DOI: 10.14529/hsm210116

COMBINED PHYSICAL AND HYPOXIC EXERCISES – A PERSPECTIVE DRUG-FREE METHOD FOR INCREASING PHYSICAL WORKING CAPACITY

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Aim. The paper aims to increase physical working capacity through intensive muscle training in normobaric hypoxia. **Materials and methods.** The training programs included 15 cycles of a 3-hour stay of volunteers in a normobaric hypoxic chamber, where they performed physical activity on an exercise bike and a treadmill. The power was set at 70–100 W with a duration of 120–140 min with several breaks. Participants of the main group (14 males aged 19–23 years) were subjected to training under low (up to 16–17 %) oxygen concentration conditions in the gas environment. In the control group (10 people of the same age), hypoxic conditions were simulated. Physical working capacity was controlled by the Ruffier test and bicycle ergometer test to anaerobic threshold, as well as the breath-holding test. **Results.** Essential increase of physical working capacity was established only in the main group, and positive tendencies in all functional tests remained in remote supervision. **Conclusion.** Consequently, the method based on a rational combination of physical and normobaric hypoxic training can be considered as an effective and safe means of increasing the physical working capacity of a person engaged in intensive muscle training.

Keywords: *physical working capacity, combined physical and normobaric hypoxic training.*

Introduction. Increasing a person's physical endurance is one of the key characteristics of physical working capacity [8, 20]. Therefore, special exercises and training of various muscle groups are used, including the use of such simulators as bicycle ergometers, treadmills, etc. However, only physical training cannot provide the required level of endurance in persons whose professional (sports) activity is associated with physical loads of extreme intensity [2, 7, 11]. It is necessary to include additional means and methods aimed at acute physical fatigue reduction, restoring functional abilities, the central nervous system, physiological systems of "emergency energy supply" (blood circulation, external respiration, blood gas transport) [5–7, 17].

Another direction in solving this problem is the search and implementation of safe drug-free ways of improving functional abilities that allow to optimize the performance of oxygen transport during exhaustive exercise. Such means and methods can be considered as a specific "physiological training" of the body [4, 14].

Literature review. The following drug free ways of the so-called "physiological training" are used by athletes and persons involved in intensive physical training: hyperbaric oxygenation [12, 18]; effects of high and low temperatures [4, 14]; combined effects of physical factors of different modalities (infrared and steam heat, contrast shower, vibration massage of the spine and feet, color therapy, aromatherapy) [9]; pulsed electric current [17]; respiratory (barotherapy) training – hypobaric and normobaric hypoxia, normobaric and hyperbaric oxygen therapy [1, 5, 7], argon-hypoxic training [15] etc.

A promising direction in the development of physiological training for people involved in intensive muscle activity is the use of physical training in a hypoxic environment, which accelerates the formation of adaptive changes in the body and provides a rapid increase in physical endurance. In the modern literature on hypoxia medicine, there are numerous data on the high efficiency of training in mid-mountain conditions, as well as of combined physical and hypobaric training [2, 7]. These works show a significant increase in physical endurance and hypoxic resistance of a person with a well-structured training.

However, technical, organizational, and economic reasons significantly limit the use of hypoxic training. Despite the fact that there is a much less technically complex method of creating conditions for reduced partial oxygen pressure, until recently this method was not actually used in combination with physical training. The main reason for this is the peculiarities of technical devices, namely hypoxicators, that are most often used for creating normobaric conditions [1, 10, 11]. The disadvantages of hypoxicators include the following: "mask" breathing, limited movement, low productivity of the hypoxic breathing mixture, etc. An alternative way to create normobaric hypoxia is to use normobaric hypoxic chambers (NHC), in which a person can stay throughout the entire time (including around the clock) and perform physical activities of various nature [6, 16].

In other words, there was a technical opportunity to implement combined hypoxic and physical training under normal gas pressure.

The paper aims to increase physical working capacity through intensive muscle training in normobaric hypoxia.

Materials and methods. The study involved 24 male volunteers (aged 19–23 years) who had no medical contraindications for performing the simulated activity. All volunteers had no bad habits (alcoholism, smoking), were of the normostenic somatotype (body mass index 22–26 kg/m^2), regularly engaged in physical education classes (running, cycling, strength training, sports games) but were not elite athletes.

All volunteers were randomly divided into groups, 10 people each (main – MG, control – CG), which are comparable in terms of significant anamnestic, anthropometric and functional characteristics.

Training programs included 15 cycles of a 3-hour stay of the subjects in the NHC [16] (Fig. 1), where they performed physical activity on an exercise bike and a treadmill. The power was set at 70–100 W with a duration of 120–140 min with several breaks. Subjects from the main group had a reduced (up to 16–17 %) concentration of oxygen. The NHC also had rest rooms and sanitary blocks.

For the control group, the conditions of hypoxia were simulated: clean atmospheric air was supplied to the chambers.

Medical control of the functional state of volunteers was carried out by using visual observation; survey of complaints; heart rate, blood pressure and blood oxygen saturation measurements performed with the Microlux diagnostic system (Russia).

In their free time, volunteers carried out their usual daily activities (work, study). Other physical exercises (except for morning exercises) were excluded. After the end of the training cycle, the volunteers returned to their normal activities and movement regime.

The physical working capacity of the subjects was evaluated by using well-known functional tests [8, 21]: the Ruffier test (30 squats per 45 s) with the calculation of the Ruffier index the and bicycle ergometer test to anaerobic threshold (AT, W). In addition, the breath-holding test (Stange's test) was used [21].

The bicycle ergometer test with a stepwise

Fig. 1. Normobaric hypoxic chamber interior (Association of Developers and Producers of Monitoring Systems, St. Petersburg)

load was carried out using the Cardiovit CS-200 system (Schiller, Switzerland): the power of the first "stage" was set at 50 W, the "step" was 25 W, the duration of each "step" was 1 min, except for a step with a power of 100 W, the duration of which was 2 min. The load was removed after the subject reached AT, which was determined by the gas exchange parameters [21]. The power of the "step" was fixed, when AT was reached.

The abovementioned functional tests were carried out three times: in the initial state (2–4 days before the training cycle) – 1st stage; in 1–3 days (2nd stage) and then after about 3 weeks (stage 3) after the completion of training in the NHC.

The results were processed using the methods of variation statistics, as well as the "Excel" and "STATISTICA" programs. Mean values (M) and standard deviations (σ) were calculated and shown in the table. The significance of differences in paired parameters in related and unrelated samples was determined, respectively, by the Wilcoxon T-test and the Mann – Whitney U-test. Differences were considered significant at $p < 0.05$.

Human studies were conducted in accordance with the ethical requirements of the 1975 Declaration of Helsinki (and its revisions in 1983 and 2013). The research has been validated by an independent ethics committee.

Results. An analysis of the results showed (Table 1) that all subjects had relatively high values of physical working capacity and resistance to anoxia. This fact made it possible to prescribe hypoxic training in the main mode without preliminary "stepwise" adaptation, as recommended in individuals with initially low hypoxic resistance [1].

There were no differences between the groups at baseline for all criteria ($p > 0.05$), which was a consequence of the correct distribution of subjects in the comparison groups.

The initial high level of functional reserves allowed the subjects to complete the planned intensive physical and hypoxic training. Monitoring of the functional state during training sessions showed that the compensatory reactions in the MG was greater than those in the control group. Nevertheless, none of them was recorded unacceptable hypoxic conditions during the entire training period.

A repeated functional examination after the end of the training cycles demonstrated that significant changes occurred only in the MG, where combined physical and hypoxic training was used.

In this group, the average values of the Ruffier index decreased by 11 % compared with the initial level ($p = 0.045$) reflecting an increase in the anaerobic physical endurance of the subjects. The increase in AT was 4.7 % on average ($p1 = 0.040$), which indicates an increase in maximum aerobic performance (aerobic endurance). Moreover, MG individuals showed a significant increase in resistance to transient anoxia – an average of 7 % compared with the initial state

Table 1

Physical working capacity in subjects of the main and control groups, M (σ)

Group (number of subjects)	Survey stage Indicator, relative units		
	Ruffier Index (conventional units)	AT, W	Breath-holding test, S
Stage 1			
MG (n = 14)	3.5 (0.2)	190 (4)	128 (9)
CG (n = 10)	3.4 (0.3)	192 (5)	131 (10)
Stage 2			
MG (n = 14)	3,1 (0.2) p1 = 0.045	199 (4) p1 = 0.040	138 (9) p1 = 0.047
CG (n = 10)	3.3 (0.3)	193 (3) p = 0.049	130 (8)
Stage 3			
MG (n = 14)	2.9 (0.2) p1 = 0.031	201 (6) p1 = 0.040	144 (10) p1 = 0.041
CG (n = 10)	3.2 (0.3) p = 0.049	193 (3) p = 0.045	132 (8) p = 0.049

Note. Significance of differences: p – between groups (Mann – Whitney U-test); p1 – compared with the 1st stage of observation (Wilcoxon T-test).

(p = 0.047). The lack of statistically confirmed differences between the groups at the 2nd stage of observation, in our opinion, is primarily due to the insufficient sample size. In addition, there is a significant inertia in the formation of the expected effects of physical and hypoxic training [8, 15].

The results of the final survey confirmed this position. In individuals from MG, in the long-term period after training, there was an improvement in the evaluated physiological qualities, which was confirmed statistically. As a result, the overall decrease in the Ruffier index in the main group averaged about 17 % compared to the initial level (p = 0.031); AT values increased by 5.7 % on average (p = 0.040); the average time of holding the breath (Stange's test) increased by 12.5 % (p = 0.041).

There were no statistically significant changes in the control group, and significant intergroup differences were recorded for all functional criteria studied.

Discussion. Apparently, the high efficiency of the method of combined physical and normobaric hypoxic training is explained by the synergistic effect of these factors on the body [2, 7]. The combined effect of hypoxic hypoxia and the so-called “load hypoxia” [11] “prescribes” the body to include the available compensatory resources, quickly “switch” to a new, physiologically more reliable level of functioning, in other words, to expand its functional abilities.

As intimate mechanisms of cyclic hypoxic effects are considered: the adaptive restructuring of all components of the body's gas transport system, specific metabolic and regulatory shifts [1, 11, 13]. Changes in the circulatory system are to improve regional blood circulation and microcirculation, optimize the diastolic function of the heart, and reduce the hyperreactivity of the heart and resistive vessels to external influences. The consequence of hypoxic training is an increase in the proportion of perfused and ventilated alveoli, bronchodilator and vasodilation effects. The main mechanism of hypoxia compensation from the blood system is an increase in the erythropoietic activity of the blood-forming organs, which leads to a significant increase in the oxygen capacity of the circulating blood [3, 19].

It is also important to emphasize that the peculiarity of hypoxic training is the continuation of the formation of structural and functional changes in the body for a long time after the training, which leads to the consolidation and prolongation of their sanogenic and ergogenic effects [13, 15]. This fact should be taken into account when planning the training process and predicting the peak performance.

Conclusion. Thus, from the tested short-term training options, physical and hypoxic training turned out to be significantly more effective in relation to an emergency increase in physical performance (anaerobic and aerobic endurance), and resistance to transient anoxia. The optimal technical option for the implementation of such training is normobaric hypoxic complexes with the area sufficient for both sports simulators and ensuring the normal movement of trainees. Such NHCs should provide an opportunity to select the optimal hypoxic training mode, up to a 24-hour stay of the trainees in hypoxic environments of the required composition. At the same time, direct monitoring of a person's functional state should be simplified as much as possible. The data obtained allow us to consider combined physical and hypoxic training as a highly effective and safe means of increasing the physical working capacity of people whose activities are associated with intensive muscle training.

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Received 12 November 2020

УДК 796.071.424.2 **DOI: 10.14529/hsm210116**

СОЧЕТАННЫЕ ФИЗИЧЕСКИЕ И ГИПОКСИЧЕСКИЕ ТРЕНИРОВКИ – ПЕРСПЕКТИВНЫЙ НЕМЕДИКАМЕНТОЗНЫЙ МЕТОД ПОВЫШЕНИЯ ФИЗИЧЕСКОЙ РАБОТОСПОСОБНОСТИ

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Цель – повышение физической работоспособности человека посредством интенсивных мышечных тренировок в условиях нормобарической гипоксии. **Материалы и методы.** Программы тренировок включали 15 циклов 3-часового нахождения испытуемых в помещении нормобарического гипоксического комплекса, где они выполняли физические нагрузки на велотренажере и беговой дорожке. Задаваемая мощность физической работы – 70–100 Вт, продолжительность 120–140 мин с несколькими перерывами. Лица основной группы (14 мужчин в возрасте 19–23 лет) выполняли тренировки в условиях пониженной (до 16–17 %) концентрации кислорода в газовой среде. У добровольцев контрольной группы (10 человек аналогичного возраста) условия гипоксии имитировались. Физическая работоспособность в динамике наблюдения контролировалась с помощью пробы Руфье, велоэргометрической ступенчато возрастающей нагрузки с достижением анаэробного порога, проб с задержкой дыхания. **Результаты.** Установлено, что существенное повышение физической работоспособности имело место только у лиц основной группы, а положительные тенденции в динамике показателей всех используемых функциональных проб сохранились и в отдаленном периоде наблюдений. **Заключение.** Метод, основанный на рациональном сочетании физической и нормобарической гипоксической тренировок, может рассматриваться как эффективное и безопасное средство повышения физической работоспособности человека, занимающегося интенсивной мышечной деятельностью.

Ключевые слова: *физическая работоспособность, комбинированные физические и нормобарические гипоксические тренировки.*

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Поступила в редакцию 12 ноября 2020 г.

ОБРАЗЕЦ ЦИТИРОВАНИЯ

Zahodyakina, K.Yu. Combined Physical and Hypoxic Exercises – a Perspective Drug-Free Method for Increasing Physical Working Capacity / K.Yu. Zahodyakina, A.V. Kuzmin, Yu.A. Kovaleva // Человек. Спорт. Медицина. – 2021. – Т. 21, № 1. – С. 124–131. DOI: 10.14529/hsm210116

FOR CITATION

Zahodyakina K.Yu., Kuzmin A.V., Kovaleva Yu.A. Combined Physical and Hypoxic Exercises – a Perspective Drug-Free Method for Increasing Physical Working Capacity. *Human. Sport. Medicine*, 2021, vol. 21, no. 1, pp. 124–131. DOI: 10.14529/hsm210116