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HEMODYNAMICS PARAMETERS AS RISK MARKERS OF POTENTIAL DISEASES IN THE CARDIOUVASCULAR SYSTEM AND THEIR ASSESSMENT IN YOUNG MEN WITH DIFFERENT TYPES OF BLOOD CIRCULATION SELF-REGULATION

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Functional state of the cardiovascular system is a basic criterion applied for assessing health and adaptive reactions of a human body; therefore, it seemed to be advisable to examine compensatory mechanisms of a human body under exposure to adverse external factors. Our research goal was to study functional parameters of cardiohemodynamics in young men depending on a type of blood circulation self-regulation. We examined 368 young male students born in the northern-eastern regions of Russia. Their average age was equal to 18.5±0.08. We measured basic anthropometric parameters of each young student, namely body height and body mass. Cardiohemodynamics parameters were determined in young male students at rest, in a sitting position, via volumetric compression oscillometry with a set of hardware and software complex for non-invasive research of the central hemodynamics ("Globus", Belgorod). Results. We analyzed distribution of individual TBS (type of blood circulation self-regulation) index values and revealed that 48.1 % young men had cardiac TBS; 35.9 %, cardiovascular TBS; and 16,0 %, vascular TBS. Young people with the vascular TBS tended to have the highest systolic and diastolic blood pressure, stroke volume, the most powerful left ventricular contraction and overall peripheral vessels contraction; on the contrary, young men with the cardiac TBS tended to have the lowest values of these parameters. Young men with the cardiovascular TBS were somewhere in between the two previously mentioned groups. But at the same time, such parameters as heart rate (HR), pulse wave velocity (PWV), and Kerdo vegetative index (KVI) were the highest in young men with the cardiac TBS; and the lowest ones, in young men with the vascular TBS. This research allows to assess risks of diseases in the cardiovascular system and diabetes in young men so that relevant preventive activities can be performed.

Key words: *young men; functional parameters of cardiohemodynamics; types of blood circulation self-regulation; northern-eastern regions of Russia.*

Functional state of the cardiovascular system is a basic criterion used to assess health and adaptive responses of a human body.

Adverse external influences cause compensatory insufficiency in a body which can lead to adaptation failure and pathological changes. Given that, it seems quite necessary to develop new methodical approaches to assessing adaptation capabilities of a human body and it is a vital task for preventive medicine since such approaches can allow to determine prenosological changes in functional systems and to work out targeted preventive activities [1-3].

Some experts state that a set of natural-climatic, ecological, and social-hygienic environmental factors exerts great influence on physical development, formation of functional systems in a human body, and population health [4, 5]. Since arctic and subarctic areas are being developed and development programs for these territories are being enlarged, it becomes more and more important to examine adaptation and health preservation under extreme climatic conditions existing in the northern regions; research that has been previously performed in the sphere confirms that

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such conditions exert negative impacts on human health [6-10]. N.I. Arinichin et al. performed an integral assessment of the cardiovascular system functions and analyzed a ratio of the cardiac and vascular components in the central hemodynamics; basing on the results of their assessment and analysis, they detected that there were three basic (standard) types of blood circulation self-regulation in adult people, namely, cardiac, vascular, and cardiovascular one [11, 12]. A type of blood circulation self-regulation (TBS) is an informative prenosological integral parameter that reflects peculiarities of adaptive responses and phenotypic body properties among healthy people. TBS determination makes it possible to assess strain in the cardiovascular system regulation at various stages in ontogenesis. It was shown that if the vascular component prevailed in blood circulation self-regulation, it meant the process was economized and functional reserves of the cardiovascular system grew to provide long-term adaptation; but if the cardiac component prevailed, it meant that the cardiovascular system functioning was strained and it was necessary to provide adaptation to sudden short-term exposure to perturbing environmental factors. But if TBS is cardiovascular, it means that blood circulation self-regulation is balanced in the most optimal way.

At present a stable population consisting of alien Eastern Slavs is being formed in the northeast Russia. Most young people who live in the region belong to the 1st-3rd generation of Caucasians. The cardiovascular system is one of the most significant body systems that can show whether a body has truly adapted to extreme conditions in the North; health of people who permanently live and work here directly depends on the cardiovascular system functioning.

Our research goal was to examine functional parameters of cardiohemodynamics depending on a type of blood circulation self-regulation in young males born in the northeast Russia.

Research object and methods. We examined cardiohemodynamics in practically healthy young males who studied at a higher educational establishment, were born in Magadan and Magadan region, and belonged to the 1st-2nd generation of Caucasians. The examination was performed before lunchtime in a room with a comfortable temperature. Overall, we examined 368 young males, their average age being 18.5±0.08. We measured basic anthropometric parameters of each young male student (body height - BH, cm, and body weight - BW, kg) with conventional techniques. Cardiohemodynamics parameters were determined in young males at rest, in a sitting position, via volumetric compression oscillometry with a set of hardware and software complex for non-invasive research of the central hemodynamics ("Globus", Belgorod). We registered the following direct and calculated parameters of the central and peripheral hemodynamics: systolic (SBP) and diastolic (DBP) blood pressure (mmHg), heart rate (HR, strokes/min), cardiac output (CO, l/min), stroke volume (SV, ml), power of the left ventricular contraction (PLVC, Wt), energy consumption required to transfer 1 liter of CO per minute (EC, Wt), overall (OPVR, dyn.*s*cm^{-5}) and specific (SPVR, arbitrary units) peripheral vascular resistance, pulse wave velocity (PWV, cm/s), vascular compliance (VC, ml/mmHg), type of blood circulation self-regulation (TBS, arbitrary units). TBS index which varies from 90 to 110 means a person has cardiovascular TBS; if TBS index is more than 110, a person has vascular TBS, and if it is less than 90, a person has cardiac TBS. Basing on all the obtained data, we calculated Kerdo vegetative index (KVI, arbitrary units) as per the following formula: KVI = (1-DBP/HR)*100.

We accomplished our research in full conformity with the principles stated in Helsinki Declaration (2008). The research protocol was approved by the Ethics Committee for medical and biological research at the Northeastern Scientific Center of the RAS Far Eastern Brunch. All the examined young males were provided with complete information on the essence and goals of the research and gave their written consent to take part in it.

The obtained data were statistically processed with such conventional software as Microsoft Excel and StatSoft Statistica 6.0 applied statistical software package. We applied Shapiro-Wilk test W to check whether the obtained data were compliant with the normal distribution law, calculated average values (M), their standard errors (±m), and standard devia-

tions (±σ). Statistical significance of discrepancies was estimated with Student's t-test for independent samplings provided that distribution was normal. Discrepancies at $p \leq 0,05$ were considered to be statistically significant.

Results and discussion. Our research revealed that average TBS index value was equal to 92.4±0.9 if taken for the overall group on average and it meant that young males tended to have cardiovascular TBS. However, after we analyzed distribution of individual TBS index values, we revealed that 48.1% among examined young males had cardiac TBS (78.4 ± 0.6 arbitrary units); 35.9%, cardiovascular TBS (98.8 ± 0.5 arbitrary units); and 16.0%, vascular TBS (120.1 ± 1.1 arbitrary units). Young males with different TBS didn't have any discrepancies in average values of their body height and body weight. In order to detect peculiarities in the cardiovascular system functioning in young males with different TBS, we analyzed distribution of individual hemodynamics parameters as per TBS index (Table).

Table

Anthropometric and hemodynamic parameters in young male students with different types of blood circulation self-regulation living in Magadan ($M \pm \sigma$)

Parameters	Type of blood circulation self-regulation			P
	Cardiac (1)	Cardiovascular (2)	Vascular (3)	
	n = 177	n = 132	n = 59	
BH, cm	179.3 ± 7.4	179.8 ± 7.8	178.7 ± 6.7	
BW, kg	69.9 ± 11.9	72.8 ± 12.5	73.1 ± 11.9	
SBP, mmHg	125.8 ± 12.7	128.3 ± 11.5	132.1 ± 14	$P<0.011^{1-3}$
DBP, mmHg	61.8 ± 7.7	67.0 ± 8.1	73.2 ± 11.5	$P<0.001^{1-2}$ $P<0.001^{2-3}$ $P<0.001^{1-3}$
BP pulse, mmHg	63.9±14.5	61.3±13.1	58.9±14.1	$P<0.05^{1-3}$
HR, strokes/min	79.7 ± 12.1	68.1 ± 8.9	61.2 ± 10.4	$P<0.001^{1-2}$ $P<0.001^{2-3}$ $P<0.001^{1-3}$
CO, l/min	6.21 ± 0.89	6.21 ± 0.79	6.19 ± 0.75	
SV, ml	79.6 ± 16.4	92.8 ± 17.0	103.9 ± 22.5	$P<0.001^{1-2}$ $P<0.001^{2-3}$ $P<0.001^{1-3}$
PLVC, Wt	2.96 ± 0.68	3.44 ± 0.64	4.01 ± 0.90	$P<0.001^{1-2}$ $P<0.001^{2-3}$ $P<0.001^{1-3}$
PWV, cm/sec	999.4±124.9	975.5±96.4	940.3±101.7	$P<0.001^{2-3}$ $P<0.001^{1-3}$
VC, ml/mmHg	1.32±0.19	1.61±0.19	1.86±0.25	$P<0.001^{1-2}$ $P<0.001^{2-3}$ $P<0.001^{1-3}$
OPVR, dyn.*sec*cm^{-5}	1042 ± 135	1073 ± 111	1128 ± 146	$P<0.05^{1-2}$ $P<0.05^{2-3}$ $P<0.001^{1-3}$
SPVR, arbitrary units	24.1 ± 2.4	25.2 ± 2.5	26.6 ± 3.5	$P<0.001^{1-2}$ $P<0.01^{2-3}$ $P<0.001^{1-3}$

Note: validity of discrepancies is calculated as per M ± m

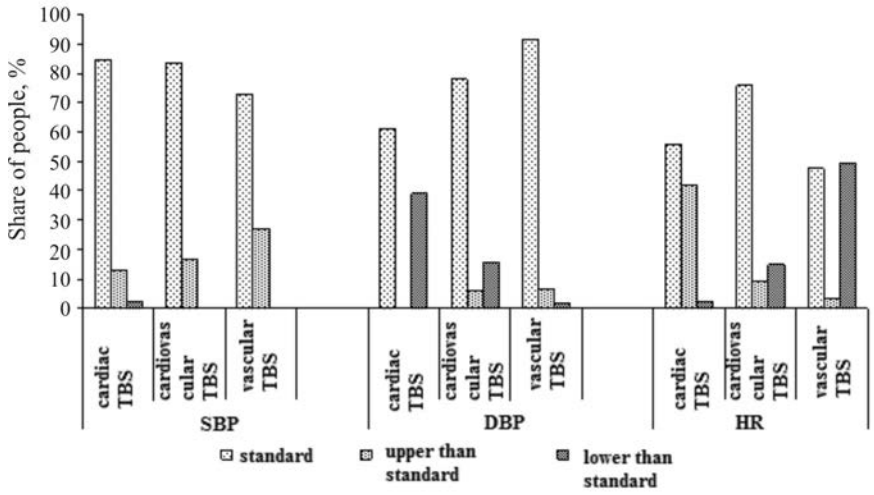

Figure. Distribution of young males as per individual values of SBP, DBP, and HR within groups with different types of blood circulation self-regulation (%)

The analysis revealed that there were significant discrepancies in values of the examined hemodynamic parameters in young males with different types of blood circulation self-regulation. We detected that people with vascular TBS tended to have the highest values of such functional parameters of the cardiovascular system as SBP, DBP, SV, PLVC, OPVR, SPVR, and VC; people with cardiac TBS tended to have the lowest values of the same parameters; and young males with cardiovascular TBS were somewhere in between as per values of these parameters. At the same time, such parameters as BP pulse, HR, PWV, and KVI were the highest in young males with cardiac TBS; the lowest, in those with vascular TBS. We didn't reveal any authentic discrepancies in CO between young males with different TBS; it means that blood circulation in all young males, regardless of their TBS, is at its optimal level when a body is at rest and all the physiological needs are quite satisfied.

Systolic and diastolic blood pressure and heart rate are the most available for detection and informative functional hemodynamics parameters. We detected that average values of these parameters, both among the overall sampling and in groups with different TBS, corresponded to age-related standards in spite of all statistically significant discrepancies between groups; thus, average SBP was 100–139 mmHg; average DBP, 60–89 mmHg; and HR, 60–80 strokes per minute. However, averaged values don't allow to estimate variability of individual parameters within groups. To assess it, we analyzed individual values of the examined parameters in groups with different TBS (Figure).

The performed analysis allowed to reveal that individual SBP, DBP, and HR were significantly labile in each group of young males. Thus, distribution as per SBP showed that the highest shares of people who had this parameter within "standard" were in groups with cardiac TBS (84.7%) and cardiovascular TBS (83.3%); the lowest share was in the group with vascular TBS (72.9%). An insignificant share of people with low SBP was found only among young males with cardiac TBS (2.3%); the highest share of people with the parameters exceeding the standards was detected among young males with vascular TBS (27.1%). As regards DBP, we detected an inverse correlation here: the share of people with DBP within "standards" prevailed significantly among young males with vascular TBS (91.5%) against those with cardiac TBS (61.0%). DBP that was lower than "standards" was more frequently detected among young people with cardiac TBS (39.0%) than among those with cardiovascular TBS (15.9%) and vascular TBS (1.7%); DBP that was higher than "standard" was detected only in the group with vascular TBS (6.8%). Young males with cardiovascular

TBS were somewhere in between as regards distribution as per DBP value. Distribution as per HR values revealed that the highest share of people with this parameter being within "standards" was among young males with cardiovascular TBS (75.8%), while a significant number of people with cardiac TBS had this parameter higher than "standards" ("tachycardia", 41.8%), and about a half young males with vascular TBS (49.1%) had this parameter lower than "standards", or, in other words, they had "bradycardia".

Pulse blood pressure (BP pulse) is known to depend not only on the heart contractility but also on vascular compliance of large arteries. The more blood is pumped into the bloodstream and the more rigid an arterial wall is, the higher is pulse blood pressure. Our research results revealed a trend for lower BP pulse values from cardiac TBS to vascular one (63.9±1.1 → 58.9±1.8 mmHg) and statistically significant discrepancies between the two end types of blood circulation self-regulation ($P<0.05$).

Stroke volume (SV) and power of the left ventricle contraction (PLVC) are important parameters that characterize the heart functioning. The comparative analysis revealed that young males with vascular TBS tended to have the highest values of these parameters, and young males with cardiac TBS tended to have the lowest ones. Distribution as per PLVC values showed that 22.0% young males with vascular TBS and 6.1% young males with cardiovascular TBS had this parameters higher than the standard. 9% young males with cardiac TBS had insufficient PLVC, and we didn't detect anything similar in two other groups. All the rest young males had PLVC values within age-related standards (2.0–4.5 Wt).

We revealed statistically significant discrepancies between groups with different TBS as per pulse wave velocity (PWV) and vascular compliance (VC) that characterize vessels elasticity and conveying capacity of the artery bloodstream as a whole. The highest PWV values were detected among young males with cardiac TBS (999.4 ± 9.4 cm/sec); the lowest ones, among those with vascular TBS (940.3 ± 13.2 cm/sec). Young males with cardiovascular TBS were somewhere in between as per this parameter. We saw an inverse picture as per VC values as the highest ones were detected among young males with vascular TBS, and the lowest ones were detected among those with cardiac TBS. We should note that, despite any discrepancies, average PWV and VC values were within the standards in each group of young males (600-1000 cm/sec and 1.03-2.35 mmHg). However, distribution of males as per individual PWV values revealed that a certain number of people within each group had PWV higher than the upper boundary of the standard. Thus. the highest share of people with PWV exceeding the standard was detected among young males with cardiac TBS (53.7%), and the lowest one, among those with vascular TBS (28.8%); there were 38.6% young males with their PWV higher than the standards in the group with cardiovascular TBS. All the rest young males in all three groups had their PWV within the standards. As regards VC, 92.66% young males with cardiac TBS and 96.6% young males with cardiovascular TBS had this parameter within the standards. VC values that were lower than the standard were detected only among young males with cardiac TBS (7.34%); and VC values that were higher than the standard were detected only among those with vascular TBS (3.4%). All the young males with cardiovascular TBS had this parameter within the standards.

N.V. Gorymanova et al (2015) and v.V. Skibitsky et al (2018) detected a correlation between PWV and vessels elasticity, blood pressure, and carbohydrate metabolism [13, 14]. It was shown that the greater pulse wave velocity was, the more rigid were the arteries, and the higher were concentrations of dextrose and glycated hemoglobin in blood. In these authors' opinion, elevated PWV is associated with carbohydrate metabolism disorders in relation to tissues being less sensitive to effects produced by insulin [13]. I.V. Averyanova and A.L. Maximov showed that 25-28% out of young male students examined by them in Magadan had dextrose concentration in their blood at the upper boundary of the standard or

even exceeding it, and it allowed the authors to conclude that these young males were in prediabetic state and to assign them into a group of people who ran a risk of possible persistent disorders in carbohydrate metabolism [15].

We compared the data which we obtained for PWV values with the results obtained by the above-mentioned authors and it allowed us to make a tentative conclusion that young males with PWV >1000 cm/sec, who were present in each TBS group had carbohydrate metabolism disorders and were prone to accelerated biological ageing of the vessels. We also detected statistically significant discrepancies as per OPVR and SPVR parameters between the groups with different TBS. The highest OPVR and SPVR values were detected among young males with vascular TBS (1,128 ± 19 dyn.*s*cm^{-5} and 26.6 ± 0.5 arbitrary units); and the lowest ones, among young males with cardiac TBS (1,042 ± 10 dyn.*s*cm^{-5} and 24.1 ± 0.2 arbitrary units).

Conclusion. Practically healthy young males who lived in Magadan could have any of the three types of blood circulation self-regulation, namely cardiac, vascular, or cardiovascular one, depending on a ratio of the cardiac and vascular components. We detected that blood pressure and cardiac output that were integral parameters of tissue circulation efficiency were maintained with different regulatory mechanisms in young males from Magadan with the end hemodynamics regulation types when their bodies were at rest. If a young male had cardiac TBS, these parameters were regulated due to higher heart rate and prevailing sympathetic influence on the heart functioning (KVI = 21.6±0.6); if a young male had vascular TBS, they were maintained due to greater contractility of the cardiac muscle, greater stroke volume, and overall peripheral vessels resistance with prevailing parasympathetic regulation (KVI = -20.1±1.1). Young males with cardiovascular TBS had the most well-balanced blood circulation self-regulation (KVI=1.2±0.5). Intragroup dynamics of SBP, DBP and HR values distribution allowed us to conclude that central hemodynamics regulation mechanisms related to the cardiac component prevailed among young males who were born in Magadan. There was a certain number of people with elevated SBP (13% in cardiac TBS group; 16.7%, in cardiovascular TBS group; and 27.1%, in vascular TBS group) and DBP values were rather labile; it proves there is a risk of arterial hypertension, especially among young males with vascular TBS. Our research revealed that there were young males with SBP values higher than the standards in each group. Basing on the literature sources [13, 14, 15] and the data which we obtained in our research we can make a tentative conclusion that SBP values which are considerably higher than the upper boundary of the standard, which is especially characteristic for young males with cardiac TBS, can be adverse predictors of risks related to persistent disorders in carbohydrate metabolism and diabetes, susceptibility to thrombus occurrence, greater "rigidity" of the arteries and cardiac and cerebrovascular complications.

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