_6 significantly increases the LF component and reduces the HF component, and CR_{15} slightly affects the LF component and significantly increases the HF component of the spectral respiration power. It is also noted that CR_6 and CR_{15} activate various regulatory links of system hemodynamics: at CR_6: an increase in the LF component of respiration regulation is transferred to the LF component of regulation of HR, SBP and DBP, while the decrease of the HF components of respiratory regulation does not significantly affect -components of HR, SBP and DBP; at CR_{15}: as light increase in the LF components of respiration regulation practically does not affect the LF components of regulation of SBP and DBP and reduces the LF component of regulation of HR, and asignificant increase in the HF components of respiration regulation is transferred to the HF components of regulation of SBP and DBP and practically does not affect on the HF component of the HRV. Thus, the data obtained during testing can be used for the comprehensive evaluation of reactivity and depressor changes in the activity of the sympathetic and parasympathetic ANS units in the regulation of the cardiopulmonary system, which are used to diagnose the functional readiness of an organism in conditions of training and competition processes.
Key words:controlled respiration, heartratevariability, systolicbloodpressure,diastolic blood pressure, athletes.

Introduction.

The most important in the diagnosis of disorders of the regulation of the body's systems is the functional state of the autonomic nervous system (ANS). Today it is well-known that the static and pulse wave velocity characteristics of the heart rate (HR) alone can determine the activity of the sympathetic and parasympathetic channels of regulation, whereas functional tests provide an opportunity to obtain the most important information about the vegetative maintenance and vegetative reactivity (Romanchuk et al.,2006; Guzii, 2017; Romanchuk, 2013, 2019; Noskin et al., 2018). The influence of various tests restructures the regulation forming a new functional state, which is not stable but caused by everyday needs (Vaschillo et al.,2014).

When evaluating the parameters of heart rate variability (HRV) at all stages of the functional tests, it is recommended to take into account not only the average values of parameters, but also the dynamics of their changes. Reducing the LF by increasing HF is a criterion of coming through the test satisfactorily(Nakamura et al.,2016).

Relevant researches propose to use two standard cardiovascular tests (according to D. Ewing, 1985) to assess the status of the cardiopulmonary system, which allow to evaluate the activity of parasympathetic (respiration rate: 6 times per minute) and sympathetic (orthostatic test) regulation circuits(Romanchuk, 2018).

It is believed that a test case with controlled respiration 6 times / min is aimed at detecting violations in the parasympathetic regulatory circuit, since some scholars have found that the effect of respiration extends to oscillations of HR, which are defined as HF oscillations, and is due to general mechanisms of regulation of cardiovascular and respiratory systems (Bazhora, 2018; Herzig,2018,2016).

However, there is no consensus in the interpretation of the results of this test. Analysis of numerous studies suggests the existence of several types of answer: a) "inconsistency or rigidity" on the sympathetic or parasympathetic canal; b) redistribution of balance in the direction of parasympathicotonia by increasing HF

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(Karemaker et al.,2017); c) redistribution of balance in the direction of sympathicotonia with an increase of not only HF, but also LF (Kazmi et al., 2016).

Some researchers have discovered that pathological responses to a controlled-breath test of 6 times / min (CR_6) indicative of autonomic dysfunction are found in 62% of patients with vegetative-vascular dystonia. It is believed that the reaction of HR is determined by hypercapnia (Monfredi et al., 2014), change in pulmonary volumes, functional rearrangement of cardiorespiratory CNS neurons (Iellamo et al., 2000; Flatt et al., 2017). Unfortunately, the available literature data on the use of other tests with controlled breathing, and in particular with CR 12, 15 per minute is not sufficient. However, we can assume that they are the same as the test for CR_6, which are vegetotropic, the nature of which requires clarification.

Materials and methods.

Approaches to the analysis, evaluation and interpretation of indicators of variability of the functions of the cardiovascular system are related to the definition of the spectral power of the variability of functions and involve the calculation of indices in different frequency bands, which, according to many researchers, characterize the activity of regulatory influences of various components of the ANS. In the range of less than 0.04 Hz (ultra-low frequency component): super-segmental effects, in the range from 0.04 to 0.15 Hz (low frequency component): sympathetic effects, in the range from 0.15 to 0.4 Hz (high frequency component): parasympathetic effects (Flatt et al., 2017). Traditionally, these indicators are presented in ms^2 for HRV, in $mmHg^2$ for the variability of the systolic (SBPV) and diastolic (DBPV) blood pressure and in $(l/min)^2$ for the respiratory variability (RV) (Figure 1 – 3).

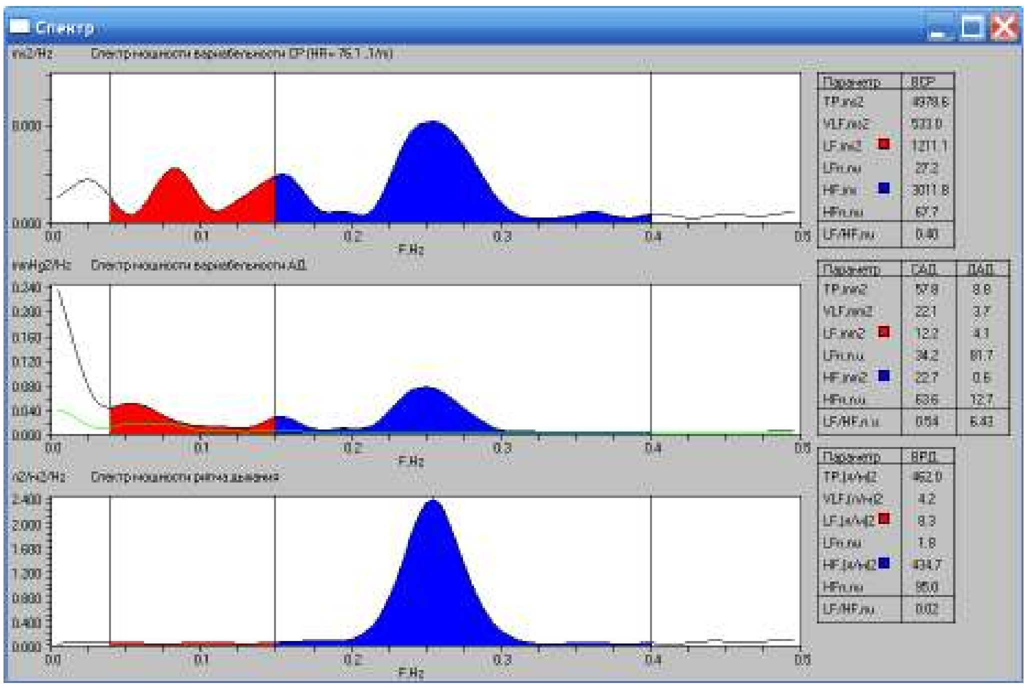

Fig. 1. Graphic representation of spectral capacities of variability of HR, SBP, DBP of athlete K's respiration in a state of rest with spontaneous respiration.

The long-term use of this method revealed a high level of informativeness in evaluating the functional state of the cardiopulmonary relationship system, however, for qualified athletes, an obligatory condition is the inclusion of respiration rate (RR) (Guzii,2017), which significantly influences the spectral power of the variability of the cardiovascular system functions. As an example, we will show the differences in the spectra of the Fourier transform of the studied functions of the same athlete at spontaneous respiration (Figure 1), controlled respiration with a frequency of 6 times per minute (Figure 2) and 15 times per minute (Figure 3) (further: CR_6 and CR_{15}, respectively. In earlier studies, we have shown that an inversely proportional relationship between the RR and the indices of HRV and SBPV is detected, and HRV, SBPV and DBPV are stabilized within the range of 6 to 10 breaths per minute at RR 15 / min. (Romanchuk, 2005).

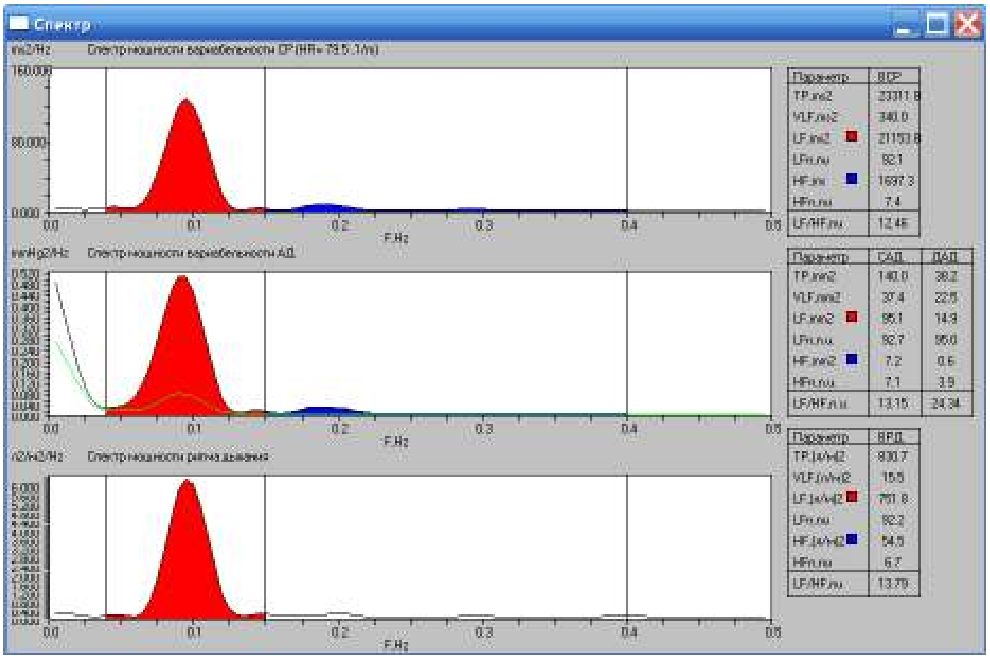

Fig. 2. Graphic representation of spectral capacities of variability of HR, SBP, DBP of athlete K's respiration in a state of rest at CR_6.

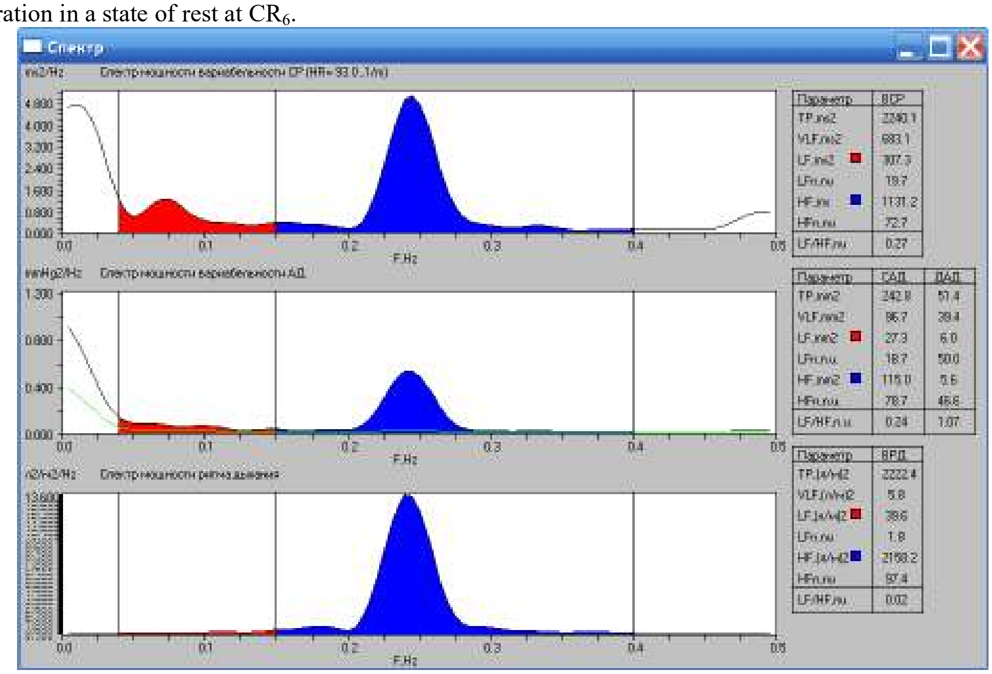

Fig. 3. Graphic representation of spectral capacities of variability of HR, SBP, DBP of athlete K's respiration in a state of rest at CR_{15}.

Even the superficial review of Fig. 1-3 reveals that the effect of CR_6 and CR_{15}on the variability of cardiovascular functions is significantly different. At CR_6 the LF component predominates while an HF component prevails at CR_{15}.

It was this circumstance that prompted us to elaborate a protocol of inspection, which included three consecutive two-minutes measurements using the SACR, followed by an analysis of individual components of the spectral power of HRV, SBPV and DBPV, as well as spontaneous and controlled respiration according to the designed percentile tables(Guzii, 2018), the ranges of which are significantly different.

The purpose of the present study was to develop criteria for multifunctional express-evaluation for the diagnosis of the body of athletes.

According to the proposed protocol using spiroarteriocardiorhytmography (SACR) (Pivovarov, 2006), 1930 skilled male athletes under the age of 22 ± 1.3 years were examined.

Results.

A conceptual approach to developing criteria for assessing the functional state of an athlete's body was the choice of percentile method for analyzing the results. The latter allows to level the type of distribution of indicators in the sample and operate with the relative qualitative characteristics of individual parameters, which allows enough to fully describe the individual variations in the changes of all simultaneously obtained with the use of SACR indicators of cardiovascular and respiratory systems. In this case, we used an approach that allows for the allocation of 5 informative zones of percentile distribution of indices.

The zone of normative (or optimal) values is within the limits of 25-75%, the zone of moderate increase of the indicators is within the range of 75-95%, the zone of moderate decrease is within 5-25%, the zone of the expressed increase is within the range of 95-100%, and the zone of expressed decrease is within 0-5%. That is, when taking into account the simultaneous measurement of the performance of a specific athlete, we get the opportunity to qualitatively evaluate both a ratio of individual indicators of one function and indices of different functions, such as heart rate variability and respiratory variability, or blood pressure. On the other hand, the simultaneous study of the indicators of various functions reduces the error in determining their connections almost 600 times, which has not only a significant applied value, but can also be used for the physiological and pathophysiological substantiation of the results obtained in the future. It is also possible to define new parameters of cardio-respiratory synchronization (Noskin, 2018).

Analyzing the results of the testing the athletes using SACR at rest and during controlled respiration, we have shown that the TP, which characterizes the overall power of HRV and reflects the general state of the regulatory function of the ANS (Lee et al.,2012), testifies to the substantial expansion at rest and increase of the median range in the qualified athletes in comparison with the population. The latter characterizes the peculiarities of the reorganization of the vegetative provision of cardiac activity during intensive sports, as well as the increase of its functional reserve. On the above Fig. 1-3, the modulating influence of the CR on the spectral characteristics of the HF is clearly visualized, which, in turn, is reflected in the distribution of the parameters of the total power of the spectrum. Thus, there is a marked activation of regulatory influences on HR at CR_6, and the median zone of centigrade distribution shifts substantially, significantly increasing the absolute values. At the same time, a slight decrease in this indicator is noted at CR_{15} (Table 1).

Table 1

Percentile distribution of HRV parameters of the athletes at spontaneous and controlled respiration

ParametersHRV	RR	<5	5-25	25-75	75-95	>95
TP,ms^2	SR	**<1017.6**	**1017.6-2450.3**	**2450.4-7225.0**	**7226.1-15700.1**	**>15700.1**
	CR_6	<3733.2	3733.2-9564.8	9564.9-20398.1	20398.2-31293.6	>31293.6
	CR_{15}	<795.2	795.2-1874.9	1875.0-5852.3	5852.4-11406.2	>11406.2
VLF, ms^2	SR	**<77.4**	**77.4-207.4**	**207.5-812.3**	**812.4-2152.9**	**>2152.9**
	CR_6	<193.2	193.2-424.4	424.5-1108.9	1109.0-2631.7	>2631.7
	CR_{15}	<130.0	130.0-316.8	316.9-961.0	961.1-3283.3	>3283.3
LF, ms^2	SR	**<201.6**	**201.6-552.3**	**552.4-2116.0**	**2116.1-7885.4**	**>7885.4**
	CR_6	<2631.7	2631.7-7259.0	7259.1-17004.2	17004.3-24617.6	>24617.6
	CR_{15}	<118.8	118.8-282.2	282.3-876.2	876.3-1764.0	>1764.0
HF, ms^2	SR	**<265.7**	**265.7-835.2**	**835.3-3481.0**	**3481.1-7551.6**	**>7551.6**
	CR_6	<278.9	278.9-691.7	691.8-3036.0	3036.1-6178.0	>6178.0
	CR_{15}	<201.6	201.6-655.4	655.5-3469.2	3469.3-9643.2	>9643.2
LF/HF,ms^2/ms^2	SR	**<0.13**	**0.13-0.37**	**0.38-1.47**	**1.48-5.53**	**>5.53**
	CR_6	<2.28	2.28 - 4.20	4.21 - 12.60	12.61 - 26.53	>26.53
	CR_{15}	<0.13	0.13 - 0.20	0.21 - 0.73	0.74 - 1.45	>1.45

Analyzing changes in other HRV parameters, it should be noted that super-segmental component of the HRV is the least variable, which is most pronounced in the CR_6 within the median values of the centenary distribution, the least being at spontaneous respiration, however, it is insignificant. This tendency is observed in all defined centenary ranges. The least exposed to the CR is the high-frequency (HF) HRV component, which is sufficiently stable for all tests of the inspection protocol.

The most varied spectral characteristic of HRV is the low-frequency component (LF), which significantly increases at CR_6, while at CR_{15} it is moderately reduced in all centenary spectrums. Accordingly, the ratio of these indicators (LF / HF) (which is calculated in the traditional form for CR_6) increases significantly, and as for CR_{15}, it decreases moderately and, at the same time, significantly.

Indicators of TP_{SBP} and TP_{DBP} characterize the total power of the spectrum of variability of SBP and DBP, respectively (Table 2 and 3). These indicators reflect the interaction of various regulatory processes, including the autonomic nervous system in the provision of blood pressure. The TP_{SBP} indicator is more related to the variability of the pumping function of the heart, which provides the value of SBP, and the TP_{DBP} index is connected with the regulation and substitution of vascular tone, its stiffness, providing the value of DBP. Indicative are the changes of TP_{SBP} and TP_{DBP} at CR.

Table 2

Percentile distribution of SBPV parameters of the athletes at spontaneous and controlled respiration

ParametersSBPV	RR	<5	5-25	25-75	75-95	>95
TP_{SBP},mmHg^2	SR	**<2.9**	**2.9-6.2**	**6.3-25.0**	**25.1-70.6**	**>70.6**
	CR_6	<7.3	7.3-16.0	16.1-54.7	54.8-130.0	>130.0
	CR_{15}	<13.0	13.0-25.0	25.1-79.2	79.3-252.8	>252.8
VLF_{SBP}, mmHg^2	SR	**<0.5**	**0.5-1.4**	**1.5-6.7**	**6.8-26.0**	**>26.0**
	CR_6	<1.2	1.2-2.5	2.6-15.2	15.3-46.2	>46.2
	CR_{15}	<2.0	2.0-5.7	5.8 -34.8	34.9-88.4	>88.4
LF_{SBP}, mmHg^2	SR	**<0.8**	**0.8-2.2**	**2.3-9.6**	**9.7-28.1**	**>28.1**
	CR_6	<2.9	2.9-9.6	9.7-33.6	33.7-88.4	>88.4
	CR_{15}	<1.7	1.7-3.2	3.3-13.0	13.1-43.6	>43.6
HF_{SBP}, mmHg^2	SR	**<0.8**	**0.8-2.0**	**2.1-6.7**	**6.8-20.3**	**>20.3**
	CR_6	<0.6	0.6-1.4	1.5-4.8	4.9-14.4	>14.4
	CR_{15}	<2.6	2.6-7.8	7.9-37.2	37.3-112.4	>112.4
LF/HF_{SBP}, mmHg^2/ mmHg^2	SR	**<0.31**	**0.31-0.75**	**0.76-2.27**	**2.28-6.05**	**>6.05**
	CR_6	<1.59	1.59-3.85	3.86-11.72	11.73-22.00	>22.00
	CR_{15}	<0.10	0.10-0.17	0.18-0.68	0.69-2.78	>2.78

In comparison with spontaneous respiration, TP_{DBP} significantly increases at CR_6 (Table 3), whereas TP_{SP} does at CR_{15} (Table 2). At the same time, a more careful analysis of SBP changes in the respiration phases allowed us to show that the variability of the SBP increases due to its more pronounced decrease during inhalation.

Table 3

Percentile distribution of DBPV parameters of the athletes at spontaneous and controlled respiration

ParametersDBPV	RR	<5	5-25	25-75	75-95	>95
TP_{DBP},mmHg^2	SR	**<1.4**	**1.4-3.2**	**3.3-12.2**	**12.3-31.4**	**>31.4**
	CR_6	<7.3	7.3-13.7	13.8-33.6	33.7-68.9	>68.9
	CR_{15}	<3.2	3.2-7.8	7.9-24.0	24.1-65.6	>65.6
VLF_{DBP}, mmHg^2	SR	**<0.4**	**0.4-1.0**	**1.1-4.8**	**4.9-16.8**	**>16.8**
	CR_6	<1.2	1.2-2.0	2.1-6.7	6.8-16.8	>16.8
	CR_{15}	<1.2	1.2-3.2	3.3-9.6	9.7-38.4	>38.4
LF_{DBP}, mmHg^2	SR	**<0.4**	**0.4-1.0**	**1.1-4.4**	**4.5-13.0**	**>13.0**
	CR_6	<3.6	3.6-8.4	8.5-23.0	23.1-44.9	>44.9
	CR_{15}	<0.6	0.6-1.6	1.7-5.7	5.8-12.3	>12.3
HF_{DBP}, mmHg^2	SR	**<0.3**	**0.3-0.6**	**0.7-2.0**	**2.1-6.3**	**>6.3**
	CR_6	<0.6	0.6-1.0	1.2-2.9	3.0-7.8	>7.8
	CR_{15}	<0.5	0.5-1.4	1.5-6.2	6.3-18.5	>18.5
LF/HF_{DBP}, mmHg^2/ mmHg^2	SR	**<0.44**	**0.44-1.09**	**1.10-3.29**	**3.30-7.59**	**>7.59**
	CR_6	<1.77	1.77-4.66	4.67- 12.52	12.53- 23.18	>23.18
	CR_{15}	<0.21	0.21 - 0.55	0.56 - 1.81	1.82 - 4.71	>4.71

In the same way, the low-frequency (VLF_{SBP}) component of the variability of SBP (Table 2) changes in the TP_{SBP}, which allows to relate the increase of TP_{SBP} at CR_{15} to super-segmental effects on the pumping function of the heart. Similar changes take place during very low frequency (VLF_{DBP}) effects on DBP (Table 3).

Table 4

Percentile distribution of RV parameters young people at spontaneous and controlled respiration

ParametersRV	RR	<5	5-25	25-75	75-95	>95
TP_R, (l/min)^2	SR	<96.0	96.0-289.0	290.0-635.0	635.1-1108.9	>1108.9
	CR_6	<231.0	231.0-432.6	432.7- 1024.0	1024.1-2410.8	>2410.8
	CR_{15}	<228.0	228.0-566.4	566.5-3036.0	3036.1-8574.8	>8574.8
VLF_R, (l/min)^2	SR	<0.5	0.5-1.2	1.3-4.8	4.9-13.7	>13.7
	CR_6	<2.6	2.6-4.8	4.9-14.4	14.5-30.3	>30.3
	CR_{15}	<1.4	1.4-2.5	2.6-13.7	13.8-32.5	>32.5
LF_R, (l/min)^2	SR	<2.6	2.6-7.8	7.9-33.6	33.7-219.0	>219.0
	CR_6	<158.8	158.8-334.9	335.0-761.7	761.8-1608.0	>1608.0
	CR_{15}	<6.8	6.8-12.2	12.3-50.4	50.5-153.8	>153.8
HF_R, (l/min)^2	SR	<57.8	57.8-207.3	207.4-547.5	547.6-912.0	>912.0
	CR_6	<37.2	37.2-62.4	62.5-204.5	204.6-630.0	>630.0
	CR_{15}	<207.4	207.4-552.2	552.3-2926.8	2926.9-8136.0	>8136.0
$LFHF_R$, (l/min)^2/ (l/min)^2	SR	<0.013	0.013-0.024	0.025-0.150	0.151-1.245	>1.245
	CR_6	<1.393	1.393-2.527	2.528-7.208	7.209-10.726	>10.726
	CR_{15}	<0.011	0.011-0.015	0.016-0.027	0.028-0.049	>0.049

Analyzing the parameters of respiration (Table 4) when performing tests on CR compared with spontaneous respiration it should be noted that CR_6 significantly increases the LF component and reduces the HF component, and CR_{15} slightly affects the LF component and significantly increases the HF component of the spectral breathing power.

Discussion of the findings.

While combining evaluation of HRV according to the data of our study protocol, we can objectivize the reactivity and depression of sympathetic effects, taking into account TP transitions between different centripetal ranges. For example, in the transition from the median range (25-75%) to the range of elevated centile (75-95%), when performing the test on CR_6, it is possible to state the increased reactivity of the sympathetic HR regulating circuit, and when it passes to the same range when performing the test with CR_{15} it is possible to spot the lack of depression of sympathetic effects, etc.

In general, the effect of the CR_6 and CR_{15} on the HRV is significantly different due to the activating and depressor effects of the CR_6 and CR_{15} on the LF component, respectively, which is reflected in the TP and LF / HF ratios. In this case, the VLF and HF components are practically unchanged.

Significant differences are observed in the analysis of low-frequency (LF_{SBP} and LF_{DBP}) and high-frequency (HF_{SBP} and HF_{DBP}) components of regulation of blood pressure. Expected is a significant increase in LF_{SBP} and LF_{DBP} at CR_6 and HF_{SBP} and HF_{DBP} at CR_{15}. This reveals that in the first case, the sympathetic mechanisms of regulation are strongly activated, and in the second case, they remain intact. The HF component of regulation of SBP and DBP at CR_6 varies slightly, while at CR_{15} there is an effect on both the regulation of the pumping function of the heart and the vascular tone. That is, it can be assumed that CR_{15} activates the vagotonic mechanisms of regulation of the latter, which are more often associated with HF effects.

Thus, the survey in the proposed protocol with the assessment of the developed percentile tables will allow to determine the level of activation of general (TP), super-segmental (VLF), sympathetic (LF) and parasympathetic (HF) influences on SBP and DBP in comparison with the expected, which substantially activates the state of autonomous regulation of the system of blood pressure maintenance.

Investigating the parameters of the variability of the functions of the cardiopulmonary system, which are known to characterize the mechanisms of vegetative provision, we previously obtained the results that indicate the effect of frequency-volume characteristics of respiration on the variability of the function of HR and blood pressure, which change because of muscle activity, corresponding signals from the environment, emotional state, etc (Javorka et al,2002;Saboul,2013).

Particularly relevant from these positions is the fact that the change in the mechanism of respiration regulation can lead to various variations in homeostasis, associated with the change of metabolic and metabolic and acid-base balance of the organism (Nuuttila et al, 2017), or be a consequence of the latter.

Conclusion.

In general, it can be pointed out that CR_6 and CR_{15} activate various regulatory links of system hemodynamics: at CR_6: an increase in the LF component of respiration regulation is transferred to the LF component of regulation of HR, SBP and DBP, while the decrease of the HF components of respiratory regulation does not significantly affect the HF-components of HR, SBP and DBP; at CR_{15}: a slight increase in the LF components of respiration regulation practically does not affect the LF components of regulation of SBP and DBP and reduces the LF component of regulation of HR, and a significant increase in the HF components of respiration regulation is transferred to the HF components of regulation of SBP and DBP and practically does not affect on the HF component of the HRV.

Thus, in view of the simplicity and rapid testing, the obtained data can be used for the comprehensive evaluation of reactivity and depressor changes in the activity of the sympathetic and parasympathetic ANS units in the regulation of the cardiopulmonary system, which are used to diagnose the functional readiness of an organism in conditions of training and competition processes.

Conflicts of interest

Authors have declared that no competing interests exist.

References

Romanchuk, A.P., Ovcharek,A.M., Braslavsky, I.A.(2006). [Vegetative maintenance of cardiorespiration system of athletes of different specializations].*Theory and practice of physical culture*, 7, 48–50.

Guzii, O. V., Romanchuk, A. P. (2017). Multifunctional determinants of athletes' health. *J. Medicine and Health Research*, 2(1), 12–21.

Romanchuk, A.P. (2013). Estimation of cardiovascular system reactance of sportsmen at use of tests with controlled respiration.*Journal Of Health Sciences (J Of H Ss)*, 3(4), 335–344.

Romanchuk, A.P.,Guzii, O.V. (2019). Features of the Blood Pressure Variability of Athletes with Different Levels of Functional State of the Body.*J Educ Health Sport*.,9(3),11–20. doi:10.5281/zenodo.2582406

Noskin, L.A., Rubinskiy A.V., Romanchuk A.P., Marchenko, V.N., Pivovarov, V.V., Cherepov, A.B., Zarovkina, L.A.(2018). Study of cardiovascular and respiratory synchronization in different types of breathing]. *Patogenez [Pathogenesis],* 16(4), 90-96 (in Russian). DOI: 10.25557/2310-0435.2018.04.90-96

Vaschillo, E.G., Fonoberova, M., Mezic, I., Buckman, J. F., Fonoberov, V., Mezic, A.J., Vaschillo, B., Bates, M.E. (2014). A Computational Physiology Approach to Personalized Treatment Models: The Beneficial Effects of Slow Breathing on the Human Cardiovascular System. *AJP Heart and Circulatory Physiology,* 307(7), 1073–1091. DOI: 10.1152/ajpheart.01011.2013

Nakamura, F. Y., Pereira, L. A., Rabelo, F. N., Flatt, A. A., Esco, M. R., Bertollo, M., et al. (2016). Monitoring weekly heart rate variability in futsal players during the preseason: the importance of maintaining high vagal activity. *J. Sports Sci*., 34, 2262–2268.doi:10.1080/02640414.2016.1186282

Romanchuk, A.P.,Guzii, O.V.(2018). Respiration variability of athletes after competition load.*Rev Bras Med Esporte.*, 24(5 Suppl.1),78.

Bazhora, Y.I., Romanchuk, O.P. (2018).Variabelnist ta pattern dykhanniapatsiientiv z persystuiuchymperebihombronkhialnoiastmy ta ozhyrinniam [Variability and Respiration Pattern of Patients with Persistent Asthma and Obesity] *Ukr. ž. med. bìol. sportu*, 3(7), 74–83.doi: 10.26693/jmbs03.07.074

Herzig, D.,Asatryan, B., Brugger, N., Eser, P., Wilhelm, M. (2018).The Association Between Endurance Training and Heart Rate Variability: The Confounding Role of Heart Rate. *Front. Physiol.*, 19(9),756. doi: 10.3389/fphys.2018.00756

Herzig, D., Testorelli, M., Olstad, D. S., Erlacher, D., Achermann, P., Eser, P., et al. (2016). Heart rate variability during deep sleep offers a time-efficient alternative to morning supine measurements - a study in world class alpine skiers. *Int. J. Sports Physiol. Perform*., 12, 1–22.

Karemaker, John M., DeBoer, Roel W. (2017). Vagal baroreflex latency in circulatory control. Comment to: Eckberg et al: Respiratory modulation of human autonomic function on Earth. *J Physiol,* 594(19), 5611-5627.

Kazmi, S. Z., Zhang, H., Aziz, W., Monfredi, O., Abbas, S. A., Shah, S. A., et al. (2016). Inverse correlation between heart rate variability and heart rate demonstrated by linear and nonlinear analysis. *PLoS One*,11(6):e0157557. doi: 10.1371/journal.pone.0157557.

Monfredi, O., Lyashkov, A. E., Johnsen, A. B., Inada, S., Schneider, H., Wang, R., et al. (2014). Biophysical characterization of the underappreciated and important relationship between heart rate variability and heart rate. *Hypertension*,64, 1334–1343. doi: 10.1161/HYPERTENSIOAHA.14.03782.

Iellamo, F., Legramante, J.M., Massaro, M., Raimondi, G., Galante, A.(2000). Effects of a Residential Exercise Training on Baroreflex Sensitivity and Heart Rate Variability in Patients With Coronary Artery Disease. *Circulation,* 102,2588-2592.

Flatt, A.A.,Esco, M.R., Allen, J.R., Robinson, J.B.,Earley, R.L., Fedewa, M.V., Bragg, A., Keith, C.M.,Wingo, J.E. (2017). Heart rate variability and training load among national collegiate athletic association division 1 collegefootball players throughout spring camp. *J. Strength. Cond. Res.,* 32, 3127–3134.

Flatt, A.A.,Hornikel, B.,Esco, M.R. (2017). Heart rate variability and psychometric responses to overload and tapering in collegiate sprint-swimmers. *J. Sci. Med. Sport,* 20, 606–610.

Guzii, O.V., Romanchuk, A.P.(2017). Heart rate variability during controlled respiration after endurance training. *Journal of Physical Education and Sport,* 30, 2024 – 2029. DOI:10.7752/jpes.2017.03203

Romanchuk, O.P. (2005). Do pytanniaotsinkyaktyvnostivehetatyvnoinervovoisystemy u sportsmeniv [To a question of an estimation of activity of autonomic nervous system at sportsmen].*Medical rehabilitation, balneology, physiotherapy*], 4, 31–34.

Guzii, O.V., Romanchuk, A.P. (2018). Determinants of the functional state of sportsmen using heart rate variability measurements in tests with controlled respiration.*Journal of Physical Education and Sport,*18(2), 715 – 724.

Pivovarov, V. V. (2006). Spiroarteriocardiorytmograf. Med. Tekh, 1, 38–41.

Lee,C.M., Mendoza, A. (2012). Dissociation of heart rate variability and heart rate recovery in well-trained athletes. *Eur J ApplPhysiol*, 112, 2757–2766. DOI 10.1007/s00421-011-2258-8

Javorka, M., Zila, I., Balharek, T., Javorka, K. (2002) Heart rate recovery after exercise: relations to heart rate variability and complexity.*Braz J Med Biol Res,* 35,991-1000.

Saboul, D., Pialoux, V., Hautier, C. (2013). The impact of breathing on HRV measurements: implications for the longitudinal follow-up of athletes. *Eur. J. Sport Sci*., 13, 534–542. doi10.1080/17461391.2013.767947.

Nuuttila, O.-P., Nikander, A., Polomoshnov, D., Laukkanen, J. A., Häkkinen, K. (2017). Effects of HRV-guided vs. predetermined block training on performance, HRV and serum hormones. *Int. J. Sports Med.* 38, 909–920. doi10.1055/s-0043-115122.