STATE OF THE CARDIORESPIRATORY RESERVE OF THE BODY UNDER THE INFLUENCE OF INHALATION OF HIGHLY CONCENTRATED OXYGEN DURING STEADY-STATE EXERCISE

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Abstract

The article discusses the effect of inhalation of highly concentrated oxygen on the state of the cardiorespiratory reserve during steady-state exercise.

Material and methods. Commonly, 25 aerobically untrained men were measured and tested. The subjects measurable averaged to a mean weight of 76.8±15.6 kg, a mean height of 172.5±5.8 cm, and a mean age of 22.7±3 years. The variables that were measured and recorded were rating of perceived exertion (RPE), respiratory exchange ratio (RER), heart rate (HR), VO_2 relative and VO_2 absolute. After primary measurement, immediately following their warm-up, the subjects self-administered five deep inhalations of the oxygen canister, containing 95% concentrated oxygen (Tesla's Secret by Eco Medical Europe Ltd Oxygen Breathing Mixture). The subjects attempted to maintain veloergometry during inhalations.

Results. During the entire observation period, there was a lower perceived exertion at 8 minutes of observation, as well as a decrease in recovery time after inhalation of highly concentrated oxygen (p <0.05). While analyzing the heart rate before and after inhalation of highly concentrated oxygen, the increase in heart rate at 2, 6, 8 minutes of physical activity was less than similar indicators before oxygen inhalation (p <0.05).

After inhalation of highly concentrated oxygen, a lower level of pressure in the cardiorespiratory system was observed - due to a decrease in RER by 2, 4, 6, 10, 12, and 15 minutes (p <0.05) with the same initial value during warm-up. A lower heart rate was observed during warm-up, as well as at 2, 8 and 15 minutes of observation after inhalation of highly concentrated oxygen (p<0.05). Significant shortening of the recovery time was set (p<0.05). The absolute oxygen pressure increased at all stages of observation by 20-50% - at the 2nd, 4th, 8th, 10th, 12th, 14th minutes of physical exertion and during the restitution period (p <0, 05).

Physical efficiency, with the use of inhalations of highly concentrated oxygen, increased in 2.3 times. The percentage of increase in double product (DP) was 25.5% (p <0.05). Accordingly, the chronotropic reserve index increased by 14.3% and the inotropic reserve index by 16.2%.

Keywords: cardiorespiratory reserve, highly concentrated oxygen, steady-state exercise, resturion.

Actuality. In the conditions of sports activity, high requirements are imposed on the respiratory reserve of athletes, the implementation of which ensures the effective functioning of the entire cardiorespiratory system [1, 5]. During strenuous physical exertion, the respiratory system can indirectly limit the delivery of oxygen to working muscles during work at the level of submaximal and maximal threshold load, both due to the development of arterial hypoxemia and due to reflex redistribution of blood flow between the respiratory apparatus and working muscles. The use of inhalations of highly concentrated oxygen as one of the effective measures of improving the functional state of the respiratory system of athletes has been shown in a number of studies [2, 3, 12]. At the same time, a number of issues related to the use of highly concentrated oxygen in sports remain poorly understood. There are contradictory observations regarding the time of action of the hyperoxic stimulus, the effectiveness of using an air breathing mixture with an increased oxygen content as a measure of restoring the functional state of the respiratory system of athletes. From this point of view, the study of the efficasy of inhalation of air breathing mixture with an increased oxygen content on the functional capabilities of the respiratory system of athletes is an urgent problem [6, 7].

Various efforts of the body systems - emotional, intellectual, physical - are accompanied by an increase in oxygen demand. The brain, myocardium and skeletal muscles, which are rich in myoglobin and mitochondria, are extremely sensitive to its deficiency. Under exertion, a kind of competition may even arise between these bodies [14].

When training athletes, as well as during their participation in competitions of various levels, great physical and emotional stress is inevitable. The need for a recovery period is due to an extremely sharp tension of the body's functional and metabolic reserves and, in some cases, the threat of their complete depletion. In this situation, the development and application of technologies that provide compensation and prevention of oxygen deficiency are of particular importance [10, 13].

Insufficient oxygen supply to tissues is fraught not only with a deterioration in their energy supply, but also with the formation of under-oxidized products, as well as reactive oxygen species such as superoxide, hydroxyl and perhydroxyl radicals, the excessive formation of which causes serious consequences due to damage to functionally important proteins, nucleic acids, biomembrane lipids, etc. In this regard, the problem of preventing the decompensation of the functions of external respiration, directed adequate supply of oxygen to the tissues of the body during and after the period of energy stress, arises very keenly. Improving the supply of oxygen to the lungs and to its main transporters - erythrocytes - contributes to the normalization of respiratory processes. Supplemental oxygen (including inhalation with oxygen-enriched air mixtures) is not prohibited in materials that contain practical recommendations for physicians on the use of the WADA Prohibited List [4, 8, 9].

At the same time, studies on the use of highly concentrated oxygen as an operative means of restoring sports performance after physical exertion are clearly insufficient today.

The aim of the study was to study the effectiveness of inhalation of highly concentrated oxygen on the state of the cardiorespiratory reserve during steady-state exercise.

Material and methods. Commonly, 25 aerobically untrained men were measured and tested. The subjects' measurables averaged to a mean weight of 76.8±15.6 kg, a mean height of 172.5±5.8 cm, and a mean age of 22.7±3 years.

The variables that were measured and recorded were rating of perceived exertion (RPE), respiratory exchange ratio (RER), heart rate (HR), pressure of O_2 - VO_2 relative and VO_2 absolute. For the recording of RPE, the subjects gave the test taker a number between 1-10 on their perception of how much exertion their workout was at that moment in time. The RPE was recorded every two minutes throughout the trial. The heart rate was measured a fingertip oximeter.

The investigation consisted of a two-minute of inhalations of high concentrated oxygen, fifteen minutes of steady exercise on a cycle ergometer a pace that was equivalent to the subject's 70% HR max and a two-minute rest.

After primary measurement, immediately following their warm-up, the subjects self-administered five deep inhalations of the oxygen canister, containing 95% concentrated oxygen (Tesla's Secret by Eco Medical Europe Ltd Oxygen Breathing Mixture). The subjects attempted to maintain bicycle ergometry during inhalations.

Bicycle ergometry (BEM) was performed according to the generally accepted method in the position of the subject sitting on a bicycle ergometer "VE-02" (82008) according to the step continuous method with a duration of 3 minutes for each step at a pedaling speed of 60 rpm, depending on the level of aerobic capacity (maximum oxygen consumption, MOC) according to existing schemes. In this method first degree of design load was 20% MOC, II - 35% MOC, III - 50% MOC, IV (submaximal) - 75% of MOC. As a load, control used submaximal heart rate (SHR, bpm) according to the formula: SHR = [(220 - A) x 85] / 100, where A is the years of patient's age.

During BEM, the following indicators were evaluated: 1) double product (PD); 2) the percentage of achieved load (AL); 3) physical fitness (PF); 4) chronotropic reserve index (CRI); 5) inotropic reserve index (IRI).

As a control of the stress test used a 3-channel electrocardiograph "NIHON CONDEN" (№93081) with ECG recording in 12 leads (recorded the original ECG, at the end of each stage of exercise, after 1-3-5 minutes of restitution). Once the subjects finished their five inhalations, they then continued their fifteen-minute exercise at 70% HR max , then proceeded to perform a two-minute cool-down.

For statistical analysis of the results we used Statistica for Windows Version 10.0 (Stat Soft inc., USA). Parameters are presented in the form M±m, where M is the Mean, m is standard deviation. At the case of $p<0.05$, differences were statistically significant.

Results. In general, during the entire observation period, when comparing perceived exertion before and after inhalation of highly concentrated oxygen, there was a lower perceived exertion at 8 minutes of observation, as well as a decrease in recovery time after inhalation of highly concentrated oxygen ($p<0.05$), Fig. 1.

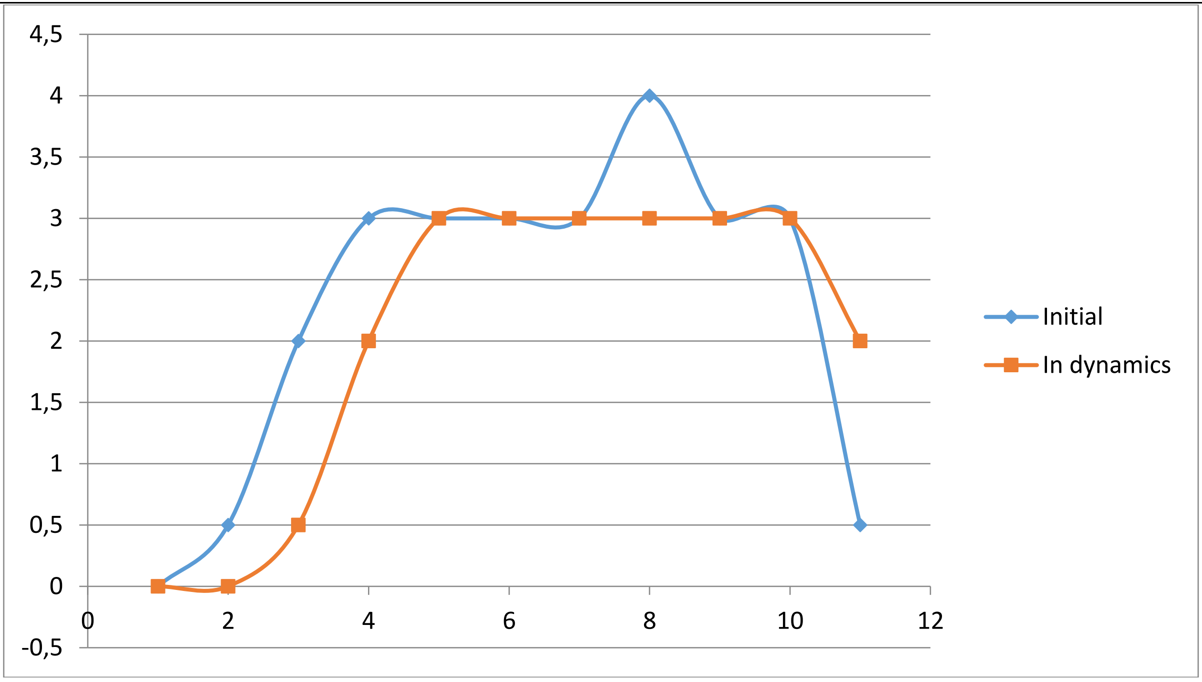

Fig. 1. Rating of perceived exertion (RPE) in both groups of observation.

In addition, with inhalation of highly concentrated oxygen, a decrease in the respiratory metabolism coefficient, which reflects the tension of the respiratory muscles, was noted. At the same time, in the case of oxygen inhalation, an increase in the stress coefficient was characteristic at the 2nd minute of observation, with a consistently lower respiratory stress until the end of the observation period ($p < 0.05$), Fig. 2.

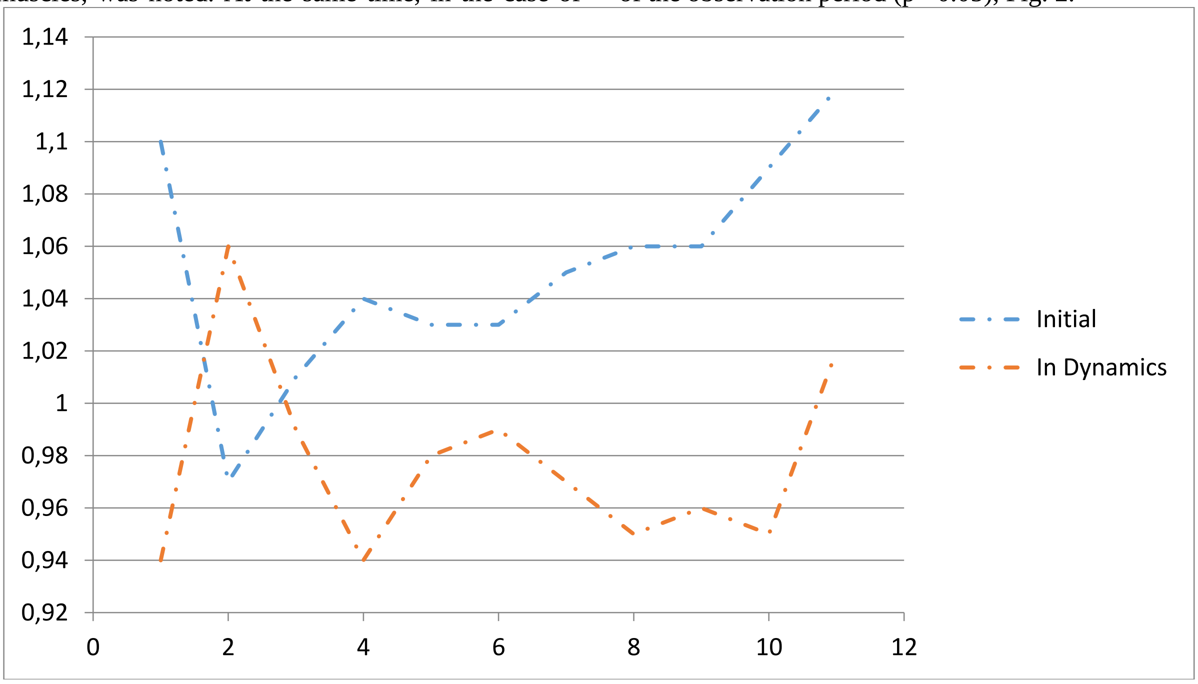

Fig 2. Respiratory exchange ratio (RER) in the groups of observation.

Similar results were obtained when analyzing the dynamics of heart rate before and after inhalation of highly concentrated oxygen, Fig. 3. In particular, the increase in heart rate at 2, 6, 8 minutes of physical activity was less than the same parameters before oxygen inhalation ($p < 0.05$).

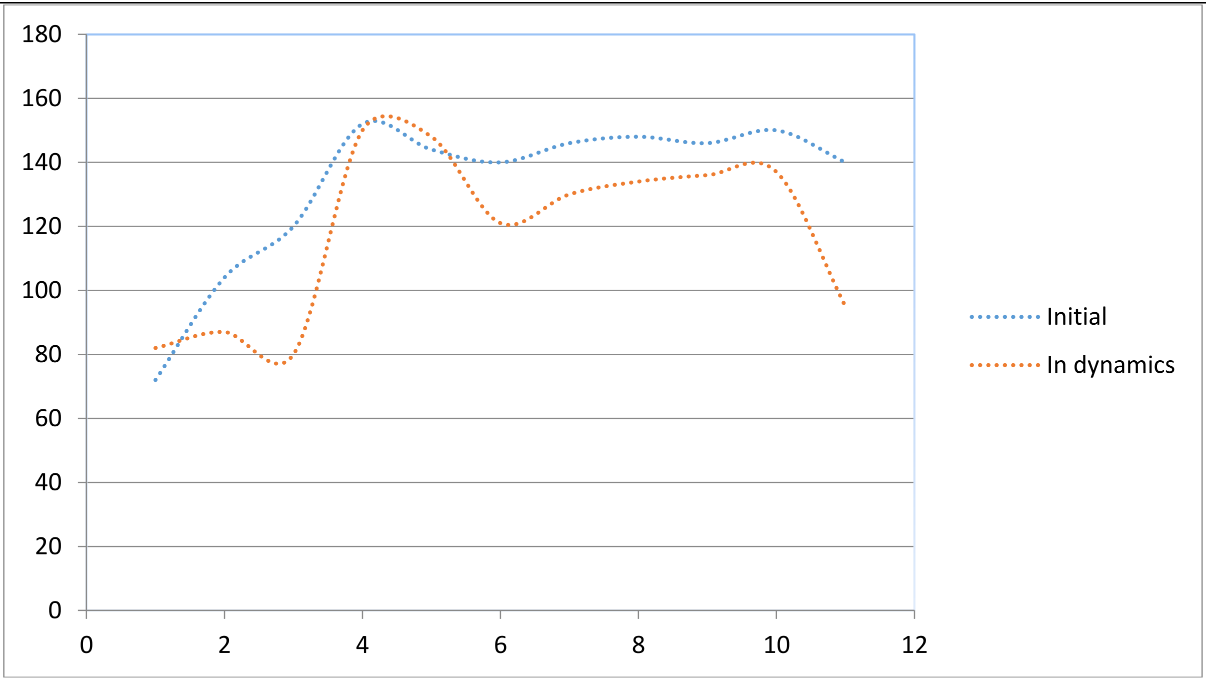

Fig 3. Dinamics of heart rate during physical activity and in restitutional period.

As can be seen from the analysis of the diagrams obtained, after inhalation of highly concentrated oxygen, the subjects showed a lower level of stress in the cardiorespiratory system - due to a decrease in RER by 2, 4, 6, 10, 12 and 15 minutes (p <0.05) with the same initial indicator during warm-ups, tab. 1. A lower heart rate was also found during warm-up, as well as at 2, 8 and 15 minutes of observation after inhalation of highly concentrated oxygen (p <0.05), table. 1. Also characteristic was a significant shortening of the recovery time (p <0.05), table. 1.

Table 1

Indicators of respiratory stress and heart rate in the dynamics of observation in the subjects

Parameters	**RER**		**HR**	
	Initial	*In dynamics*	*Initial*	*In dynamics*
Rest	1,1±0,02	0,94±0,03	72±5	82±6
Warm-up	0,97±0,03	0,96±0,04	104±8	87±6*
2 min.	1,01±0,01	0,99±0,01	120±10	80±8*
4 min.	1,04±0,03	0,94±0.02*	152±12	150±14
6 min.	1,03±0,03	0,98±0,02*	144±12	148±11
8 min.	1,03±0,02	0,99±0,02	140±13	121±10*
10 min.	1,05±0,04	0,97±0,03*	146±7	130±5
12 min.	1,06±0,03	0,95±0,04*	148±8	134±6
14 min.	1,06±0,04	0,96±0,03*	146±11	136±10
15 min.	1,09±0,06	0,95±0,04*	150±5	137±6*
Cool-down	1,12±0,03	1,02±0,03*	140±10	95±8*

Sign:
* – reliability of the difference in indexes in the dynamics of observation (p <0.05).

The opposite pattern of relationship was established when assessing the relative and absolute oxygen pressure volume in the observation dynamics. In particular, the relative oxygen pressure in capillary blood, according to pulse oximetry data, increased from 2 to 5 units (p <0.05), Fig. 4.

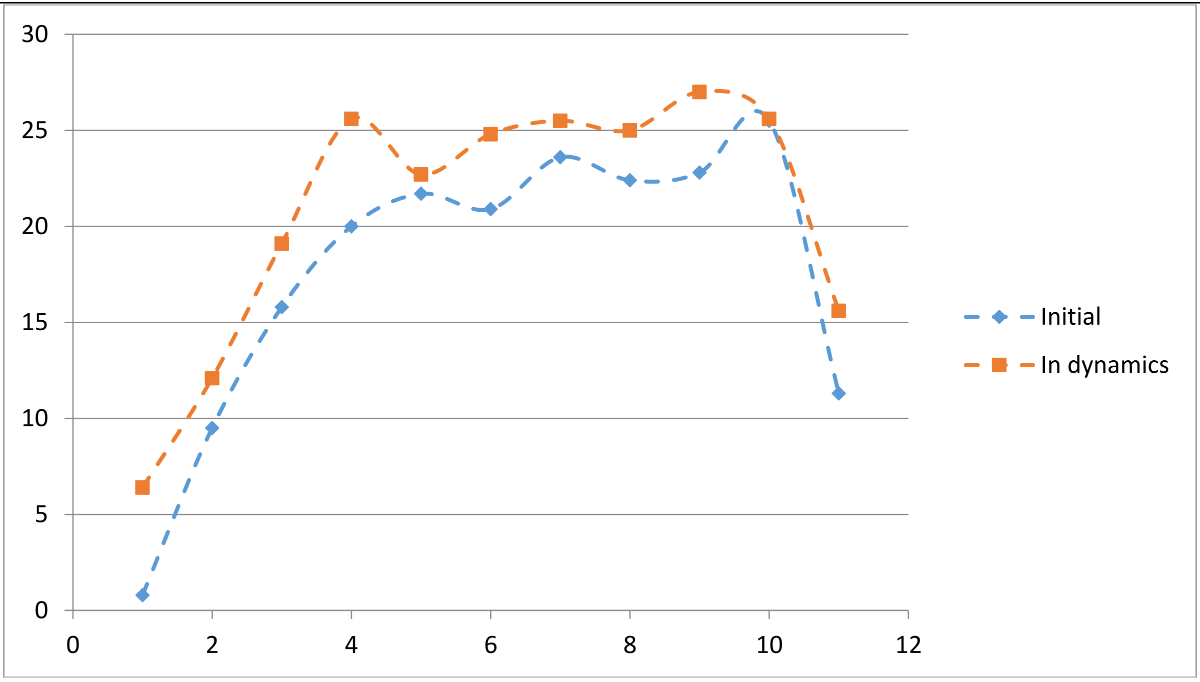

Fig 4. The level of VO2 relative in the observational groups.

The absolute oxygen pressure increased at all stages of observation by 20-50% ($p < 0.05$), Fig. 5.

According to the results of both methods, the relative and absolute oxygen pressure was higher during the restitution period after physical exertion, which is also confirmed by the shorter restitution time ($p<0.05$), Fig. 4-5.

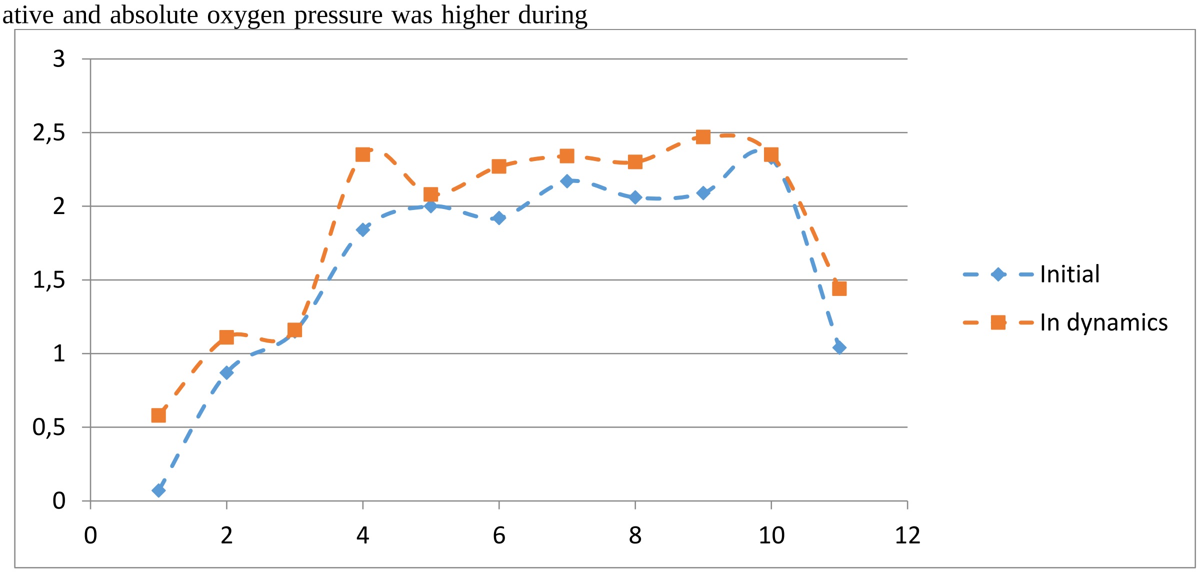

Fig 5. The level of VO2 absolute during physical activity and in restitution period.

Digital parameters representing the relative and absolute oxygen pressure in the dynamics of the observation are presented in Table 2.

In particular, the relative oxygen pressure was 27%, 21%, 28%, 18.6%, 10.4%, 15.5% higher during warm-up, as well as on the 2nd, 4th, 8th, 12th, 14th minutes of physical activity, as well as during the entire period of restitution ($p < 0.05$), Tab. 2.

The absolute oxygen pressure was significantly higher during the warm-up period, at the 2nd, 4th, 8th, 10th, 12th, 14th minutes of physical exertion and during the restitution period ($p < 0.05$), Tab. 2.

Table 2

Indicators characterizing the relative and absolute oxygen pressure in the dynamics of observation in the subjects

Parameters	VO2 relative		VO2 absolute	
	Initial	*In dynamics*	*Initial*	*In dynamics*
Rest	5,8±0,02	6,4±1,23	0,07±0,01	0,58±0,12*
Warm-up	9,5±1,4	12,1±2,8*	0,87±0,05	1,11±0,07*
2 min.	15,8±3,0	19,1±4,2*	1,15±0,05	1,16±0,04
4 min.	20±3,2	25,6±3,0*	1,84±0,4	2,35±0,3*
6 min.	21,7±1,2	22,7±2,6	2±0,02	2,08±0,03
8 min.	20,9±2,3	24,8±2,9*	1,92±0,12	2,27±0,18*
10 min.	23,6±1,8	25,5±2,2	2,17±0,09	2,34±0,12*
12 min.	22,4±1,4	25±2,7*	2,06±0,06	2,3±0,2*
14 min.	22,8±2,8	27±4,1*	2,09±0,05	2,47±0,1*
15 min.	25,5±4,8	25,6±3,5	2,33±0,03	2,35±0,04
Cool-down	11,3±3,1	15,6±3,6*	1,04±0,1	1,44±0,12*

Sign:
* - reliability of the difference in indicators in the dynamics of observation (p <0.05).

The use of inhalations of highly concentrated oxygen caused reliable changes of indicators of physical fitness (PF) and the achieved load (AL), table 3, (p <0.01). Accordingly, there was an increase in inotropic and chronotropic reserves of the heart after inhalation of highly concentrated oxygen (p <0.01), table 3.

Table 3

Indicators of bicycle ergometry (BEM) in observation groups

Parameters	*Initial*	*In dynamics*
PF (kgm)	207.0±45.2	471,0±32.1 p<0,01
AL, (Wt)	102.0±8.2	128.2±6.7 p<0,01
CRI (U)	153,5±7.4	175.3±7.8 p<0,01
IRI (U)	129.2±6.3	150.1±9.5 p<0,05

Sign:
* - reliability of the difference in indicators in the dynamics of observation (p <0.05).

Physical fitness (efficiency), with the use of inhalations of highly concentrated oxygen, increased 2.3 times. The percentage of increase AL in BEM was 25.5% (p <0.05). Accordingly, the chronotropic reserve index (CRI) increased by 14.3% and the inotropic reserve index (IRI) - by 16.2%. That is, the indicators of stress test tolerance, which characterize the growth of coronary blood flow in accordance with the level of physical activity, had a significant increase with the use of oxygen inhalations.

Conclusions. During the entire observation period, there was a lower perceived exertion at 8 minutes of observation, as well as a decrease in recovery time after inhalation of highly concentrated oxygen (p <0.05).

A decrease in the respiratory metabolism coefficient was noted with an increase in the coefficient at the 2nd minute of observation, with a consistently lower respiratory stress until the end of the observation period (p <0.05). When analyzing the heart rate before and after inhalation of highly concentrated oxygen, the increase in heart rate at 2, 6, 8 minutes of physical activity was less than similar indicators before oxygen inhalation (p <0.05).

After inhalation of highly concentrated oxygen, a lower level of tension in the cardiorespiratory system was observed - due to a decrease in RER by 2, 4, 6, 10, 12, and 15 minutes (p <0.05) with the same initial value during warm-up. A lower heart rate was observed during warm-up, as well as at 2, 8 and 15 minutes of observation after inhalation of highly concentrated oxygen (p <0.05). Significant shortening of the recovery time was also characteristic (p <0.05).

The opposite pattern was established when assessing the relative and absolute oxygen pressure in the dynamics of observation. The relative oxygen pressure in capillary blood, according to pulse oximetry data, increased from 2 to 5 units (p <0.05) - by 27%, 21%, 28%, 18.6 %, 10.4%, 15.5% higher during warm-up, as well as at the 2nd, 4th, 8th, 12th, 14th minutes of physical activity, as well as during the entire restitution period (p <0.05).

The absolute oxygen pressure increased at all stages of observation by 20-50% - at the 2nd, 4th, 8th, 10th, 12th, 14th minutes of physical exertion and during the restitution period (p <0, 05).

Physical fitness (efficiency), with the use of inhalations of highly concentrated oxygen, increased in 2.3 times. The percentage increase in AL was 25.5% (p <0.05). Accordingly, the chronotropic reserve index increased by 14.3% and the inotropic reserve index by 16.2%.

Discission. Thus, oxygen inhalations improve adaptation to heavy physical activity, promote timely correction of the functional state of athletes, increase physical endurance and quickly restore the body's reserves. A number of such studies involved 20 volunteers and 160 athletes of both sexes in various sports (martial arts, cyclic, game, complex coordination). At the same time, a number of positive points were revealed. Thus, inhalations do not cause negative consequences that could be recorded during a clinical examination of athletes. Relatively small (within 7%) changes in the parameters of the body's oxygen supply, as well as shifts in glucose and lactate levels, in our opinion, reflect the increased "oxygenation" of body tissues and are adaptive [6, 9].

To monitor the effectiveness of oxygen inhalations, the function of external respiration, general hemodynamics and blood gas composition should be evaluated. The comfortable mode of giving of mix for the sportsman has to be selected individually taking into account his physical status, a functional condition of his organism and specificity of a sport [1, 8].

In other studies, the training load following inhalations of highly concentrated oxygen was accompanied by a significantly smaller decrease in the value (in some cases not exceeding 10%) of the criteria of the state of the functional systems of athletes in comparison with the control groups. Inhalations improve pulmonary ventilation, reduce the level of arterial hypertension, systolic and diastolic pressure, increase acuity and expand the field of view [10, 13].

At the same time, the successful and rapid implementation of this technique in the practice of physical training of athletes is possible only when addressing the issue of equipping sports medicine centers and teams with appropriate equipment - stationary and portable [2, 7].

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