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O.N. Ragozin, I.A. Pogonysheva, E.Yu. Shalamova, D.A. Pogonyshev, V.V. Postnikova, M.S. Kuchumov

HEMODYNAMIC INDICATORS OF NORTH RESIDENTS ENGAGED IN WINTER SWIMMING

Рагозин О.Н., Погонышева И.А., Шаламова Е.Ю., Погонышев Д.А., Постникова В.В., Кучумов М.С.

ГЕМОДИНАМИЧЕСКИЕ ПОКАЗАТЕЛИ ЖИТЕЛЕЙ СЕВЕРА, ЗАНИМАЮЩИХСЯ МОРЖЕВАНИЕМ

Abstract. The purpose of the study is to assess changes in hemodynamic parameters in areas of the northern city (Khanty-Mansiysk Autonomous Okrug – Yugra) under the influence of extreme cold temperature. Determination of hemodynamic parameters was carried out by compression oscillometry method using the APKO-8-RITS-M circulatory parameters analyzer. Results: under the influence of extreme cold water, all subjects showed an increase in the values of systolic and mean arterial pressure and pulse pressure. There was an increase in cardiac output, stroke volume of blood, cardiac index and stroke index; significant differences in the dynamics of these indicators were revealed. For the majority of surveyed people (77.7%), engaged in winter swimming, a tendency to increase arterial stiffness under conditions of general cold stress was revealed. Conclusion: in general, the tolerance of extreme cold stress in men can be assessed as satisfactory, since on average there is an increase in cardiac output, largely due to stroke output; there is a correspondence between the actual resistance of peripheral vessels and the working specific peripheral resistance. Since there were no significant changes in the diameter of the brachial artery with an increase of pulse wave velocity after swimming in cold water, this suggests the preservation of the observed elastic properties of the vascular wall. Data obtained from a limited number of examined people indicate the possibility of identifying the initial stages of disorders of the elastic properties of the aorta using compression oscillometry and

Аннотация. Цель исследования – оценить изменение гемодинамических показателей жителей северного города (Ханты-Мансийский автономный округ – Югра) под влиянием экстремального холодового температурного воздействия. Определение гемодинамических показателей проводилось методом компрессионной осциллометрии с использованием анализатора параметров кровообращения «АПКО-8-РИЦ-М». Результаты: под воздействием экстремальной холодовой аква-нагрузки у всех обследуемых мужчин отмечено увеличение значений систолического и среднего артериального давления, пульсового давления; отмечалось повышение сердечного выброса, ударного объема крови, сердечного индекса, ударного индекса, в динамике этих показателей выявлены значимые отличия. Для большинства обследованных (77,7%), занимающихся моржеванием, выявили тенденцию к увеличению жесткости артерий в условиях общего холодового стресса. Выводы: в целом переносимость экстремальной холодовой нагрузки у мужчин может оцениваться как удовлетворительная, так как в среднем происходит увеличение сердечного выброса в большей степени за счет ударного выброса; наблюдается соответствие фактического удельного сопротивления периферических сосудов рабочему удельному периферическому сопротивлению. Так как не отмечено значимых изменений диаметра плечевой артерии при приросте показателей скорости пульсовой волны после плавания в холодной воде, это позволяет предполагать сохранность у обследуемых эластических свойств сосудистой стенки. Полученные на ограниченном количестве обследуемых данные, свидетельствуют о возможности выявления начальных стадий expanding the capabilities of early diagnosis of signs of aortic stiffness.

Keywords: compression oscillometry; hemodynamic parameters; winter swimming; north; adaptation.

About the authors: Oleg N. Ragozin, ORCID: 0000-0002-5318-9623, Doctor of Medical Sciences, Khanty-Mansiysk State Medical Academy, Khanty-Mansiysk, Russia; Nizhnevartovsk State University, Nizhnevartovsk, Russia, oragozin@mail.ru; Irina A. Pogonysheva, ORCID: 0000-0002-5759-0270, Candidate of Biological Sciences, Nizhnevartovsk State University, Nizhnevartovsk, Russia, severina.i@bk.ru; Elena Yu. Shalamova, ORCID: 0000-0001-5201-4496, Doctor of Biological Sciences, Khanty-Mansiysk State Medical Academy, Khanty-Mansiysk, Russia, selenzik@mail.ru; Denis A. Pogonyshev, ORCID: 0000-0001-8815-1556, Candidate of Biological Sciences, Nizhnevartovsk State University, Nizhnevartovsk, Russia, dapogonyshev@nvsu.ru; Victoria V. Postnikova, ORCID: 0000-0001-7846-7864, Nizhnevartovsk State University, Nizhnevartovsk, Russia, missmadcon@mail.ru; Mihail S. Kuchumov, ORCID: 0000-0003-4714-5023, Nizhnevartovsk State University, Nizhnevartovsk, Russia, mixaelok@mail.ru

нарушения эластических свойств аорты с помощью компрессионной осциллометрии и расширении потенциала ранней диагностики признаков жесткости аорты.

Ключевые слова: компрессионная осциллометрия; гемодинамические показатели; моржевание; север; адаптация.

Сведения об авторах: Рагозин Олег Николаевич, ORCID: 0000-0002-5318-9623, д-р мед. наук, Ханты-Мансийская государственная медицинская академия, г. Ханты-Мансийск, Россия; Нижневартовский государственный университет, г. Нижневартовск, Россия, oragozin@mail.ru; Погонышева Ирина Александровна, ORCID: 0000-0002-5759-0270, канд. биол. наук, Нижневартовский государственный университет, г. Нижневартовск, Россия, severina.i@bk.ru; Шаламова Елена Юрьевна, ORCID: 0000-0001-5201-4496, д-р биол. наук, Ханты-Мансийская государственная медицинская академия, г. Ханты-Мансийск, Россия, selenzik@mail.ru; Погонышев Денис Александрович, ORCID: 0000-0001-8815-1556, канд. биол. наук, Нижневартовский государственный университет, г. Нижневартовск, Россия, dapogonyshev@nvsu.ru; Постникова Виктория Владимировна, ORCID: 0000-0001-7846-7864, Нижневартовский государственный университет, г. Нижневартовск, Россия, missmadcon@mail.ru; Кучумов Михаил Сергеевич, ORCID: 0000-0003-4714-5023, Нижневартовский государственный университет, г. Нижневартовск, Россия, mixaelok@mail.ru

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According to the literature data, such a social phenomenon as “winter swimming” refers to the hardening system and combines different types of cold exposure (immersion in cold water, winter swimming, winter sports swimming). Interest in winter swimming has been increasing in recent years; people visit amateur clubs and sports sections [5; 6]. The influence of extreme cold exposure on the human body and, in particular, on the cardiovascular system, is assessed ambiguously; the observed functional manifestations illustrate complex adaptation to the stress factor.

Several foreign studies describe the positive effects of winter swimming on the cardiovascular system; there is a decrease in the risk of cardiovascular diseases, normalization of the lipid profile [3; 7; 13] and blood pressure (BP) [10]. Results have been published showing an increase in systolic blood pressure (SBP) and diastolic blood pressure (DBP) by 20 mmHg in the first 60 seconds of extreme cold exposure, which was a hyperreactivity observed mainly in subjects with hypertension or in individuals prone to hypertension in later life [15]. Indian scientists assessed the cardiovascular system's response to cold using a stress test. Healthy young people immersed their hands up to the wrist in cold water with a temperature of 5°C. Before the test and 1, 3 and 5 minutes after the dive, blood pressure measurements were taken with a sphygmomanometer. The majority of subjects had a statistically significant increase in blood pressure, diastolic by 16.02%, systolic by 12.10%. An increase in heart rate (HR) by 23.09% was also detected. Heart rate increased significantly after 1 minute of immersion and by the end of 5 minutes it almost reached normal values ($p < 0.05$). Despite the statistically significant increase in these indicators, they were within normal limits [14].

According to Popov A.V., Suxovej, Yu.G. et al. (2003), prolonged cold exposure can lead to depletion of functional systems that implement adaptation mechanisms, including the immune system. The authors note the different effects of cryogenic regimes on organs and systems, which depend on the premorbid background; primarily the fitness of the body, the presence of chronic diseases, clinical and anamnestic signs of immune deficiency, etc. [16; 17]. E.G. Kostolomova (2006) conducted a comparative analysis of the parameters of the immune system of “almost healthy people” and “winter swimmers” in response to immersion in ice water. It was revealed that “winter swimmers” develop a special type of immune status, manifested by a redistribution of the activation-proliferative component of the lymphocyte-cell link, an increase in the level of immunoglobulins of classes M and G against the background of a decrease in large-molecular circulating immune complexes, a decrease in the intensity of phagocytosis of neutrophils and the activity of oxygen-dependent metabolism of monocytes [12].

A number of authors believe that in the process of hardening, especially winter swimming, the psycho-emotional state is normalized, increases efficiency, and anxiety decreases [5; 6]. It was also found that regular winter swimming can have a beneficial effect on the sleep and well-being of patients diagnosed with depression. The study involved patients aged 20 to 69 years who practiced cold water swimming twice a week [8]. According to the results of a study by P. Huttunen, L. Kokko, V. Ylijukuri (2004), at the end of a four-month period of winter swimming, swimmers felt more energetic, active and cheerful, compared to the examined of the control group. All swimmers with a history of rheumatism and/or fibromyalgia reported that winter swimming relieved their pain [9].

The effect of regular winter immersion in water on the activity of the sympathoadrenal system was studied. Some findings suggest that winter swimming significantly activates the sympathetic nervous system even after cold acclimation, without affecting the adrenal medulla. The change in plasma epinephrine levels is likely dependent on the level before cold exposure. Swimmers whose plasma adrenaline levels dropped during the test dive had higher predive levels than those whose adrenaline levels increased. Individual characteristics may also influence the amount of cortisol released in response to cold exposure. These results may explain why some "winter swimmers" find swimming in ice-cold water stimulating while others find it relaxing [11].

The circulatory system plays a significant role during adaptation to extreme hypothermic exposure. The purpose of the study is to evaluate changes in hemodynamic parameters under the influence of extreme cold temperature exposure.

The study was conducted in the suburbs of Nizhnevartovsk (KhMAO-Yugra, a region equated to the regions of the Far North), Lake Molodezhnoye. At the time of the study (February 28, 2023), the following weather conditions were recorded: air temperature was –5 °C; water temperature +1.8 °C; atmospheric pressure 743 mmHg.; southern wind at a speed of 5.7 m/s; air humidity 84%. The temperature of water and air didn't change during the study. Members of the "Bodryachok" club engaged in winter swimming, a total of 39 people, were examined. We interpreted hemodynamic parameters in subjects with initially normal blood pressure values, according to national and European recommendations of cardiologists [2; 4]. The table presents the results of 18 men with initial blood pressure corresponding to normal values, who are in the second period of adulthood. 21 people (53.8%) were excluded from the analyzed sample because 20 minutes before immersion in cold water they had high resting blood pressure (the threshold of 140/90 mmHg was exceeded). The average age of the formed sample is 43.4±1.5 years. The hardening experience averaged 2.1±0.14 g. The average time spent in cold water was 2.4±0.5 minutes. The study was approved by the Local Ethics Committee of the Federal State Budgetary Educational Institution of Higher Education "Nizhnevartovsk State University" (Protocol No. 1 dated 01/23/2023). All participants signed voluntary informed consent to participate in the study.

Determination of hemodynamic parameters was carried out by compression oscillometry method using the APKO-8-RITS-M circulatory parameters analyzer (automatic non-invasive complex for express diagnostics of the cardiovascular system). The technique allows to determine the pulse wave velocity (PWV) on the brachial artery by computer analysis of changes in the instantaneous values of the volume of the brachial artery and the pressure in it under the influence of increasing pressure in the pinch cuff. The advantage of this method is the ability to determine, in addition to PWV, 17 more vascular and cardiac parameters. Oscillometric determination of linear parameters of blood flow in the brachial artery is a reliable way to study not only peripheral, but also central hemodynamics [1, 18]. Hemodynamic parameters were measured twice: before swimming in cold water (20 minutes); immediately after the end of cold exposure.

The Excel 2010 and Statistica 10.0 software package was used for statistical processing of primary data. The normality of the distribution of these characteristics was checked using the Kolmogorov–Smirnov test. For comparative analysis, the nonparametric Mann-Whitney test for two independent samples was used. The data is presented in the form: M±m (M – arithmetic mean, m – error of the arithmetic mean). The significance level (p) was calculated: differences between the compared values were considered significant at ($p \leq 0.05$).

As it turned out, in 13 subjects (72%) 20 minutes before extreme cold exposure, SBP increased to an average of 132.2 ± 2.85 mmHg (measured using the Korotkov method –

auscultatory method), which is possibly the body's reaction to upcoming stress and is implemented through the mechanism of a conditioned reflex (see table).

Table

Hemodynamic parameters of men engaged in winter swimming (n=18)

Indicator	Value (M±m)		Resting value
	before cold exposure	after cold exposure	
Blood pressure according to compression oscillometry method			
SBP, mmHg	118,5±2,65	124,7±2,84*	86–109
DBP, mmHg	64,2±1,67	63,5±1,70	50–71
MAP, mmHg	91,2±2,04	93,4±2,10	75–97
PP, mmHg	54,4±1,16	61,8±1,35*	25–40
Cardiac activity			
HR, bpm	61,7±1,05	59,2±1,24	60–90
CO, L/min	5,1±0,23	6,3±0,38*	5,0 ± 1,5 ind. norm
SV, L/min/m^2	2,9±0,20	3,6±0,15*	3,0 ± 1,0 ind. norm
CI, ml	84,2±2,05	121,3±2,87*	70 ± 20 ind. norm
SI, ml/m^2	47,4±1,18	69,3±1,75*	40 ± 10 ind. norm
Vascular parameters			
BAD, cm	0,38±0,04	0,27±0,06	0,3–0,6
BAC, ml/mmHg	0,12±0,02	0,25±0,04	0,03–0,3
LBFV, cm/sec	62,3±2,95	66,2±2,86	90 ± 30
PWV, cm/sec	590,5±12,04	657,8±15,95*	500–900 ind. norm
TPR, ml/mmHg	2,2±0,07	2,78±0,09	0,3–3,0 ind. norm
TPR, din*cm^{-5}*sec	1425,6±64,28	1178,5±59,45*	1100–2100
PVP, %	103,1±9,47	109,3±10,05	85–115
Blood pressure according to Korotkov			
SBP, mmHg	132,2±2,85	144,1±2,69*	<129 (120–129)
DBP, mmHg	80,3±1,98	82,4±2,03	<84 (80–84)

Note: * – significance of differences in indicators under the influence of extreme cold water.
Ind. norm – the value of the indicator is assessed by deviation from the range of the individual norm for each subject [1].

According to the results of compression oscillometry, at rest in the examined sample, an increase in the average values of SBP and pulse pressure (PP) was detected; the average values of DBP and MAP were within normal limits. Under the influence of extreme cold water, all subjects showed an increase in the values of SBP, PP, and MAP. Significant differences were revealed in the parameters of SBP and PP; there were no significant differences in the parameters of DBP and MAP (see table).

After swimming in cold water, a decrease in heart rate was found in 66.6% of the examined men; no significant differences were found. Such a paradoxical reaction may indicate overstrain of the sympathetic division and parallel activation of the parasympathetic division of the autonomic nervous system under conditions of such extreme exposure as general cold stress. After cold exposure, all subjects showed an increase in cardiac output (CO), stroke volume (SV), cardiac index (CI), stroke index (SI), and linear blood flow velocity (LBFV). Significant differences were revealed in the dynamics of these indicators. It should be noted that an excessive increase in SV may be a risk factor for arterial hypertension. The brachial artery diameter (BAD) after extreme cold water decreased insignificantly; no decrease in brachial artery compliance (BAC) was noted (see table).

In general, the tolerance of extreme cold stress in the examined can be assessed as satisfactory, since on average there is an increase in cardiac output (CO) to a greater extent due to stroke output; there is a correspondence between the actual specific resistance of peripheral vessels and the working specific peripheral resistance.

For the majority of examined (77.7%), a tendency towards an increase in arterial stiffness under conditions of general cold stress was revealed. The device used determines the stiffness of the arterial bed by increasing the speed of propagation of the pulse wave. The pulse wave velocity in 77.7% of men was higher than the individual norm (see table). A decrease in the elastic properties of the brachial artery was confirmed by an increase in the amplitude of oscillations during compression oscillometry. The mean arterial diameter showed a statistically insignificant decrease after cold exercise. Since there were no significant changes in the diameter of the brachial artery with an increase in pulse wave velocity after swimming in cold water, this suggests that the elastic properties of the vascular wall were preserved in the subjects.

The value of total peripheral vascular resistance (TPR), which is determined by the degree of patency of the precapillary bed, was within the normal range in all subjects before and after the influence of cold water; on average, it decreased after swimming in cold water. The values of vascular compliance (VC), which is functionally consistent with blood pressure, as well as with changes in vascular elasticity, didn't go beyond the individual norm; on average, after swimming in cold water, TPR didn't increase significantly. The degree of peripheral vascular patency (PVP) was on average normal; after swimming there was a tendency to a constrictor reaction of peripheral vessels; no significant differences were found (see table).

Conclusion. The data obtained on a limited number of subjects indicate the possibility of identifying the initial stages of a violation of the elastic properties of the aorta using compression oscillometry and expanding the possibilities of early diagnosis of signs of aortic stiffness. Such changes indicate additional stress on the vascular system as a whole. This is confirmed by the data recorded from examined using the APKO-8-RITS-M apparatus, in particular by an increase in the speed of the pulse wave. The results obtained indicate the importance of systematic monitoring of the functional state of a group of participants in extreme cold hardening. First of all, it is necessary to control the level of systolic and diastolic blood pressure before swimming in cold water, which shouldn't exceed the threshold of 140/90 mmHg. Such precautions will help prevent the development of cardiovascular pathology.

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