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Features of the Blood Pressure Variability of Athletes with Different Levels of Functional State of the Body

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Abstract

To determine the features of the distribution of the parameters of the systolic (SBPV) and diastolic (DBPV) blood pressure variability dependent on the level of functional state (FS) of the athletes’ body "Spiroarteriocardiorhythmograph" was used. 104 male athletes, at the age of 20.6 ± 0.9, who were engaged in various sports, were analyzed. Taking into account the level of the FS, they were divided into 3 groups: the first group with a high level of FS was 39 people (“high”), the second group was 46 (“average”), the third group was 19 (“low”). This report analyzes the differences in the ranks of the parameters of the SBPV and DBPV – TP_{SBP} ($mmHg^2$), VLF_{SBP} ($mmHg^2$), LF_{SBP} ($mmHg^2$), HF_{SBP} ($mmHg^2$), LF/HF_{SBP} ($mmHg^2/mmHg^2$), TP_{DBP} ($mmHg^2$), VLF_{DBP} ($mmHg^2$), LF_{DBP} ($mmHg^2$), HF_{DBP} ($mmHg^2$), LF/HF_{DBP} ($mmHg^2/mmHg^2$)

There were no possible differences in any registered SBPV values. We can speak about the reducing tendency in regulatory influences in all frequency grades, with the exception of high-frequency ones (HF_{SBP} $mmHg^2$), which is invalid tendency. After analyzing the DBPV data it becomes clear that in terms of VLF_{DBP} ($mmHg^2$) possible differences between “high” and “low” are quite pronounced.

The analysis of the distribution ranks of the SBPV and DBPV parameters showed that the data on the measurement of the blood pressure variability in ultra-short measurements allows a sufficiently clear differentiation of the “low” level of FS, which is characterized by an increase in the total power of regulatory influences on the SBP due to supra-segmental effects and sympathetic effects, as well as an increase in low-frequency effects on DBP.

Key words: blood pressure variability, sportsmen, functional state.

Introduction. The problem of finding informational criteria of the functional state (FS) of the athlete's body is related to the possibilities of expressing determination and evaluation of functional parameters, primarily cardiovascular and respiratory systems, which would allow to measure and characterize the functional support and functional reserves of the organism [2, 5, 11, 12, 20].

The important indicator of the FS of the body of athletes is blood pressure, which, in combination with the parameters of heart rate (HR), characterizes the hemodynamic provision of the organism [3, 21]. Absolute values of systolic and diastolic pressure, as well as their derivatives, indirectly determine the cardiac output power, the nature of vascular resistance, the volume of circulating blood, etc. [16, 17, 22]. Analysis of the pulse wave allows, in view of the point of registration of blood pressure, to characterize the time of its delay, the stiffness of the vascular wall and a number of other functional indices, indicating the passage of blood volume through the vessels and characterizing the state of the vascular wall [10, 18, 26]. In the sport practice, it is important to determine these indicators to identify conditions of fatigue, overstrain, overtraining, when in the conditions of the training and competitive process it is necessary to change quickly and qualitatively the direction of training or recovery of the organism after them [3, 13, 14, 18, 20, 21]. The study of the variability of blood pressure according to the recording of the pulse wave on each heartbeat by photoplethysmographic method has been used for a long time, but, due to various circumstances, it has not been widely used [4, 7, 23, 24]. We will try to fill this gap to some extent.

Our attention was drawn to the multifunctional method of studying the state of the organism - "Spiroarteriocardiorhythmography" (SACR), which, in the simultaneous registration mode, allows to determine the function of the heart, blood vessels and respiration [15, 25]. Previously, we have analyzed the changes in the parameters of the heart rate variability for the influence of the cycle of training loads both before and after the training load, which allowed to establish their peculiarities in the development of training and taking into account the response to standard physical activity [11, 12, 13, 14, 29, 30, 31].

In previous studies, on the basis of a survey using 1930 SACR, the limits of percentile distribution in the ranges < 5%, 5-25%, 25-75%, 75-95%, and > 95% for indicators of systolic (SBPV) and diastolic (DBPV) blood pressure variability (Tabl.1) for qualified athletes at the age of 22.0 ± 1.3 years were calculated, which made it possible to detect differences from practically healthy persons of different ages [28].

Table1

Percentile distribution of systolic and diastolic blood pressure variability parameters

Parameter BPV	<5	5-25	25-75	75-95	>95
TP_{SBP}, $mmHg^2$	<2.9	2.9-6.2	6.3-25.0	25.1-70.6	>70.6
TP_{DBP}, $mmHg^2$	<1.4	1.4-3.2	3.3-12.2	12.3-31.4	>31.4
VLF_{SBP}, $mmHg^2$	<0.5	0.5-1.4	1.5-6.7	6.8-26.0	>26.0
VLF_{DBP}, $mmHg^2$	<0.4	0.4-1.0	1.1-4.8	4.9-16.8	>16.8
LF_{SBP}, $mmHg^2$	<0.8	0.8-2.2	2.3-9.6	9.7-28.1	>28.1
LF_{DBP}, $mmHg^2$	<0.4	0.4-1.0	1.1-4.4	4.5-13.0	>13.0
HF_{SBP}, $mmHg^2$	<0.8	0.8-2.0	2.1-6.7	6.8-20.3	>20.3
HF_{DBP}, $mmHg^2$	<0.3	0.3-0.6	0.7-2.0	2.1-6.3	>6.3
$LFHF_{SBP}$, $mmHg^2/mmHg^2$	<0.31	0.31-0.75	0.76-2.27	2.28-6.05	>6.05
$LFHF_{DBP}$, $mmHg^2/mmHg^2$	<0.44	0.44-1.09	1.10-3.29	3.30-7.59	>7.59

The purpose of this study was to determine the peculiarities of the distribution of the parameters of the SBPV and DBPV depending on the level of functional state of the body of athletes.

Material & methods. For this purpose, 104 male athletes, age 20.6 ± 0.9 years old, who were engaged in various sports, were analyzed for the SBPV and DBPV indices. Taking into account the level of the FS, they were divided into 3 groups: first group with a high level of FS was 39 people (“high”), second group – 46 (“average”), third group – 19 (“low”).

To determine the FS of the body of athletes, we used the system of assessment of the level of somatic health (LSH) by G. L. Apanasenko, which has a close connection with VO_2max of the body. Thus, the low level of LSH corresponds to VO_2max: 16±7 ml/min.×kg, below the average: 23±8 ml/min×kg, an average: 29±4 ml/min×kg, above the average: 41±3 ml/min.×kg, and high: 62±6 ml/min×kg. In determining the level of FS of the organism, high and higher LSH levels were characterized as “high” FS, average LSH as the “average” FS, low and lower than average LSH as “low” FS [2]. Non-parametric methods of statistical analysis with determination of Mann-Whitney criterion were used to evaluate the obtained results of the study.

Table 2 shows the average data of the analysis of measurements of the parameters of the body structure of athletes of the studied groups.

Table 2

Characteristics of physical development parameters of studied groups, M (Q_1; Q_3)

Parameters	High	Average	Low
Weight, kg	71.0 (69.0; 78.0)*	75.5 (70.0; 80.0)	77.0 (72.0; 80.0)
Length, cm	178.0 (175.0; 181.0)	179.0 (174.0; 182.0)	180.0 (175.0; 182.0)
BMI, kg /m^2	22.7 (21.6; 23.7)	23.7 (22.0; 24.9)	23.5 (22.5; 24.2)
Dynamometry of wrists r., kg	50.0 (46.0; 54.0)	48.0 (44.0; 52.0)	48.0 (42.0; 52.0)
Dynamometry of wrists l.,kg	46.0 (42.0; 50.0)	47.0 (42.0; 52.0)	48.0 (42.0;49.0)
SI, %	70.4 (65.6; 77.9) *#	65.7 (61.1; 67,7)	60.5 (57.6; 67.5)
VLC, ml	4900 (4550; 5500)	4850 (4500; 5150)	4900 (4300; 5500)
VI, ml/kg	68.5 (64.3; 72.8) *	65.1 (61.0; 72.5)	63.3 (56.9; 71.8)

* - p<0.05 in comparison “High” and “Average” with “Low”; # - p<0.05 in comparison “High» with “Average”

Analyzing the data of the structure of the body of “high” athletes, first of all, it is necessary to stress on the differences associated with FS, which is here significantly smaller ($p<0.05$) than in “low”, however, not differing from “average”. At the same time, according to the body mass index (BMI), which is an integral characteristic of body mass, the probable differences in the groups of athletes are not registered. Significant differences were observed in the strength index (SI) in “high” compared to “average” and “low” ($p<0.05$), as well as vital index (VI) compared to “low” ($p<0.05$). With regard to the latter, it should be noted that the absolute values of the VLC are not likely to differentiate the groups [15].

Table 3

Characteristics of the results of the measurement of cardiovascular system performance and results of the calculation of the main integral indexes used to evaluate the functional state of the organism in the studied groups (M (Q_1; Q_3))

Parameters	High	Average	Low
HR, min^{-1}	66,2 (60,8; 73,3)*	69,8 (63,6; 77,1)*	77,8 (65,9; 82,9)
SBP, mmHg	110 (110; 120)	120 (110; 130)	120 (110; 130)
DBP, mmHg	60 (60; 70) *#	70 (60; 80)	70 (70; 80)
Baevsky’s AP	1.86 (1.71; 2.01)*#	2.02 (1.89; 2.26)	2.06 (1.90; 2.30)
Pirogova’s LPC	0.785 (0.736; 0.852) *#	0.718 (0.639; 0.786)	0.688 (0.592; 0.786)
Skibinska’s index	6578 (4958; 8546)	5931 (4813; 7500)	6655 (4809; 7840)
Robinson’s index	72 (62.4; 79.2)*#	79.2 (70.2; 86.4)	79.2 (72.0; 92.4)
Kerdo index	0.00 (-0.17; 0.09)*	-0.03 (-0.17; 0.09)*	-0.17 (-0.21; 0.09)

* - $p<0.05$ in comparison “High” and “Average” with “Low”; # - $p<0.05$ in comparison “high» with “Average”

As can be seen from Table 3, for all indices, in the formula for calculating of which either HR or SBP parameters in a resting state are included, there are probable differences in individuals with “high” FS. This applies to Baevsky’s adaptive capacity (Baevsky’s AP), Pirogova’s level of physical condition (LPC), and RI, the differences between the groups “high” are probable compared to “average” and “low”. However, there were no probable differences between “average” and “low” according to these indices. In view of this, special attention deserves the lack of differentiation of Skibinska’s index indices, which in the studied groups do not differ at all. It is worth mentioning that its calculation includes the VLC and inhibition time, analyzing which earlier we did not establish the probable differences in the studied groups. The results of calculating the Kerdo index proved to be informative enough to show that in “high” and “average” they are significantly different from the results in “low”. In addition, in “low” (with low FS), there was a fairly distinct propensity to moderate parasympathetic content, in contrast to “high” and “average”, in which variants of the normotonium with a certain tendency to parasympathetic content were superior [15, 29].

The study of the cardiorespiratory system was performed using SACR and assumed an examination for spontaneous breathing (SB). This report analyzes the differences in the ranks of the parameters of the SBPV and DBPV – TP_{SBP} ($mmHg^2$), VLF_{SBP} ($mmHg^2$), LF_{SBP} ($mmHg^2$), HF_{SBP} ($mmHg^2$), LF/HF_{SBP} ($mmHg^2/mmHg^2$), TP_{DBP} ($mmHg^2$), VLF_{DBP} ($mmHg^2$), LF_{DBP} ($mmHg^2$), HF_{DBP} ($mmHg^2$), LF/HF_{DBP} ($mmHg^2/mmHg^2$) [1, 7, 25, 29].

Results and discussion. No probable differences were observed in any registered SBPV values that are shown in the Tabl. 4. We can speak about the reducing tendency in regulatory influences in all frequency ranges, with the exception of low-frequency ones (LF_{SBP} $mmHg^2$), which is even void of tendency.

Having analyzed the DBPV data it seems obvious that in terms of VLF_{DBP} ($mmHg^2$) probable differences between "high" and "low" are quite noticeable (Tabl. 4). It is due to this component that DBPV value differs significantly from TP_{DBP} ($mmHg^2$) in "high" from "low". And given the data of other scholars [6, 8, 9], we can assume that the activity of angiotensin II and Nitric oxide synthase (NOS) that are associated with the VLF range of DBPV in "high" differs from "low". A similar conclusion can be drawn about the activity and L-type Ca^{2+}-channels involved in the formation of vascular myogenic response and related to the occurrence of arrhythmic complications [19, 27]. 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" 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} [19].

Table 4

Results of registration of systolic and diastolic blood pressure indices using SACR in the studied groups (M (Q_1; Q_3))

Parameter BPV	High	Average	Low
TP_{SBP}, $mmHg^2$	23,0 (18,5; 36,0)*	26,0 (15,2; 41,0)	30,3 (20,3; 47,6)
TP_{DBP}, $mmHg^2$	9,6 (5,3; 13,7)*	10,9 (6,3; 16,0)*	12,3 (10,2; 21,2)
VLF_{SBP}, $mmHg^2$	6,8 (4,0; 13,0)	10,2 (4,8; 21,2)	10,9 (4,8; 22,1)
VLF_{DBP}, $mmHg^2$	2,0 (1,2; 3,6)$^{*\#}$	3,8 (2,3; 7,8)	4,4 (2,0; 7,3)
LF_{SBP}, $mmHg^2$	6,8 (4,4; 11,6)*	6,3 (4,4; 9,6)*	8,4 (5,8; 15,2)
LF_{DBP}, $mmHg^2$	4,4 (2,6; 6,8)	4,2 (2,3; 6,8)	5,3 (3,2; 7,3)
HF_{SBP}, $mmHg^2$	4,4 (2,6; 9,0)	5,1 (3,2; 9,6)	4,8 (2,6; 12,3)
HF_{DBP}, $mmHg^2$	1,0 (0,5;2,3)	1,0 (0,6; 1,7)	1,4 (0,6; 2,0)
$LFHF_{SBP}$, $mmHg^2/mmHg^2$	1,28 (0,55; 4,20)	1,36 (0,83; 1,96)	1,51 (0,67; 5,43)
$LFHF_{DBP}$, $mmHg^2/mmHg^2$	4,67 (2,02; 7,67)	3,76 (2,16; 8,35)	3,80 (2,10; 5,90)

* - $p<0.05$ in comparison "High" and "Average" with "Low"; $^\#$ - $p<0.05$ in comparison "High" with "Average"

In order to achieve the goal and to determine the changes in the indexes of the SBPV and DBPV for athletes with different levels of the FS, an individual assessment of the SBPV and DBPV indices at spontaneous breath was performed with the definition of the individual parameter rank (Table 5).

Table 5

Characteristics of the BPV indices ranges

Characteristics of the indices ranges	Value ranges	Centile range
pronounced decrease	-2	<5
moderate decrease	-1	5-25
norm	0	25-75
moderate increase	+1	75-95
pronounced increase	+2	>95

Here is an example of the application of the approach to the determination and evaluation of the SBPV and DBPV. At the examination of an athlete K. 21 years old, who had an average level of FS, using the SACR with SB, the following parameters were obtained: TP_{SBP} - 5.8 $mmHg^2$ (rank - -1), VLF_{SBP} - 1.4 $mmHg^2$ (rank - -1), LF_{SBP} - 1.7 $mmHg^2$ (rank - -1), HF_{SBP} - 2.3 $mmHg^2$ (rank - 0), LF_{SBP}/HF_{SBP} - 0.69 $mmHg^2$/ $mmHg^2$ (rank - -1).

According to the results of the analysis of the SBPV indicators, it is shown (Table 6) that with the decrease in the level of the FS there is a tendency to increase the total power of the SBP variability (TP_{SBP}, $mmHg^2$), which occurs due to increased activity of the supra-segmental regulation mechanisms (VLF_{SBP}, $mmHg^2$) and activity of the sympathetic link (LF_{SBP}, $mmHg^2$). The activity of high-frequency influences (HF_{SBP}, $mmHg^2$) on SBP at athletes from different groups almost does not differ, except for certain predominance of moderate increase variants at average FS level. At the same time, there is no clear propensity to predominate vegetative influences, except for a certain increase in the high-frequency component at a high level of the FS, the normotonic variants – at average level, and low-frequency – at low level. However, according to this parameter, the high and low levels of FS differentiate insignificantly.

Table 6

Distribution of Parameters SBPV according to Ranks

Parameters SBPV	FS level	Rank, %				
		-2	-1	0	1	2
TP_{SBP}, $mmHg^2$	high	0.0	2.6	59.0	**38.5**	0.0
	average	0.0	2.2	50.0	**39.1**	8.7
	low	0.0	0.0	47.4	**47.4**	5.3
VLF_{SBP}, $mmHg^2$	high	2.6	5.1	48.7	**41.0**	2.6
	average	0.0	10.9	34.8	**37.0**	**17.4**
	low	0.0	0.0	31.6	**63.2**	5.3
LF_{SBP}, $mmHg^2$	high	0.0	12.8	59.0	23.1	5.1
	average	0.0	10.9	69.6	17.4	2.2
	low	0.0	10.5	47.4	**26.3**	**15.8**
HF_{SBP}, $mmHg^2$	high	0.0	20.5	51.3	20.5	7.7
	average	2.2	15.2	43.5	**34.8**	4.3
	low	0.0	15.8	52.6	21.1	**10.5**
$LFHF_{SBP}$, $mmHg^2$/ $mmHg^2$	high	5.1	**33.3**	23.1	23.1	**15.4**
	average	4.3	19.6	58.7	13.0	4.3
	low	5.3	26.3	21.1	26.3	**21.1**

In Tabl. 7 it is shown the results of the analysis of DBPV parameters, which characterize the regulatory effects on the vascular tone. In this case, the total power of DBP variability (TP_{DBP}, $mmHg^2$) is the most balanced at high FS level and tends to a moderate increase at the average and low levels of FS. The contribution of individual components at different levels of the FS differs and is characterized by a tendency to reduce the contribution of very-low-frequency influences (VLF_{DBP}, $mmHg^2$) with a high level of FS and increase at the average and low levels of FS. Significantly, the low level of FS was clearly differentiated by the activity of low-frequency influences (LF_{DBP}, $mmHg^2$), which shows a shift in the distribution towards moderate and pronounced increase in such variations.

Table 7

Distribution of Parameters DBPV according to Ranks

Parameters DBPV	FS level	Rank, %				
		-2	-1	0	1	2
TP_{DBP}, $mmHg^2$	high	0.0	10.3	**64.1**	25.6	0.0
	average	0.0	2.2	58.7	**34.8**	4.3
	low	0.0	5.3	52.6	**36.8**	5.3
VLF_{DBP}, $mmHg^2$	high	0.0	**33.3**	48.7	17.9	0.0
	average	0.0	15.2	50.0	**32.6**	2.2
	low	0.0	15.8	42.1	**42.1**	0.0
LF_{DBP}, $mmHg^2$	high	0.0	2.6	59.0	**30.8**	7.7
	average	0.0	8.7	52.2	**34.8**	4.3
	low	0.0	5.3	31.6	**47.4**	**15.8**
HF_{DBP}, $mmHg^2$	high	5.1	**41.0**	35.9	17.9	0.0
	average	6.5	**32.6**	45.7	10.9	4.3
	low	0.0	26.3	52.6	5.3	**15.8**
$LFHF_{DBP}$, $mmHg^2$/ $mmHg^2$	high	2.6	7.7	25.6	**35.9**	**28.2**
	average	0.0	8.7	39.1	28.3	**23.9**
	low	0.0	15.8	26.3	**36.8**	**21.1**

On the other hand, at the parameter of high-frequency influences (HF_{DBP}, $mmHg^2$), at high and average levels of the FS there is a tendency to decrease the effects, which is more pronounced at high FS, and at low – the predominance of pronounced variants against the background of the almost expected distribution. The lack of differentiation according to the parameter of the ratio of low and high-frequency influences on the DBP seems informative enough.

Conclusions.

The analysis of the distribution ranks of the SBPV and DBPV parameters showed that the data on the measurement of the blood pressure variability in ultra-short measurements allows a sufficiently clear differentiation of the low level of FS, which is characterized by an increase in the total power of regulatory influences on the SBP due to supra-segmental effects and sympathetic effects, as well as an increase in low-frequency effects on DBP. The data obtained will further unify the individual options for assessing regulatory influences on blood pressure.

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