Article

A Fresh View at Sports PSM-Systems

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Abstract. The syndrome of heart chronic physical overstrain is the condition of functional disadaptation, which a coach must diagnosis by himself. If he misses the development of this condition (especially for juniors) then subsequent training or competitive activities may cause development of hypertrophic cardiomyopathy and increase the risk of sudden cardiac death. The syndrome of heart chronic physical overstrain is the main reason of «professional sports aging».

Keywords: Sport; Cardiomyopathy; Heart Rate; Monitoring; Functional; Athlete Readiness

1 Introduction

Physiological state monitoring (PSM-systems) is an IT systems used to record various physiological parameters of the human body [1]. The purpose of the PSM-systems is to monitor the viability of a person in extreme conditions (diseases, injuries, extreme physical exertion, etc.) [2].

It is generally accepted that the degree of the person's efficiency in the terms of specific intensity and tension (sports of high achievements, fighting actions, extreme activities, etc.) is determined by complex interactions of the following components:

- health;
- physical (athletic) shape;
- technical (special) education;
- psychological motivation (morally volitional qualities).

For the clear understanding interactions of these components in athletic pedagogy, the term «Athlete's Functional Readiness» is used [3].

2 The Athlete's functional readiness

In 2014, a group of scientists-physiologists and engineers from Bauman Moscow State Technical University created a methodological guide for Russian Ice Hockey Federation, dedicated for national teams' coaches, called: «General and special functional readiness of ice hockey players» [4].

Following relevant issues were reviewed and summarized in the manual:

1) biochemical regulation of energy supply processes during specific work on the ice;
2) physiological mechanisms of controlling ice hockey players' functional readiness;
3) new specific methods of functional testing during training camps and international competitions.

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The concept of «athlete functional readiness» has a very complex and multifaceted context [5]. Functional readiness may be defined as «a relatively settled state of the organism, determined by the level of development of key functions required for the certain sport, as well as their specialized properties that directly or indirectly determine the effectiveness of the competitive activity».

Physical education and sports theory distinguish technical, tactical, physical and psychological readiness. All functional components of the functional readiness develop in one way: muscle exercise, organized in a certain way within the specific biomechanical structure. Physical exercises used in training classes and sports game are very often aimed only at developing the motor component of functional training. However, an athlete effectiveness in sport and adaptation to specific sports activities may be greatly enhanced by targeted additional methods of influence on all functional components of preparedness.

In 2015-2017 Bauman Moscow State Technical University jointly with The University of Alabama (USA) carried out a research «A study of applicability of a breathing sensor PACT2.0 in determination of aerobic-anaerobic potential of professional athletes (junior ice hockey player) ». This study has been approved by the Institutional Review Board for the protection of human subject request for approval of research involving human subjects (IRB Protocol #15-024-ME 2015/12/14), as well as by the Decisions of the Ethics Committee of Bauman Moscow State Technical University No.1 from 2015/11/11 and No.2 from 2016/10/01).

The purpose of the proposed study is disclosure of correlations between the dynamics of the Respiration Rate (RR) and Heart Rate (HR) when performing the intermittent operation at maximum power on a cycle ergometer. The study will be conducted to determine aerobic-anaerobic capacity of sportsmen in the framework of their functional preparedness and to evaluate feasibility of developing a non-medical methodology for assessing the state of chronical over-exertion.

The necessity for this research was determined by current requirements of the strategical item for a coach the information about how professional athletes in team kinds of sport (hockey, football, handball, basketball, etc.) match each other in speed-strength qualities, as well as a determination of a possibility for their mutual substitution without loss of a game quality during competitive cycles.

Developed during this study the specific PSM-system named RheoCaR.

RheoCaR solves the global problem in the determination of the individual dynamic of changes in the levels of functional readiness of each sports team member, it allows effectively to maintain high levels of team efficiency in the whole during a competitive macrocycle.

The convenience of this sports functional testing is that it is held directly in the conditions of a stadium without involving any complex diagnostic medical equipment.

3 Physiological basis of work RheoCaR

The Heart rate (HR) is most often used as a load intensity evaluation criterion in sports. There is a linear relationship between heart rate and training intensity.

To lead the most useful endurance training, it should be performed on the certain intensity level, when the entire oxygen-transport system is activated, i.e. in a so-called aerobic-anaerobic zone. When you have such intensity, the accumulation of lactate (lactic acid) does not occur [6].

Often, endurance trainings (aerobic exercises) are performed by the athletes at the heart rate of about 180 beats per minute (bpm). For many athletes, this heart rate significantly exceeds the aerobic-anaerobic transition area. The boundaries of the aerobic-anaerobic transition area vary greatly at different people, but roughly it is between 140 and 180 bpm.

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To calculate training intensity and monitor an athlete's functional state, the basic heart rates are used: your resting heart rate, maximum heart rate, reserve heart rate and heart rate abnormalities, as well as target heart rate, characterizing the beyond of the aerobic-anaerobic zone.

Maximum heart rate (HR_{max}) is the maximum number of contractions that the heart may be made within 1 min. After 20 years, HR_{max} gradually begins to decline by about 1 beat per year. So HR_{max} is calculated by the following formula [7]:

$$HR_{max} = 220 - The\ Age\ (years) \quad (1)$$

For the calculation of the load intensity is also used the method of heart rate reserve (HR_R), which was developed by Finnish scientists Karvonen. HR_R is the difference between HR_{max} and HR rest (HR_0):

$$HRR = HR_{max} - HR_0 \quad (2)$$

Knowing the HR reserve, you can calculate the target of the heart rate (HRM). Target heart rate (HR_M) is the optimal heart rate, which does not allow going beyond the aerobic-anaerobic zone during the intensity of the performed exercise M (%):

$$HR_M = HR_0 + M \times HR_R \quad (3)$$

At the same time, knowing HR_0 and HR_{max}, according to the Karvonen's formula, it is possible to calculate with what intensity (M) the athlete performs the exercise:

$$M = (HR\ during\ exercise - HR_0) / (HR_{max} - HR_0) \times 100\% \quad (4)$$

Thus,

$$M = (HR\ during\ exercise - HR_0) / (220 - Age - HR_0) \times 100\% \quad (5)$$

4 The algorithm of the execution of the sports standard RheoCaR

The sports standard RheoCaR was designed for a functional testing of the professional athletes during training camps and competitions. The basis of this functional testing is registration of the biometric (blood pressure, pulse rate and breath rate) and anthropometric (height and weight) indicators with the further complex of the mathematical processing.

The test consists of two parts:

- performing of the Daily functional observations (DFO) using the program DiVa-S;
- performing of the Stage complex examination (SCE) using RheoCardioMonitor with modulus of athlete's functional readiness.

DFO are performed during training camps for the operational control of health and dynamics of adaptation of the athletes' bodies to training loads, and during the competitive period with the aim of increasing of the correction efficiency of the pharmacological protective individual schemes in extreme conditions (see **Fig. 1** and **Table 1**).

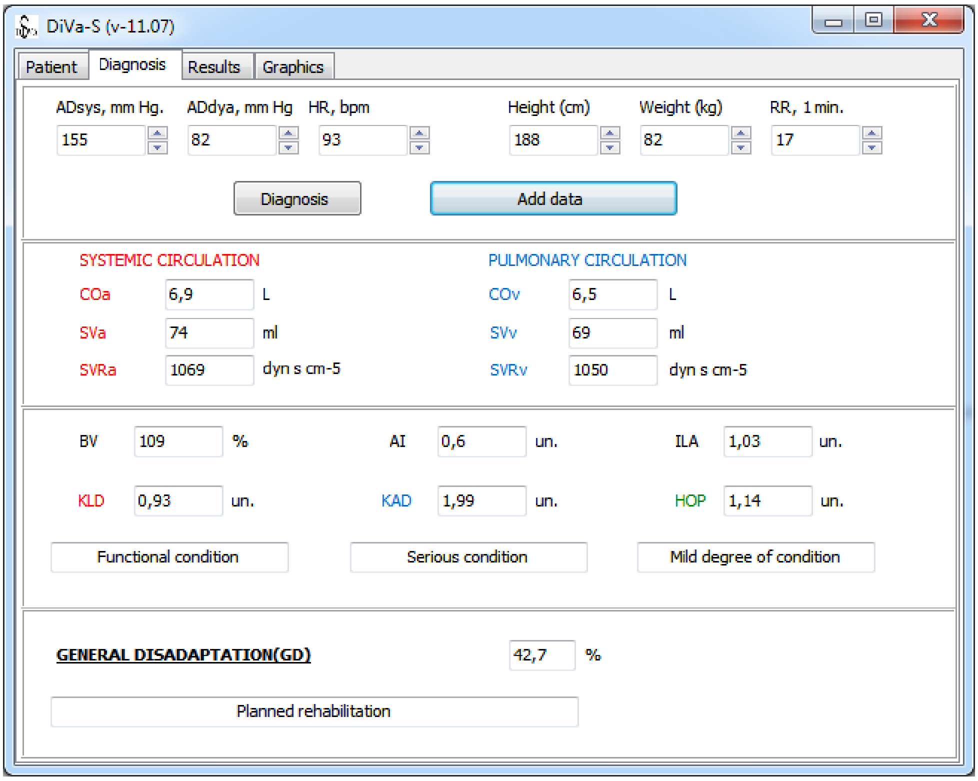

Fig. 1. Software DiVa-S.

Table 1. Physiological characteristics and prognostic coefficients.

Abbreviation	Full name	Units
ADsys	Systolic component of arterial tension	mm Hg
ADdya	Diastolic component of arterial tension	mm Hg
HR	Heart rate	bpm
Height	Body height	centimeter
Weight	Body weight	kg
RR	Breath rate	rpm

COa	Cardiac output of left ventricle of heart	liter per minute
COv	Cardiac output of right ventricle of heart	liter per minute
SVa	Stroke volume of left ventricle of heart	ml
SVv	Stroke volume of right ventricle of heart	ml
SVRa	Systemic vascular resistance	dyn·s·cm-5
SVRv	Pulmonary vascular resistance	dyn·s·cm-5
BV	Blood volume	% of body weight
ILA	Index of pulmonary adaptation	dimensionless
AI	Algever's index	dimensionless
KLD	Coefficient of latent disadaptation	dimensionless
KAD	Coefficient of apparent disadaptation	dimensionless
MD (HOP)	Metabolic dysfunction	dimensionless
GD	General disadaptation	%
IH	The level of individual health	dimensionless

DFO aims, implemented with the help of the sports standard RheoCaR (**Fig. 2**):

- Individualization and effectiveness increasing of the educational training process and recovery;
- Determination of the functional readiness level, making of the correction in the individual training plans;
- Prescription of the recommendations to improve adaptive capacity, the implementation of preventive, therapeutic and rehabilitation measures;
- Determination for a sportsman's health admission to the training sessions and competitions.

The stage complex examination (SCE) are usually performed twice (at the beginning and at the end of the educational training camp) to determine the levels of the functional readiness and athletes' adaptation to the special work.

During SCE, a load test on the Bicycle Ergometer is conducted, in which an individual intensity (power) of the performed exercise (M, %) and the threshold value of anaerobic metabolism (HR_M, bpm) for each athlete are received, as well as objective information in the five-point scale on the indicators:

- Total energy capacity (the capacity of the ATP-system);
- Aerobic system (oxygen system readiness);
- Anaerobic system (lactate system);
- General adaptation of the blood circulation system.

Based on results of the sports standard RheoCaR, make an individual biomedical program, including recommendations, is composed:

- Additional work or rest during educational training camp;
- Preventive measures;
- Using of the selective methods of restoring the functions of ATP-system, Aerobic-system and Anaerobic-system;
- Plan correction of a medical and biological providing and a pharmacological protection in extreme sport's conditions.

№	Name	ADsys	ADdya	HR	Height	Weight	RR	COa	COv	SVa	SVv	SVRa	SVRv	BV, %	ILA, units	AI, units	KLD, units	KAD, units	MD, units	GD, %
1	Белоглазова Дарья	105	66	68	163	51	20	5,4	3,9	79	58	724	650	76	0,67	0,65	1,04	0,86	1,04	26
2	Водопьянова Елена	105	60	50	161	58	16	5,2	4,4	105	89	528	499	79	0,37	0,48	0,85	0,45	1,15	46,8
3	Канаева Диана	100	60	67	170	58	20	5,2	3,9	77	58	705	634	73	0,67	0,67	1,09	0,82	1,06	33,2
4	Кадырова Фануза	118	70	69	152	64	16	5,8	4,6	84	67	752	699	85	0,65	0,58	0,95	0,93	1,49	28,5
5	Штарёва Алевтина	109	57	57	173	68	16	5,3	4,7	94	82	606	579	82	0,47	0,52	0,9	0,61	1,13	43,7
6	Шохина Анна	120	70	61	170	65	22	5,8	4,9	95	80	666	629	88	0,51	0,51	0,84	0,75	1,23	48,5
7	Доброденева Екатерина	99	64	72	157	56	18	5,2	3,6	72	50	758	666	70	0,77	0,73	1,15	0,93	1,22	22,5
8	Надеждина Мария	93	51	54	154	54	16	4,8	3,9	90	72	555	512	70	0,46	0,58	1,01	0,5	1,21	44,3
9	Разимова Алсу	90	50	56	150	50	16	4,8	3,7	85	65	572	520	67	0,5	0,62	1,06	0,53	1,21	45
10	Дорофеева Маргарита	120	65	78	168	60	22	5,8	4,9	74	63	850	807	88	0,83	0,65	1,05	1,24	1,17	37,5
11	Фалясова Гандыш	101	51	72	156	51	20	5,1	4,3	71	59	753	707	76	0,78	0,71	1,17	1	1,17	8,7
12	Лизачёва Екатерина	110	61	68	171	55	16	5,5	4,5	80	66	728	680	79	0,66	0,62	1,04	0,85	0,94	27,7
13	Верховцева Карина	125	74	74	153	51	19	6	4,9	81	66	817	765	91	0,73	0,59	0,93	1,14	1,22	29,8
14	Кокошкина Мария	118	62	77	168	60	18	5,7	4,9	74	64	835	796	88	0,82	0,65	1,05	1,22	1,1	33,2
15	Короткова Кристина	113	57	63	169	64	18	5,5	4,9	87	77	675	649	85	0,57	0,56	0,94	0,78	1,16	39,2
16	Ганеева Лиана	118	71	69	163	59	20	5,8	4,6	84	67	752	697	85	0,65	0,58	0,95	0,93	1,2	18,3
17	Зубок Дарья	94	50	73	176	56	18	4,9	3,9	67	53	753	692	70	0,83	0,78	1,25	1	0,92	9,7
18	Пирогова Нина	105	50	57	172	68	16	5,2	4,7	90	82	599	579	82	0,48	0,54	0,93	0,63	1,14	42,7
19	Середина Дарья	110	64	61	161	62	18	5,5	4,4	90	73	653	608	79	0,53	0,55	0,95	0,67	1,27	46,2
20	Боброва Светлана	118	75	82	171	62	20	5,8	4,4	71	54	897	818	82	0,91	0,69	1,11	1,28	1,12	38,9
21	Гамова Мария	126	88	61	166	64	16	6,1	4,6	101	76	678	617	88	0,49	0,48	0,78	0,74	1,17	52,9
22	Клявина Анна	120	62	58	173	58	18	5,7	5,2	98	90	629	612	91	0,47	0,48	0,81	0,71	0,99	45,9
23	Лобова Екатерина	124	64	58	168	70	24	5,8	5,4	100	93	633	619	91	0,46	0,47	0,8	0,68	1,41	59,6
24	Роднова Елизавета	123	67	69	164	60	18	5,9	5,1	85	74	756	721	88	0,64	0,56	0,94	0,93	1,17	17,7

Fig. 2. Physiological characteristics and prognostic coefficients (software DiVa-S).

5 Pedagogical interpretation of the test

The results of the implementation of the sports standard RheoCaR allow to realize pedagogical monitoring of the levels of both general and special functional readiness of sportsmen in accordance with the characteristics of S.V. Fomin's model (1984) [8] (see **Fig.**), where:

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- M (%) – the intensity of the performed exercise. It characterizes the condition of the neurodynamical component of the control system and the powering component of implementation system.
- HR_0 (bpm) – pre-start HR. It characterizes the condition of the neurodynamical component of the control system.
- HR_{max} (bpm) – maximum HR achieved by the athlete performing a load test. It characterizes the condition of the neurodynamical component of the control system and the powering component of implementation system.
- HR_M (bpm) – the target HR at which the athlete moves from the mixed zone of energy supply purely in the anaerobic zone. It characterizes the condition of the powering component of implementation system.
- Time (s) – time to run a load test by an athlete. It characterizes the condition of the driving component of implementation system.

The level of the athlete's functional readiness (AFR, units) shows the athlete's work effectiveness during performing a load test regarding the state of her physical health, skills and psychological motivation (on **Fig.** for ice hockey players (women) levels of athlete's functional readiness are presenting the adaptation to Special Ice Work).

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«Ice test – 5×54 m», Russian ice hockey junior (18) women's team, 2014/11/04

№	Name	HR start	HR max	M, %	t, s	HRм	ATP-system	Aerobic-system	Anaerobic-system	General adaptation	Adaptation to Special Ice Work	Sports recommendations
1	Белоглазова Дарья	138	174	69,74	46,66	142	5	4	5	4	3,1	Poor motivation.
2	Водопьянова Елена	146	188	81,18	48,63	162	4	2	4	3	2,6	Requires an increase in aerobic work.
3	Канаева Диана	121	180	73,86	47,8	150	5	4	5	3	3,1	Poor motivation.
4	Кадирова Фануза	103	181	74,17	44,33	152	3	5	5	3	3	Poor ATP-system.
5	Штарёва Алевтина	109	179	74,85	46,86	148	4	2	5	3	2,6	Requires an increase in aerobic work.
6	Шохина Анна	130	182	76,10	44,93	153	4	3	4	3	2,7	Requires an increase in aerobic work.
7	Добродеева Екатерина	160	184	75,68	48	157	4	5	4	4	3,2	Poor motivation.
8	Надеждина Мария	103	166	67,47	50,65	130	4	2	5	3	2,4	Requires an increase in aerobic work.
9	Рахимова Алсу	128	179	75,00	47,21	148	4	2	5	3	2,6	Requires an increase in aerobic work.
10	Дорофеева Маргарита	150	188	77,46	49,48	163	4	4	5	3	3,1	Poor motivation.
11	Фаляхова Ландыш	101	172	67,57	46,36	140	4	5	4	5	3	Poor motivation.
12	Лихачёва Екатерина	146	171	67,76	47,32	138	5	4	5	4	3	Poor motivation.
13	Верховцева Карина	127	178	71,23	43,83	148	4	4	5	3	2,8	Poor motivation.
14	Кокошкина Мария	130	163	60,14	46,13	129	5	4	5	3	2,6	Poor motivation.
15	Коротких Кристина	140	177	72,61	48,06	146	4	3	5	3	2,7	Requires an increase in aerobic work.
16	Ганеева Лиана	132	182	74,83	47,8	154	4	5	5	4	3,4	Poor motivation.
17	Зубок Дарья	140	191	80,27	46,81	168	5	5	4	5	3,8	Adapted.
18	Пирогова Нина	120	189	80,98	45	164	4	2	5	3	2,8	Requires an increase in aerobic work.
19	Середина Дарья	142	178	73,58	50,52	147	4	3	5	3	2,8	Requires an increase in aerobic work.
20	Боброва Светлана	140	177	68,84	46,56	147	5	3	5	3	2,8	Requires an increase in aerobic work.
21	Гамова Мария	117	182	76,10	49,17	153	4	3	3	3	2,5	High risk of failure of adaptation.
22	Климкина Анна	120	168	67,90	47,88	133	5	3	4	3	2,5	Requires an increase in aerobic work.
23	Лобова Екатерина	116	176	72,84	46,59	144	3	3	4	2	2,2	Requires an increase in aerobic work.
24	Роднова Елизавета	123	178	72,19	48,75	148	4	5	5	4	3,2	Poor motivation.
	Averages on team	*128*	*178*	*73*	*47,3*	*148*	*4,2*	*3,5*	*4,6*	*3,3*	*2,8*	

M, % - intensity of ice work; **t, s** - time of run «Ice test»; **HRм** - heart rate transition of the mixed zone to the anaerobic zone

(green) - very well	(blue) - middling
(yellow) - good	(red) - bad

Fig. 3. Pedagogical interpretation of the sports standard RheoCaR results.

6 Research methods

The stage on the study of the General athlete functional readiness (GAFR) was performed using the method RheoCaR and the Bicycle Ergometer in 16 volunteers (10 men, 6 women), whose average age was 21±1.17 years. All volunteers were members of the university sports club.

Using test was based on the achievement by athletes of the maximum power of muscle load in 5 (five) series of 45′′, in which the heart rate rises to maximum values, followed by recovery pauses of 90′′:

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To determine the sports potential of the volunteers in this study, we used own Coefficient Anaerobic-Aerobic Capacity (CANAC Q, beats):

$$Q = \sqrt{\frac{HR_{start}}{BR_{start}} \cdot \frac{HR_{finish}}{BR_{finish}}} \qquad (6)$$

Continuous recording of the heart rate and respiratory rate of volunteers in the maximum power sports test was carried out by the «RheoCardioMonitor» device with an athlete functional readiness module based on the method of Transthoracic electrical impedance rheography (TEIRG) [9]–[13].

The method of Transthoracic electrical impedance rheography, which allows registering (allows to register) the frequency characteristics of the volunteer's bioimpedance response on the sport test of maximum power, thereby simultaneously recording the characteristics of his productive work of the heart channel, the effectiveness of the blood gas transport function, as well as to reliably assess its reactivity and adaptive potential.

TEIRG is based on measuring the modulus of electrical impedance of biological tissue when passing a high-frequency (30-150 kHz), low-intensity alternating current, which corresponds to electrical safety standards for the patient [14]. The maximum effective value of the probing current is determined by the electrical safety standard IEC60601 and for a frequency of 100 kHz corresponds to less than 10 mA [15].

The «ReoCardioMonitor» system has the following technical characteristics:

1. Power supply – 220 V ± 10%, frequency 50 ± 0.5 Hz;
2. Power consumption - no more than 20 W;
3. Electrical safety - class II, B;
4. Rheogram measurement method - tetrapolar;
5. Measuring current – 100 kHz, 8 mA;
6. Measurement range of base impedance - from 0 to 240 Ohm;
7. Measurement error of base impedance - ± 0.2 Ohm;
8. Measurement range of pulse impedance - ± 0.5 Ohm;
9. Measurement error of pulse impedance - ± 0.1 mOhm;
10. Number of channels - 2 (impedance) + 1 (ECG);
11. ECG lead - from rheographic electrodes.

In technical terms, the «ReoCardioMonitor» System represents a two-channel impedance measuring converter, a patient's cable system, and a personal computer. The first channel (**Fig. 4**, Channel 1) is designed to measure the transthoracic impedance of the chest (base and pulse components, impedance breathing pattern) with an ECG measurement channel from the same impedance electrodes. The transthoracic channel is used to calculate stroke output and cardiac output. The second channel (**Fig. 4**, Channel 2) measures breathing pattern.

The measurement method is tetrapolar. A source that creates an alternating current of high frequency is connected to the current electrodes. The signal is recorded from potential electrodes. With an increase in the distance between the current and potential electrodes, their influence on each other decreases and the accuracy of the measurement result increases [16]. **Fig. 4** shows the selected scheme of applying the electrodes.

The use of such a scheme for applying electrodes ensures greater uniformity of the current passing through the investigated area and reduces the effect on the measurement result of resistance variations at the electrode-skin interface [17].

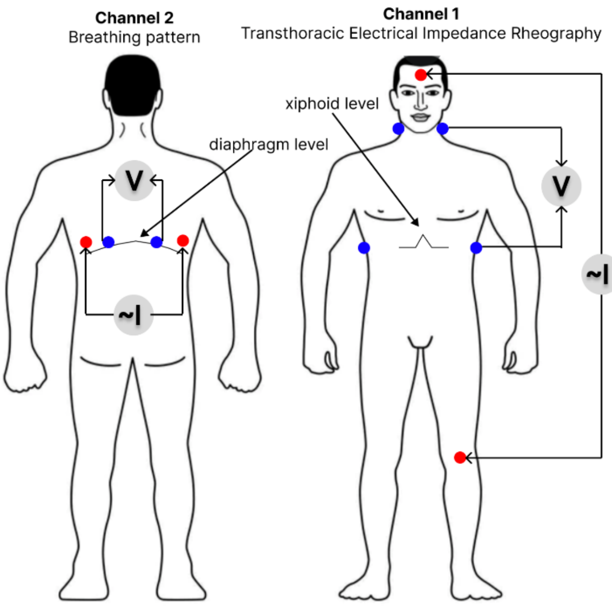

Fig. 4. Electrode arrangement diagram.

Contact with the patient's body was provided with disposable ECG electrodes of the White Sensor 4500 made Ambu company, electrode size 50 x 48 mm. The inner electrodes, marked in blue in the diagram, are measuring and registering the voltage change ΔU(t), which is used to calculate and register the impedance signal dZ. External electrodes are required to pass AC ~ I with high frequency and low amplitude. The change in impedance is recorded as a function of time Z(t).

7 Research results

The results of the study (**Fig. 5**, **Tab. 2**) measure the low levels of the General Athlete Functional Readiness of volunteers: on average GAFR=2,5 units was in all test series. Professional athletes must have a GAFR of at least 3,7 units.

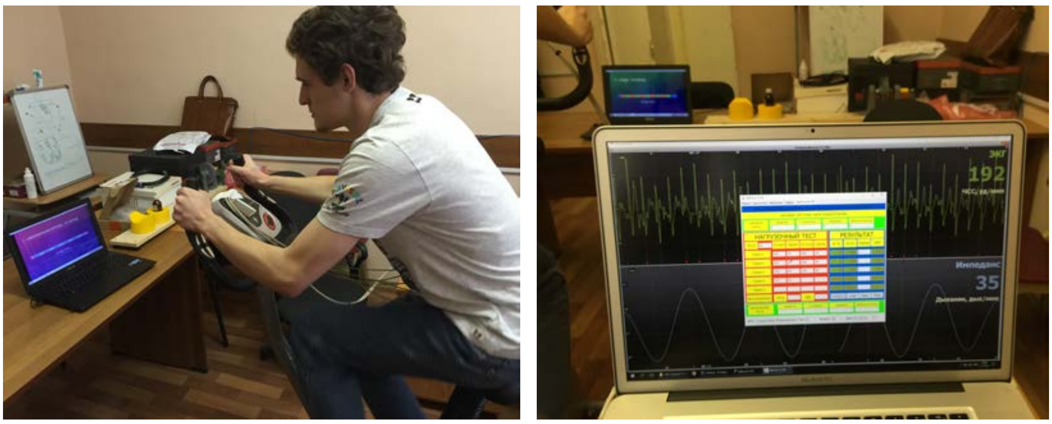

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Fig. 5. RheoCardioMonitor with moduls of athlete's functional readiness (RheoCaR).

Table 2. Results of the study of the General Athlete Functional Readiness with using the method RheoCaR in all series.

Functional indicators	1st series	2nd series	3rd series	4th series	5th series
HR_{start}, bpm	102,8±13,6	137,1±15,7	144,4±17,9	148,2±15,1	152,1±16,2
HR_{finish}, bpm	158,4±15,7	167,9±14,7	173,1±11,9	173,9±11,6	176,8±11,9
BR_{start}, rpm	17,1±6,9	19,4±4,7	22,1±5,7	23,4±4,7	24,1±6,0
BR_{finish}, rpm	33,7±6,5	35,1±5,1	37,6±7,2	39,5±7,9	40,0±7,6
M, %	66,7±8,4	65,9±7,2	67,7±5,9	67,2±7,1	68,4±7,0
HR_M, bpm	129,5±18,1	134,7±17,4	134,7±17,4	140,1±15,7	143,4±15,7
GAFR, units	2,51±0,70	2,48±0,63	2,59±0,64	2,54±0,60	2,61±0,57
CANAC Q, beats	5,7±1,29	5,9±0,87	5,7±1,13	5,4±0,92	5,5±0,99

The results of the study (**Tab. 2**) measure the low levels of the General Athlete Functional Readiness of volunteers: on average GAFR=2,5 units was in all test series. Professional athletes must have a GAFR of at least 3,7 units.

The value of the individual intensity (power) of the exercise (M) did not reach 70% in any of the test series. The Threshold value of anaerobic metabolism (HR_M) does not go beyond 145 bpm (the professional sports quality level must at least 165 bpm).

Positive correlations of functional indicators (M, HR_M, GAFR) with the Coefficient of Anaerobic-Aerobic Capacity (CANAC Q) were registered in the first two test series. However, during continuing series of work with increased power the correlations between the functional indicators began to destroy due to the pronounced fatigue of the volunteers (**Tab. 3**).

Table 3. The degree of correlation of functional indicators with CANAC Q in all series of the study.

Functional indicators	1st series	2nd series	3rd series	4th series	5th series
M, %	r=0,50 p<0,01	r=0,41 p<0,01	r=0,18 p>0,05	r=0,09 p>0,05	r=0,02 p>0,05

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HR_M, bpm	r=0,55 p<0,01	r=0,40 p<0,01	r=0,19 p>0,05	r=0,08 p>0,05	r=0,04 p>0,05
GAFR, units	r=0,53 p<0,01	r=0,51 p<0,01	r=0,38 p<0,05	r=0,29 p>0,05	r=0,33 p>0,05

The average maximum heart rate (HR_{finish}) of volunteers could not overcome the mark of 170.0±14.8 bpm (**Tab. 4**), although according to the Karvoner's formula, their maximum heart rate can reach 199 bpm.

Table 4. Results of the study of the general athlet's functional readiness with using the method RheoCaR for group in full.

Functional indicators	**Group in full (n=80)**
HR_{start}, bpm	136,9±23,7
HR_{finish}, bpm	170,0±14,8
BR_{start}, rpm	21,2±6,2
BR_{finish}, rpm	37,1±7,4
CANAC (Q, beats)	5,6±1,07

The maximum respiratory rate (BR_{finish}) also turned out to be excessively high 37.1±7.4 rpm (**Tab. 4**), which also indicates a very weak physical working capacity of this group of volunteers.

Table 5. The degree of correlation of functional indicators with CANAC Q for group in full.

Functional indicators	**Group in full (n=80)**	**Degree of correlation with CANAC Q**
M, %	67,2±7,2	r=0,241 p<0,01
HR_M, bpm	137,5±17,1	r=0,237 p<0,01
GAFR, units	2,55±0,63	r=0,406 p<0,01

The degree of correlation of functional indicators (M, HR_M, GAFR) with CANAC Q for the group in full (n=80) occurred at a very high level (**Tab. 5**), which confirmed the effectiveness of using the Coefficient Anaerobic-Aerobic Capacity (CANAC Q) in assessing the general functional readiness of an athlete.

8 Conclusions

Thus, the results of the study showed a very low average level of the General Athlete Functional Readiness among university sports club volunteers when using the sports standard RheoCaR (GAFR=2.55±0.63 units with the required level of more than 3.7 units). Moreover, the same result was obtained using a new sports indicator - the Coefficient Anaerobic-Aerobic Capacity (CANAC Q), which amounted to 5.6 ± 1.07 beats with the required level of more than 10,0 beats.

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The fundamental idea of CANAC Q is calculating of the ratio of increase in heart rate (HR) to increase of breath rate (BR) during intensive physical activity: than less BR spent to achieve maximum heart rate, thereby will be higher the anaerobic-aerobic capacity of athletes.

CANAC Q is measured in "beats" of the heart and recorded very accurately using the method of transthoracic electrical impedance rheography (TEIRG). For this reason, as a promising sports PSM-system, it can replace the methods for determining the athlete functional readiness by blood lactate concentration and maximum oxygen consumption.

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