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MULTIFUNCTIONAL DETERMINANTS OF ATHLETES' HEALTH

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AUTHORS' CONTRIBUTIONS
This work was carried out in collaboration between both authors. Author APR determined the line of the study and organized it. Author OVG conducted the study, performed the statistical analysis of the study results. Both authors read and approved the final manuscript.

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ABSTRACT

Aim: The aim of the study was to determine the multifunctional criteria of athletes' health.

Materials and Methods: 58 males aged 20.6±0.9, engaged in various sports, were surveyed. A medical examination took place in the morning hours, fasting and included measurement of parameters of physical development, registration of performance of the cardio respiratory system using Spiroarteriocardiorhythmograph (SACR) and Martinet functional tests. A nonparametric statistical method of determining the likelihood criterion by Mann-Whitney was used for the analysis of intergroup differences.

Results and Discussion: The analysis of multifunctional parameters of athletes from the first (EG_1) with "high" (n=39) and from the second examined group (EG_2) with "low" health levels (n=19) was carried out according to Apanasenko system. It revealed that the rate of total power (TP, ms^2) of heart rate variability (HRV) spectrum, indicating the overall adaptive capacity in the regulation of heart is credibly higher in EG_1 than in EG_2 ($p<0.05$). There have been credible differences ($p<0.05$) in the TP_{DBP} (total power of diastolic blood pressure) rate in EG_1 compared to EG_2, which characterize random breath economization, despite the fact that in terms of tidal volume (TV) (l), respiratory rate (RR) (1/min) and respiratory minute volume (RMV) (l/min) no credible differences between the groups were observed. Credibly different ($p<0.05$) is also an indicator of cardiac output (CO, l), revealing a more economical functioning of the cardiovascular system in people with a high level of health. The analysis of cardiointervals complex (PQRST) showed that the typical criteria of a high level of health is significantly lower values of QR (s), QRS (s) and QTs (s) and their increase may indicate a deterioration of health.

Conclusion: The results allowed to characterize and supplement data about the health of athletes that can be used as criteria for determining health level at screening examination.

Keywords: Health; heart rate variability; systolic and diastolic blood pressure variability; breathing pattern; variability of random breath; athletes.

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1. INTRODUCTION

The problem of early diagnosis of changes in the health of athletes faces with the need for complex multicenter examining applying modern methods of diagnosis, the use of which is possible only in multidisciplinary sports medicine centers, which cannot always be implemented in terms of the training process. However, the impact of physical activity can often lead to the development of adverse effects associated with the development of pre-pathological and pathological conditions of the cardiovascular, respiratory and nervous systems [1]. This is explained by the peculiarities of sports activities that require excessive strain of body systems, which contributes to the achievement of sports results. Mobilizing these systems involves their rigid interaction, which helps ensure the optimal level of body functioning during sports activities. It presupposes a search for function criteria of the functioning of various systems of the body, on the basis of which it would be possible to early determine changes in health that would require the reduction or suspension of training loads and additional examination of an athlete in the centers for sports medicine [2].

Our attention attracted a method of rapid assessment of the level of physical health (physical health assessment – PHA) proposed by G. L. Apanasenko, which is based on the definition of health based on the calculation and estimation of indices of physical development, as well as tolerance to physical loads [3].

G. L. Apanasenko's students found it sufficiently useful while applying it in the examination of industrial workers [4,5], individuals with various degrees of risk of coronary heart disease [6], and students relating to basic medical health group [7]. Indeed, M. V. Morozov [4] demonstrated the PHA reveals the value of reserve capacity of physiological functions of the cardio respiratory system, its adaptive capacity and degree of economization of functions at rest and during exercise dosage; and PHA reducing is accompanied by increased likelihood of chronic diseases in the body of the circulatory, respiratory and endocrine systems. While studying the evaluation system of PHA in comparison with other methods of health system assessment N. I. Sokolova [8] indicated that it is the best of the existing and developed on its basis a comprehensive system of preventive physical rehabilitation. Other scholars have shown that the PHA can be used in prevention examinations as an alternative to veloergometry test [6]. Feasibility of PHA method at testing the functional state of athletes and their physical rehabilitation are mentioned in publications by S. S. Lyuhaylo [9]. Dynamics of changes in the PHA and its components in the training process aimed at developing common and strength endurance were also discussed in our previous publications [10,11].

Today there are a number of express screening methods of body examining, the use of which is possible in the training process. Practically, the most common are express methods, which during the test allow to give as much information about the functional state of an athlete as possible [3]. Therefore, our attention was attracted by Spiroarteriocardiorhythmograph (SACR) method, which allows to simultaneously examine and describe the function of the cardiovascular and respiratory systems, their interactions and autonomic regulation [12].

2. MATERIALS AND METHODS

58 physically fit males aged 20.6 ± 0.9 engaged in various sports and with no acute and chronic diseases were examined. A medical examination took place in the morning hours, fasting and included measurement of parameters of physical development, registration of performance of the cardio respiratory system using SACR and Martinet functional tests. The indices calculations were based on the result of performed measurements (body mass (BMI), force index (FI), index by Robinson), recovery time after standard load defined as well as PHA estimated [13].

The measurement of physical development such as length (cm) and weight (kg), vital capacity (VC, ml), the contours of the chest (cm), abdomen (cm), shoulder (cm), forearm (cm), hip (cm), crurae (cm), dynamometry of wrists (kg) was performed on the basis of common methods. Body fat percentage (BFP, %) [13].

The research of cardio respiratory system was conducted using SACR [12] and was to determine heart rate variability (HRV) - TP (ms^2), VLF (ms^2), LF (ms^2), HF (ms^2), LF / HF; systolic (SBP) and diastolic (DBP) blood pressure variability – TP_{SBP} (mm Hg^2), VLF_{SBP} (mm Hg^2), LF_{SBP} (mm Hg^2), HF_{SBP} (mm Hg^2), LF_{SBP}/HF_{SBP}, TP_{DBP} (mm Hg^2), VLF_{DBP} (mm Hg^2), LF_{DBP} (mm Hg^2), HF_{DBP} (mm Hg^2), LF/HF; breathing pattern – the inspiration (ID) (sec) and expiration (sec) durations, tidal volume (Vt, l.), the speed of inspiration (IVS, l/s) and expiration (EVS, l/s) volumes, respiratory rate (RR,1/min), respiratory minute volume (RMV, l/min); variability of random breath (RBV) – TP_R (l/min)^2, VLF_R (l/min)^2, LF_R (l/min)^2, HF_R (l/min)^2, LF/HF. The baroreflex sensitivity (BR) in the low- (BR_{LF}, ms/mm Hg) and high- frequency (BR_{HF}, ms/mm Hg) ranges were measured on the basis of these figures. The SACR data were also used to determine the central hemodynamic parameters: end-diastolic volume (EDV, cm^3), end-systolic volume (ESV, cm^3), stroke volume (SV, cm^3), cardiac output (CO, l), general (GPVR, dyn×s×cm^{-5}) peripheral vascular resistance, systolic output index (SOI ml/m^2) and cardiac index (CI min^{-1}/m^2).

3. RESULTS AND DISCUSSION

Regarding the PHA by G. L. Apanasenko it should be noted that it is distributed as follows: "high" and above average – 39 athletes; below average and "low" – 19 athletes (experimental group 1 (EG_1) and experimental group 2 (EG_2)).

The average age of athletes from EG_1 was 20.6 ± 0.8 years and from EG_2 – 20.2±0.5 years. The Mann-Whitney U test for nonparametric statistics in determining the criterion of significance was used for the analysis of intergroup differences.

Analyzing the data on the structure of the body of people with the "high" level of PHA, first of all, we must examine the differences related to weight and body composition component (Table 1). Indeed, EG_1 weight is significantly lower p <0.05) than in EG_2.

However, in terms of BMI, which is an integral characteristic of body weight, no probable differences are registered in EG_1. Significant differences ($p < 0.05$) are observed regarding RBF (%), attesting to fat reduction of the body in the "high" PHA. These data results are further proved by measuring contours limbs, probable differences between which are set only for hip circumference, which is smaller in EG_1 ($p < 0.05$) as compared with EG_2. Measuring the contours of the trunk (chest and abdomen) pointed at significantly lower values of the latter in EG_1 ($p < 0.05$). As for the abdominal circumference it can be explained by lower fat content. Expected were the indexes of probable differences belonging to PHA system, such as greater force index (FI, %) in EG_1 ($p < 0.05$), and higher VI (ml/kg) compared with EG_2 ($p < 0.05$).

People with the high PHA are characterized by a strong physique as evidenced by significantly lower BMI, fat content, belly and thighs contours compared with EG_2 amid rather constant other parameters of physical development (BMI, neck contours, carpal dynamometry).

Measurement of HR and DBP applying Martinet routine methods of test revealed that people with the "high" PHA are probably ($p < 0.05$) different from EG_2, and regarding HR at rest and BP (Table 2).

That is, according to the data of the study of the cardiovascular system applying the routine methods of Martinet testing, people with the "high" PHA differ significantly from others regarding HR, the measurement results of which are taken into account in the calculation of PHA level as Robinson index (double product).

Table 1. Characteristics of physical development parameters of studied groups

Parameter	EG_1	EG_2
weight, kg	71.0 (69.0; 78.0)*	77.0 (72.0; 80.0)
length, cm	178.0 (175.0; 181.0)	180.0 (175.0; 182.0)
BMI, kg /m^2	22.7 (21.6; 23.7)*	23.5 (22.5; 24.2)
contours abdomen, cm	78.0 (77.0; 81.0)*	81.0 (78.0; 84)
contours chest (pause), cm	96.0 (93.0; 99.0)*	98.0 (95.0; 102)
contours shoulder (p.), cm	30.0 (28.5; 32.0)	30.0 (29.0; 32.0)
contours shoulder (t.), cm	33.0 (32.0; 35.0)	33.0 (32.0; 36.0)
contours forearm, cm	28.0 (26.5; 28.5)	28.0 (27.0; 29.0)
contours hip, cm	52.0 (50.0; 56.0)*	55.0 (53.0; 57.0)
contours crurae, cm	36.0 (35.0; 38.0)	37.0 (35.0; 39.0)
dynamometry of wrists r., kg	50.0 (46.0; 54.0)	48.0 (42.0; 52.0)
dynamometry of wrists l.,kg	46.0 (42.0; 50.0)	48.0 (42.0, 49.0)
FI, %	70.4 (65.6; 77.9)*	60.5 (57.6; 67.5)
VC, ml	4900 (4550; 5500)	4900 (4300; 5500)
VI ml/kg	68.5 (64.3; 72.8)*	63.3 (56.9; 71.8)
RBF, %	11.3 (9.7; 14.5)*	14.1 (11.3; 16.6)

** - p <0.05*

Table 2. Characteristics of measurement results of the cardiovascular system of studied groups using routine methods

Parameter	EG_1	EG_2
HR (at rest), min^{-1}	60 (60; 72) *	66 (60; 78)
SBP, mmHg	110 (110; 120)	120 (110; 130)
DBP, mmHg	60 (60; 70) *	70 (70; 80)
SBP mean, mmHg	85.2 (81.0; 91.0) *	92.6 (86.8; 96.8)
Δ HR reference, %	58.3 (44.4; 75.0)	63.6 (42.9; 80.0)
Δ SBP reference, %	18,2 (9.1; 23.1) *	23.1 (16.7; 27.3)
Δ DBP reference, %	-14.3 (-16.7; 0)	-14.3 (-25.0; -12.5)

**- p <0.05*

Analyzing SACR data, let us start with PQRST parameters (Table 3), the results of the analysis of which usually allow to determine the conductivity of different parts of the heart muscle. Of a special attention are the dissimilarities in heart rate at rest, which in EG_1 are credibly different from EG_2 ($p < 0.05$); however, as mentioned earlier, this parameter is taken into account in the calculation of the PHA, which certainly determines these differences. Rather informative seem differences in indices of depolarization (QR, $p < 0.05$), conduction (QRS, $p < 0.05$) of ventricular and standardized length values of electrical systole of the heart (QTs, $p < 0.05$), which is credibly lower in EG_1 than in EG_2 despite lower HR associated with higher inter-beat (RR) interval. Prolong QTs is known to be considered as a criterion for susceptibility to sudden death, although in EG_2 it does not reach the upper limit of appropriate values for men. At the same time, atrial conduction values do not differ in any of the groups. Also, the group do not differ radically in terms of the value indicating ventricular repolarization (ST), which provides adequate recovery of myocardium after reduction.

Table 4 shows the results of analysis of HRV indices that are associated with different levels of vegetative support of the heart [14]. Value of total power (TP, ms^2) of HRV spectrum indicates the overall adaptive capacity of the heart regulation, which defines functional reserve of adaptive responses of the heart muscle and body as a whole. This value is significantly higher in EG_1 than in EG_2. On the other hand, probable larger ranges of EG_1 reveal falling into excessive activity range of regulatory effects, for which the exceeding value comes to 8000-10000 ms^2 that can characterize the state of overtraining and overexertion in people with the “high” PHA. This assumption is further proved by VLF, which is associated with thermoregulation, influence of endocrine factors such as thyroxine, sex hormones, renin-angiotensin system, steroids and others [15], and psycho factors [16]. As shown in the Table 4, VLF is significantly higher ($p < 0.05$) in EG_1 than in EG_2, which may indicate a greater impact of suprasegmental structures that are realized through humoral-metabolic factors, HR at the higher PHA. On the other hand, its decrease in EG_2 may characterize energy-deficient state of people with “low” PHA. Probable differences ($p < 0.05$) between EG_1 and EG_2 were also fixed in terms of LF (ms^2), which mostly characterizes the activity of the sympathetic division of the ANS.

The “high” PHA is characterized by probable most active stress realizing system associated with the participation of sympathoadrenal mechanisms. At the same time, HF (ms^2), which certifies the activity of parasympathetic regulation mechanisms [17,18], is also the largest in the EG_1, though not significant. The latter is reflected in the index ratio LF/HF, which in EG_1 is not different from EG_2. We can conclude, therefore, that the “high” PHA is characterized by a probable increase in regulatory influences on HR by all components of the regulation, of all most likely being humoral-metabolic and stress realizing systems [19,20]. An increase in the activity of parasympathetic contour of regulation is significant, but not such compared with other groups.

No probable differences were observed in any registered SBPV values that are shown in the Table 5. We can speak about the reducing tendency in regulatory influences in all frequency ranges, with the exception of high-frequency ones (HF_{SBP} mm Hg^2), which is even void of tendency.

Having analyzed the DBPV data it seems obvious that in terms of VLF_{DBP} (mm Hg^2) probable differences between EG_1 and EG_2 are quite noticeable (Table 6). It is due to this component that DBPV value differs significantly from TP_{DBP} (mm Hg^2) in EG_1 from EG_2. And given the data of other scholars [21,22,23], we can assume that the activity of angiotensin II and Nitric oxide synthase (NOS) that are associated with the VLF range of DBPV in EG_1 differs from EG_2. A similar conclusion can be drawn about the activity and L-type Ca2+- channels involved in the formation of vascular myogenic response and related to the occurrence of arrhythmic complications [24]. Other values of regulatory impacts on SBP and DBP in the studied groups do not differ.

That is, in terms of SBPV and DBPV the high PHA is different from other levels that can characterize the activity of angiotensin II and NOS, as well as L-type Ca2+- channels reduced at low VLF_{DBP}.

Well known is the modulating effect of breathing on the circulatory system, which is realized through a series of reflex mechanisms; however, modulating effects on the respiratory center are not fully studied. They are associated with a number of neurohumoral and reflex factors, primarily the concentration of CO_2 [25] H + ions in the blood [26] and the activity of afferent fibers of the vagus nerve and nerve impulses from the cervical sympathetic host, limbic system, GABA- and serotonergic neurons [27,28], the neurons of the cerebral cortex that define the frequency, depth and RR [29,30,31].

That is why the study of differences of patterns values and variability of random breath in people with different PHA may help determine the mechanisms of regulation of the cardiovascular system, taking into account the functional state of the body associated with VO_2max.

Table 3. The results of registration of the first standard ECG parameters in the studied groups using SACR

Parameter	EG_1	EG_2
HR, min^{-1}	66.2 (60.8; 73.3)*	77.8 (65.9; 82.9)
P, s	0.104 (0.098; 0.108)	0.100 (0.095; 0.108)
PQ, s	0.142 (0.130; 0.156)	0.139 (0.121; 0.148)
QR, s	0.030 (0.028; 0.032)*	0.031 (0.030; 0.032)
QRS, s	0.089 (0.086; 0.093)*	0.093 (0.089; 0.098)
QTs, s	0.405 (0.393; 0.412)*	0.414 (0.404; 0.425)
ST, reference	0.099 (0.060; 0.126)	0.074 (0.021; 0.110)

- $p < 0.05$

Table 4. The results of registration of HRV parameters in the studied groups using SACR

Parameter	EG_1	EG_2
TP, ms^2	6021.8 (3080,3;11406.2)*	3294.8 (2275.3; 5083.7)
VLF, ms^2	761.8 (368.6; 1149.2)*	299.3 (204.5; 524.4)
LF, ms^2	1892.3 (1204.1; 5852.3)*	1036.8 (823.7; 3352.4)
HF, ms^2	1980.3 (1024.0; 3271.8)	1267.4 (734.4; 3364.0)
LF/HF, ms^2/ ms^2	1.21 (0.64; 2.89)	1.00 (0.49; 3.24)

- $p < 0,05$

Table 5. The results of registration of systolic blood pressure variability parameters in the studied groups using SACR

Parameter	EG_1	EG_2
TP_{SBP}, $mmHg^2$	23.0 (18.5; 36.0)	30.3 (20.3; 47.6)
VLF_{SBP}, $mmHg^2$	6.8 (4.0; 13.0)	10.9 (4.8; 22.1)
LF_{SBP}, $mmHg^2$	6.8 (4.4; 11.6)	8.4 (5.8; 15.2)
HF_{SBP}, mmHg.^{2}	4.4 (2.6; 9.0)	4.8 (2.6; 12.3)
$LFHF_{SBP}$, $mmHg^2$/ $mmHg^2$	1.28 (0.55; 4.20)	1.51 (0.67; 5.43)

Table 6. The results of registration of variability in diastolic blood pressure parameters in the studied groups using SACR

Parameter	EG_1	EG_2
TP_{DBP}, $mmHg^2$	9.6 (5.3; 13.7)*	12.3 (10.2; 21.2)
VLF_{DBP}, $mmHg^2$	2.0 (1.2; 3.6)*	4.4 (2.0; 7.3)
LF_{DBP}, $mmHg^2$	4.4 (2.6; 6.8)	5.3 (3.2; 7.3)
HF_{DBP}, $mmHg^2$	1.0 (0.5;2.3)	1.4 (0.6; 2.0)
$LFHF_{DBP}$, $mmHg^2$/ $mmHg^2$	4.67 (2.02; 7.67)	3.80 (2.10; 5.90)

- $p < 0,05$

The value of breath variability was shown in works related to the assessment of the functional state of athletes when the close relationship between TP_R $(l/min)^2$ and RMV (l/min) was demonstrated, which describes the RR and Vt in combination with the rhythm [2] and recovery of the body after a competitive activity. From this perspective, the data presented in Table 7 reveal that the probable differences ($p < 0.05$) of TP_R value in EG_1 compared with EG_2 characterize random breath economization, and in terms of RV (l), RR (min^{-1}) and RMV (l/min) values the groups did not differ significantly (Table 8).

Table 8 shows average values registered in breathing pattern of studied groups. It reveals that the probable differences between the groups were observed only in the parameters EVS (l/s) and the ratio inspiration/expiration durations (I/Ed). It is demonstrated that the "high" PHA is marked for probable ($p < 0.05$) reduction in expiratory flow rate and the ratio of the length of duration of inspiration to expiration.

Concluding the analysis of variability values of the cardiorespiratory system an attention should be paid to the data demonstrated in Table 9, which show the average values of α-factor (BRS) designed for low frequency (BR_{LF}, ms/mm Hg) and "high" frequency (BR_{HF}, ms/mm Hg) ranges, as well as random breath. It is worth noting that the differences between the groups are only observed in terms of baroreflex sensitivity in the low-frequency range, which at the "high" PHA is probably higher ($p < 0.05$) than at "low" level.

The latter reveals higher adaptive capacity and adequate regulation of the cardiovascular system. At the same time, the reduction of this value presupposes the development of syncope, especially clearly seen in EG_2.

For a more complete description of the criteria for a high level of health an analysis of indicators of central hemodynamic was carried out (Table 10). As shown by the volume indicators, no credible differences were recorded, while EDV (cm^3) rate in EG_2 has a clear tendency to increase. Value of cardiac output (CO, L) differs credibly between EG_1 and EG_2 ($p < 0.05$) and indicates a more economical functioning of the cardiovascular system at a high level of health. Significant differences are observed in CI ($l/min/m^2$), which is significantly ($p < 0.01$) lower in people with the PHA than in EG_2. Let us remind that as well as this index SOI (ml/m^2) is also used to describe the type of hemodynamics.

Table 7. The results of registration of variability of random breath parameters in the studied groups using SACR

Parameter	EG_1	EG_2
TP_R, $(l/min)^2$	231.0 (158.8; 342.3)*	349.7 (210.3; 524.4)
VLF_R, $(l/min)^2$	2.3 (1.4; 4.0)	2.3 (1.7; 3.2)
LF_R, $(l/min)^2$	14.4 (7.3; 84.6)	13.7 (7.8; 64.0)
HF_R, $(l/min)^2$	174.2 (62.4; 285.6)	237.2 (90.3; 404.0)
$LFHF_R$, $(l/min)^2/(l/min)^2$	0.073 (0.036; 0.774)	0.123 (0.032; 0.250)

**- p <0.05*

Table 8. The results of registration of breathing pattern parameters in the studied groups using SACR

Parameter	EG_1	EG_2
ID, sec	1.7 (1.4; 2.3)	1.8 (1.4; 2.2)
ED, sec	2.8 (2.2; 3.8)	2.7 (2.1; 3.6)
Vt, L	0.490 (0.400; 0.660)	0.470 (0.370; 0.640)
IVS, l/sec	0.28 (0.22; 0.33)	0.30 (0.26; 0.35)
EVS, l/sec	0.17 (0.14; 0.22)*	0.19 (0.17; 0.25)
I/Ed	0.64 (0.56; 0.68)*	0.68 (0.63; 0.72)
RR, min^{-1}	13.2 (9.9; 16.7)	13.5 (10.3; 17.6)
RMV, L/min	6.8 (4.9; 7.8)	7.0 (6.2; 8.9)

**- p <0.05*

Table 9. The results of estimation of additional parameters of cardiorespiratory system regulation in the studied groups using SACR

Parameter	EG_1	EG_2
BR_{LF}, ms/mm Hg	18.9 (12.6; 23.6)*	12.9 (8.8; 20.7)
BR_{HF}, ms/mm Hg	19.3 (14.8; 26.7)	19.8 (11.8; 28.6)

**- p <0.05*

Table 10. The results of registration of central hemodynamics parameters in the studied groups using SACR

Parameter	EG_1	EG_2
EDV, cm^3	92.6 (85.0; 104.3)	100.3 (90.6; 112.5)
ESV, cm^3	29.2 (23.5; 32.2)	31.4 (27.4; 43.6)
SV, cm^3	64.7 (59.3; 72.2)	66.0 (63.0; 71.6)
CO, L	4.3 (4.1; 4.6)*	5.0 (4.5; 5.8)
CI, L/min/m^2	2.32 (2.09; 2.44)**	2.58 (2.47; 2.89)
GPVR, dyn×s×cm^{-5}	1578.7 (1405.2; 1730.3)	1508.1 (1297.5; 1612.8)
SPVR, dyn×s×cm^{-1}/m^2	21.5 (20.1; 23.5)*	19.9 (16.8; 21.6)
SOI ml/m^2	33.0 (31.7; 36.8)	33.0 (32.1; 37.4)

*- p <0.05 and **- p <0.01

In this case, a clear tendency to economization (hypokinetic type) of hemodynamics is observed in the EG_1 and EG_2. Here, compared to EG_2, rather characteristic for the EG_1 is increasing SPVR (dyn×s×cm^{-1}/m^2).

The analysis of the morphometric parameters data reveal credible differences between "high" and "low" levels of PHA, which demonstrate stronger physique, lower body weight, contours of the belly, chest and thigh, and the percentage of fat in the "high" PHA ($p < 0.05$). Analysis of test results with standard physical exercise showed that people with "high" PHA do not differ from those with "low" PHA in regards of the reactivity of the cardiovascular system; and the probable differences of changes of the absolute values of HR and BP after physical activity are determined by credible differences ($p < 0.05$) in the initial state, which was registered in terms of HR (min^{-1}) and DBP (mm Hg). However, the lack of credible differences in the initial state in terms of SBP (mm Hg) after physical activity pointed to credibly lower SBP reactivity in people with "high" PHA ($p < 0.05$) compared to those with the "low" one.

Analysis of cardiointervals of PQRST complex showed (Table 11) that the characteristic criteria for a high level of health is significantly lower values of QR (s), QRS (s) and QTs (s), and their increase may indicate a deterioration of health. That is, high level of health is characterized by better intraventricular conduction, and its deceleration indicates deteriorating health of the athlete. This reveals a more optimal progress of de- and repolarization of the ventricles, as well as the lack of susceptibility to sudden hemodynamic disorders in people with a "high" PHA.

HR autonomic providing at "high" PHA suggests a higher adaptive capacity compared to "low" PHA, which is probably related to higher activity of central parts of the regulation. As for the SBP autonomic providing, no specific differences in people from "high" PHA are detected, unlike DBP autonomic providing, which can be characterized by less activity of angiotensin II and NOS, as well as L-type Ca2+-channels in the "high" PHA. Concerning the variability of random breath, only a combined value of the total power range of random breath variability (T_R $(l/min)^2$) can point to probable differences that characterize a reduce of regulatory influences on breath and its economization at "high" PHA. The latter confirms the data of the analysis of breathing pattern certifying probable reduce of the EVS (L/sec) rate and the relative increase in the duration of exhalation compared to the "low" PHA.

Table 11. Summary data of probable differences of regulation parameters of cardiorespiratory system of people with "high" compared with and "low" PHA

Parameter	Significant differences of parameters of people with "high" compared with and "low" PHA
Complex PQRST	<QR, <QRS, <QTs
HRV	>TP, >VLF, >LF
VSBP	no
VDBP	$< TP_{DBP}$, $<VLF_{DBP}$
RBV	$< TP_R$
Breathing pattern	<EVS , <I/Ed
BR	$>BR_{LF}$
Hemodynamics	< CO , <CI, > SPVR

One of the important criteria of “high” PHA is probable larger BR in the low frequency range compared to “low” PHA, which characterizes the optimal level of regulation of cardiac pump function at feedback mechanisms. In this case none of the indices of the regulation of heart function centralization, breathing and blood vessels reveal any differences among the groups. Central hemodynamics study complements the features of cardiorespiratory system state. The results of the described above research reveal probable lower cardiac output and cardiac index, as well as more specific vascular resistance at rest in a “high” PHA.

4. CONCLUSION

So, the SACR examination revealed that all studied systems of regulation, except for the regulation of systolic blood pressure (SBP), are characterized by credible differences between people with “high” and “low” PHA.

Thus, the results to some extent allowed to characterize and supplement data about the health of athletes that can be used as criteria for determining health level at screening examination.

During repeated observation of highly skilled athletes at rest an increased HR was detected, which is combined with the slowing of conduction of ventricular (QRS) and depolarization of ventricular (QR) with increased standardized QT (QTs) and a decrease in total power of HRV (TP) and HRV powers in very low frequency range (VLF) and low frequency range (LF). This may indicate a decline in functional state of organism and deterioration of the health of athletes, which requires an in-depth examination. Additional criteria of deteriorating health of athletes should also include an increase in DBP at rest, which is accompanied by an increase in total power of DBPV (TP_{DBP}) and DBPV power in very low frequency range (VLF_{DBP}), a decrease in the sensitivity of blood baroreflex (BR) in the low-frequency range (BR_{LF}), an increase in total power of spontaneous respiration variability (TP_R), an increase in expiratory speed volume (EVS) and the ratio of the length of duration of inhalation to exhalation (I / Ed). These criteria are added by an increase in cardiac output (CO), cardiac index (CI) and decrease in peripheral vascular resistance specific peripheral vascular resistivity (SPVR).

CONSENT

It is not applicable.

ETHICAL APPROVAL

All authors hereby declare that all experiments have been examined and approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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