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INDICATORS OF CENTRAL HEMODYNAMICS OF QUALIFIED ROWERS

A.V. Il'yutik, D.K. Zubovskij, A.Yu. Astashova
Belarusian State University of Physical Culture, Minsk, Belarus

Annotation. The purpose of this work was to study the functional state of the cardiovascular system of qualified athletes aged 18-20 years, specializing in rowing and canoeing, depending on the types of hemodynamics. The study involved 192 male athletes engaged in rowing and having sports qualifications (candidate for master of sports, master of sports). 73.4% of the examined athletes had a hyperkinetic type of hemodynamics, which is characterized by high indicators of cardiac output, cardiac index and low values of total peripheral vascular resistance. Rowers with hypo- and normokinetic types are characterized by more economical functioning of the cardiovascular system at rest and adequate changes in central hemodynamic parameters during exercise compared to rowers with hyperkinetic type of blood circulation.

Keywords: central hemodynamics, cardiovascular system, types of blood circulation, rowers, qualified athletes.

Introduction. An increase in the level of physical fitness of qualified rowers that ensures the development of needed motor qualities and improvement of technical and tactical training is connected with the process of adaptation of the body's physiological systems. The studies on the compensatory mechanisms of an athlete's body adaptation to strenuous physical activity are of high relevance and have a high practical value for managing and correcting the learning and training process. One of the main directions of the functional diagnosis of athletes is monitoring of the central hemodynamics (CH) indicators. It allows assessing the efficiency of the course of adaptation to the training and competitive activity, since the parameters of blood circulation are highly sensitive indicators of the functional state of the cardiovascular system and the body in whole [1-6]. Depending on the ratio of cardiac index (CI), cardiac output (CO) and total peripheral vascular resistance (TPVR), there are several types of CH: normokinetic, hypokinetic, hyperkinetic and eukinetic (between hypo- and normokinetic). High activity of the sympathoadrenal system is typical for people with the hyperkinetic type. Moreover, adaptation to physical activity is supported by inotropic and chronotropic heart functions with little involvement of the Frank-Starling mechanism [1-4]. It is known that stress on the function of the cardiovascular system can be a substantial factor that limits the sports result. At the same time, the hypokinetic type is the most economical, since in this case, the cardiovascular system possesses a great functional range.

Study on the features of blood circulation of athletes is a relevant issue of sports physiology. The evaluation of the hemodynamic indicators as signs of regulatory and adaptive rearrangements of the body during exercise allows taking a differential approach to the organization of the training process in order to prolong athletic longevity and preserve health of athletes.

The purpose of this work was to study the functional state of the cardiovascular system of qualified athletes aged 18-20 years specialized in rowing and canoeing depending on the types of hemodynamics.

Methods and organization. The study involved qualified athletes specialized in rowing (men, n=192, sports qualification – candidate for master of sports and master of sports, age – 18-20 years). The study took place during the preparatory period of the annual macrocycle.

The central hemodynamics indicators were registered with the differential tetrapolar rheography (the "Impekard-M" computer rheograph). We have studied the following CH indicators: heart rate (HR, beats/min); systolic and diastolic blood pressure (sBP, dBP, mm of

HG); stroke volume (SV, ml); cardiac output (CO, l/min×m^2); total peripheral vascular resistance (TPVR, dyn×s×m^{-5}). They were registered at rest and immediately after physical activity. We have applied the submaximal step-based test on the "Concept 2" stationary rower, the test continued up to a heart rate of 170 beats/min.

The mathematical data processing was made with variational statistics methods. The qualitative signs did not follow the law of normal distribution (according to the Shapiro-Wilk's test) and are presented in a form of median (Me) and interquartile range with a description of 25 and 75 percentiles' values: Me (25%; 75%). The significance of differences in the incidence was identified with the Fisher's exact test. The significance of differences between the indicators in the compared groups was identified with the Mann-Whitney U-test (when comparing two independent samples), Kruskal-Wallis H-test (when comparing three independent samples) and the Wilcoxon W-test (when examining differences between two samples of paired measurements). The critical value of the significance level was set to 0.05.

Results and discussion. Among the studied rowers, we have registered the following hemodynamics types. 73.4% of young men had the hyperdynamic type of blood circulation, which is more often than the normokinetic type – 22.4% ($p<0.01$ according to the Fisher's exact test, $\varphi_{emp}=10.5$) and significantly more often that the hypokinetic type – 4.2% ($p<0.01$ according to the Fisher's exact test, $\varphi_{emp}=16.1$).

The hyperkinetic type is characterized by increased values of CO and CI with reduced TPVR [1-4]. This type of hemodynamics indicates the least economical work mode of the heart, as well as reduced compensatory capabilities against the background of high activity of the sympathoadrenal system. However, the change of the blood flow regulation towards the prevalence of the hyperkinetic types may indicate the adaptation to strenuous physical activity of speed-strength nature.

The table below demonstrated the average group values of the cardiovascular system indicators in the highly qualified athletes specialized in rowing and canoeing depending on types of hemodynamics.

Table

Central hemodynamics indicators of the examined rowers
(young men, 18-20 years, candidate for master of sports, master of sports), Me (25%;75%)

Indicators before/after activity		Groups of examined rowers (young men)		
		Group 1, hypokinetic type (n=8)	Group 2, normokinetic type (n=43)	Group 3, hyyperkinetic type (n=141)
sBP, mm of Hg	before	120 (110; 130)	120 (115; 125)	120 (110; 125)
	after	190 (180; 210)	190 (180; 220)	190 (180; 210)
dBP, mm of Hg	before	70 (60; 70)	65 (60; 70)	70 (60; 70)
	after	20 (0; 45)	50 (0; 60)	40 (0; 50)
HR	before	56 (54; 58)*^{3}	57 (52; 64)	63 (59; 69)*^{1}
	after	171 (171; 174)	173 (171; 176)	173 (171; 176)
Bradycardia rate, %	before	100*$^{2, 3}$	62.8*$^{1, 3}$	36.2*$^{1, 2}$
SV, ml	before	**89.0 (82.1; 102.1)*$^{2, 3}$**	**112.5 (106.5; 123.9)*$^{1, 3}$**	**150.5 (128.7; 164.7)*$^{1, 2}$**
	after	**86.8 (71.8; 96.0)*$^{2, 3}$**	**120.6 (96,7; 133.2)*^{1}**	**144.5 (113.9; 179.2)*^{1}**
CO, l/min	before	**4.9 (4.8; 5.2)*$^{2, 3}$**	**7.1 (6.7; 7.6)*$^{1, 3}$**	**10.4 (9.3; 11.9)*$^{1, 2}$**
	after	**15.6 (12.1; 17.6)*$^{2, 3}$**	**22.0 (18.3; 26.3)*^{1}**	**24.6 (19.0; 28.7)*^{1}**

Table (continued)

CI, l/min×m^2	before	**2.4 (2.4; 2.5) *$^{2, 3}$**	**3.6 (3.3; 3.7)*$^{1, 3}$**	**5.1 (4.6; 5.8)*$^{1, 2}$**
	after	**7.2 (6.0; 8.1)*$^{2, 3}$**	**10.8 (8.6; 12.7)*^{1}**	**12 (9.3; 14.9)*^{1}**
TPVR, dyn×s×cm^{-5}	before	**1362.3 (1181.9; 1463.8) *$^{2, 3}$**	**950.9 (885.3; 1012.7) *$^{1, 3}$**	**653.0 (580.0; 731.2) *$^{1, 2}$**
	after	**849.1 (624.0; 1115.5)*^{3}**	**640.8 (582.4; 785.8)**	**494.8 (381.0; 617.2)*^{1}**
THI, c.u.	before	**131.3 (127.3; 136.0)*^{3}**	**142.3 (134.5; 151.5)**	**149.0 (138.7; 155.3)*^{1}**

Note: THI – total hemodynamic indicator; according to the Kruskal-Wallis H-test, the significant differences between three groups are highlighted in bold ($p<0.05$); * – significant differences between two groups according to the Mann-Whitney U-test ($p<0.05$), where *^{1} – significant differences of this group with the group 1, *^{2} – significant differences of this group with the group 2, *^{3} – significant differences of this group with the group 3

Mean values of sBP and dBP in rowers at rest before physical activity corresponded with the physiological norm and did not have any differences (table). Athletes with high rate had bradycardia as an indicator of economization in the function of the cardiovascular system at rest. For example, the average value of HR in athletes with the hypokinetic type amounted to 56 (54; 58) beats/min. Moreover, all rowers of this group had bradycardia. The average value of HR in young men with the normokinetic type amounted to 57 (52; 64) beats/min, bradycardia was registered in 62.8% of cases. The average value of HR in athletes with the hyperkinetic type amounted to 63 (59; 69) beats/min, which is significantly higher than those in rowers from the first group ($p<0.05$). Bradycardia in young men of the third group was registered in 36.2% cases, which is significantly rarer compared with the bradycardia rate of the first group rowers ($p<0.01$ according to the Fisher's exact test, $\varphi_{emp}=5.1$) and the second group rowers ($p<0.01$ according to the Fisher's exact test, $\varphi_{emp}=3.1$).

Low HR (less than 60 beats/min) with high SV values can be explained by a high tone of the cardiac wall which is a sign of the adaptive mobilization of the blood circulation system to physical loads of the speed-strength nature.

We have noted that 92.2% of athletes of the third group (hyperkinetic type) and 81.4% of the second group (normokinetic type) had the SV values that were higher than the physiological norm [3-4]. That explains high average group indicators of SV, CO and CI (table, the differences are significant when comparing three groups, $p<0.05$). The average group SV indicators in rowers with the hypokinetic type have amounted to 89.0 (82.1; 102.1) ml; in athletes with the normokinetic type – to 112.5 (106.5; 123.9) ml; in young men with the hyperkinetic type – to 150.5 (128.7; 164.7) ml (table, differences are significant when comparing three groups, $p<0.05$). Both average and individual high indicators of SV in athletes with normo- and hyperkinetic types of hemodynamics indicate a high performance of myocardium, adaptation to physical loads and a high level of physical qualities development.

The common factor of the increased SV in athletes is a reduced peripheral vascular resistance [3-4] that is total resistance of the arterial system to blood flow. Rowers with normo- and hyperkinetic types at rest before exercise had the TPVR indicators reduced below the physical norm (table, differences are significant when comparing three groups, $p<0.05$). The reduced TPVR is identified with post-activity effects in the peripheral vascular beds. A decrease in TPVR is important for ensuring the dismissed recovery processes: lactate metabolism and ketone bodies, glycogen refilling.

Substantial differences are found in the CI value in rowers depending on the hemodynamics type. Average group values of CI in athletes with the hypokinetic type amounted to 2,4 (2.4; 2.5) l/min×m^2, which is significantly lower compared to those in young men with normokinetic 3.6 (3.3; 3.7) l/min×m^2) and hyperkinetic types (5.1 (4.6; 5.8) l/min×m^2) (table, differences are differences are significant when comparing three groups, $p<0.05$).

After exercise, rowers from all groups had increased sBP, HR, CO, CI and decreased dBP and TPVR (table).

Attention should be paid to changes in SV after training activity. It was different between the groups. The SV indicators in rowers with the hypokinetic type slightly changes after physical activity compared to the state at rest: 89.0 (82.1; 102.1) ml before activity and 86.8 (71.8; 96.0) ml after activity (table). SV in athletes with the normokinetic type has significantly increased after physical loads. The increase has amounted to 7.2% compared to the state at rest: from 112.5 (106.5; 123.9) ml to 120.6 (96.7; 133.2) ml (table, $p<0.05$ according to the Wilcoxon W-test).

SV in rowers with the hyperkinetic type reduced (by 4.0%) from 150.5 (128.7; 164.7) ml at rest to 144.5 (113.9; 179.2) ml after testing (table), which is less favorable response to activity. Therefore, CO increase in athletes with the normokinetic type after physical loads occurs due to the both chronotropic and inotropic mechanisms of heart activity. Athletes with hypo- and hyperkinetic types have a predominantly active chronotropic mechanism.

Conclusion. Average sBP and dBp values in qualified athletes specialized in rowing and canoeing corresponded with the physiological norm regardless the initial type of hemodynamics. The examined rowers with high rate had bradycardia as an indicator of the blood circulation economization at rest: it was registered in 100% of athletes with the hypokinetic type, in 62.8% of athletes with the normokinetic type, and in 36.2% of athletes with the hyperkinetic type.

Support of the blood pressure level in case of the hyperkinetic type occurs due to the increased CI, SV, CO values and high power of the left ventricular contraction with low TPVR values, which reflects high performance of the myocardium and is a sign of the cardiovascular system’s adaptation to speed-strength physical activity. In case of the hypokinetic type of blood circulation, CI and power of the left ventricular contraction are minimal, while TPVR is maximal. The normokinetic type is characterized by intermediate values of these indicators.

An increase in CO in qualified rowers with hypo- and hyperkinetic types after exercise occurs mainly due to the chronotropic mechanism of heart activity (increase in heart rate) against the background of a decrease in SV, which reflects stress in the mechanisms of the cardiovascular system function.

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INFORMATION ABOUT THE AUTHORS:
Anna Vyacheslavovna Il'yutik – Candidate of Biological Sciences, Associate Professor, Associate Professor of the Department of Physiology and Biochemistry, Belarusian State University of Physical Culture, Minsk, e-mail: anna-iluytik@yandex.ru.
Dmitry Konstantinovich Zubovskij – Candidate of Medical Sciences, Head of the Laboratory of Functional Diagnostics and Restorative Technologies, Belarusian State University of Physical Culture, Minsk, e-mail: zubovskid@mail.ru.
Anastasia Yur'evna Astashova – Leading Specialist of the Laboratory of Functional Diagnostics and Restorative Technologies, Belarusian State University of Physical Culture, Minsk, e-mail: astashova@mail.ru.

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