Effects of single normobaric hypoxic exposure on physiological indicators of swimmers

UDC 796.03

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Abstract

Objective of the study was to assess the effects of artificial normobaric hypoxia on the biochemical and physiological indicators of swimmers working in the aerobic power zone.

Methods and structure of the study. The study was carried out at the Research Institute of Sports and Sports Medicine of Russian State University of Physical Education, Sports, Youth and Tourism. Sampled for the study were apparently healthy short- and middle-distance swimmers, who were split into the Experimental (EG) and Control (CG) Groups, 10 people each.

The athletes were asked to perform a step load test on the Monark Ergomedic 894E Peak Bike vertical cycle ergometer (Sweden). Their aerobic performance was evaluated in terms of volume, intensity and time of work using the hardware and software complex Ergomax (Russia) and specialized software (Patent No. 83004). The spirometric studies were conducted using the Cortex METALYZER 3B-R2 gas analyzer (Germany). The following gas exchange indicators were recorded: lung ventilation (LV), exhaled O_2 and CO_2 levels; O_2 consumption (VO_2). HR was measured using Polar T34 pulsometer (Finland). The blood lactate concentration (HLa, mmol/l) was measured by the electrochemical method using the NOVA Biomedical Lactate Plus (USA) analyzer. The capillary blood samples were taken in a quiescent state before the test and at the 3rd, 5th, 7th, and 10th minutes after the test. The pulse oximetry method (stationary – NONIN 8600, USA; carpal- MD300W, China) was used to record blood oxygenation (SO_2). HR and blood oxygenation during the hypoxic tests were recorded in three stages: at rest – before the hypoxic exposure, for 1 min; during the 30-min exposure to the 9% O_2 gas mixture; after the hypoxic exposure (recovery period) – under normal breathing conditions, for 3 minutes. Blood oxygenation and HR were recorded during the hypoxic test with a step of 10 seconds: before the hypoxic stimulus – at rest, for 1 minute; during the 30-min exposure to the 9% O_2 gas mixture; after the hypoxic exposure (recovery period) – under normal breathing conditions, for 3 minutes.

Results and conclusion. The findings showed an ambiguous reaction of the biochemical and physiological characteristics of the swimmers' body to the single hypoxic exposure when working in the aerobic mode. The efficiency of hypoxic exposure on the body and individual hypoxic tolerance rate, when coupled with load hypoxia, is largely determined by the rate of recovery of all the body functional systems involved. The single hypoxic exposure in the aerobic mode does not inhibit the adaptation mechanisms, and this variant of exposure may help improve physical working capacity at the specified power.

Keywords: *hypoxia, swimmers, working capacity, aerobic performance.*

Background. Today there is a large body of scientific literature on the effects of hypoxia on health, in particular physical and mental capacity, of both athletes and non-sporting people [1, 4, 5]. However, this remains a pressing problem until present [2, 3]. Sports activities cover a wide range of issues related, first of all, to the enormous workload imposed on athletes in the training and competitive periods, high demand for sports results demonstrated, correct and effective recovery of trainees and maintenance of their health [8, 9]. Moreover, particular attention should be paid to careful examination of the internal metabolic shifts that always occur under physical loads. Oxygen deficiency is among the serious problems that an athlete constantly encounters [2, 4, 5]. Hypoxia inevitably goes with a state of ever-increasing functional activity. Besides, these hypoxic states differ in intensity and are associated with the discrepancy of the energy demand of the body and the possibility of resynthesis of energy resources of cells by means of oxygen consumption. However, hypoxic states are a powerful factor in the adaptation processes of the body and contribute to the formation and reinforcement of training effects. The specific effects of oxygen deficiency in operation in different power zones can be altered under the influence of other variants of hypoxic stimulation [6, 7]. In fact, the effects that arise from the combination of cross adaptation processes and different variants of hypoxic stimulation potentiate metabolism and have a significant impact on adaptation to the existing and permanent hypoxic stimulus [2, 4, 5]. The selection of the most effective hypoxic loads in different combinations to stimulate and expand compensatory abilities and mechanisms will help realize methodological training options in elite sports.

Objective of the study was to assess the effects of artificial normobaric hypoxia on the biochemical and physiological indicators of swimmers working in the aerobic power zone.

Methods and structure of the study. The study was carried out at the Research Institute of Sports and Sports Medicine of Russian State University of Physical Education, Sports, Youth and Tourism. Sampled for the study were apparently healthy short- and middle-distance swimmers, who were split into the Experimental (EG) and Control (CG) Groups, 10 people each. At the time of the study, the subjects were examined and admitted to the experiment by a physician. They all gave their written informed consent to participate. The study was carried out in compliance with the principles of humanity and ethical standards of Helsinki Declaration, 2000, and European Community Directive 86/609).

The athletes were asked to perform a step load test on the Monark Ergomedic 894E Peak Bike vertical cycle ergometer (Sweden). Their aerobic performance was evaluated in terms of volume, intensity and time of work using the hardware and software complex Ergomax (Russia) and specialized software (Patent No. 83004). The spirometric studies were conducted using the Cortex METALYZER 3B-R2 gas analyzer (Germany). The following gas exchange indicators were recorded: lung ventilation (LV), exhaled O_2 and CO_2 levels; O_2 consumption (VO_2). HR was measured using Polar T34 pulsometer (Finland). The blood lactate concentration (HLa, mmol/l) was measured by the electrochemical method using the NOVA Biomedical Lactate Plus (USA) analyzer. The capillary blood samples were taken in a quiescent state before the test and at the 3rd, 5th, 7th, and 10th minutes after the test. The pulse oximetry method (stationary – **NONIN** 8600, USA; carpal- MD300W, China) was used to record **blood oxygenation** (SO_2). HR and blood oxygenation during the hypoxic tests were recorded in three stages: at rest – before the hypoxic exposure, for 1 min; during the 30-min exposure to the 9% O_2 gas mixture; after the hypoxic exposure (recovery period) – under normal breathing conditions, for 3 minutes. Blood oxygenation and HR were recorded during the hypoxic test with a step of 10 seconds: before the **hypoxic stimulus** – at rest, for 1 minute; during the 30-min exposure to the 9% O2 gas mixture; after the **hypoxic exposure** (recovery period) – under normal breathing conditions, for 3 minutes.

Results of the study. The experiment showed that in EG t_{work} in the aerobic power zone was 12 min 11 sec on average with a variation of 11%, the relative $VO_{2\,max}$ reached 52 ml/min/kg with a variation of ±10%, and the anaerobic exchange threshold was 74% of MOC. The effects of normobaric hypoxia were determined by combining the force of the applied hypoxic stimulus (F_iO_2) and the duration of the hypoxic exposure. The dynamics of changes in HR and SO_2 during

Table 1. *Blood oxygenation and HR during single hypoxic exposure, before aerobic work on cycle ergometer ($\bar{X} \pm \sigma$, n=5)*

Indicator	Unit of measurement	Single hypoxic exposure using the hypoxicator, before anaerobic load		
		Initial state	Hypoxic test	Recovery
Time	min	1	30	3
HR	bpm	76±4.23	84±6.02	76±5.60
SO_2	%	97±1.53	85±5.74	91±3.52

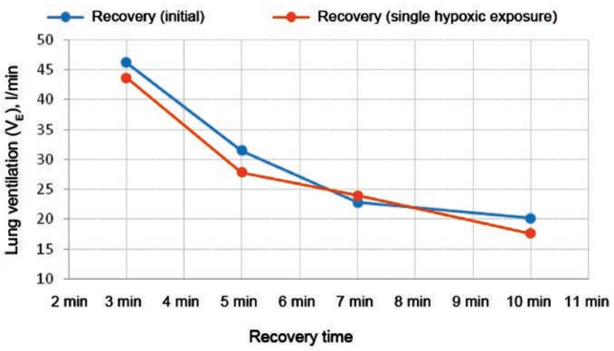

Fig. 1. *Dynamics of changes in V_E (l/min) depending on time of recovery after aerobic load with single hypoxic exposure*

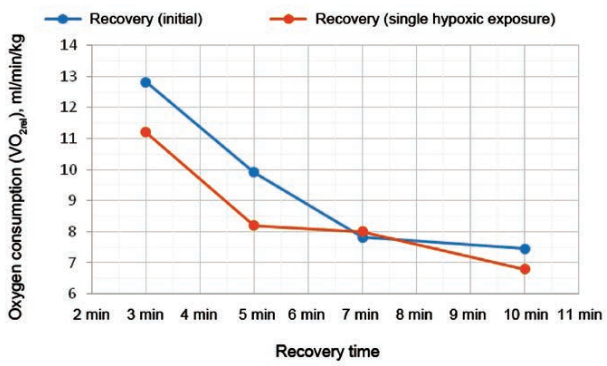

Fig. 2. *Dynamics of changes in VO_2 (l/min/kg) depending on time of recovery after aerobic load with single hypoxic exposure*

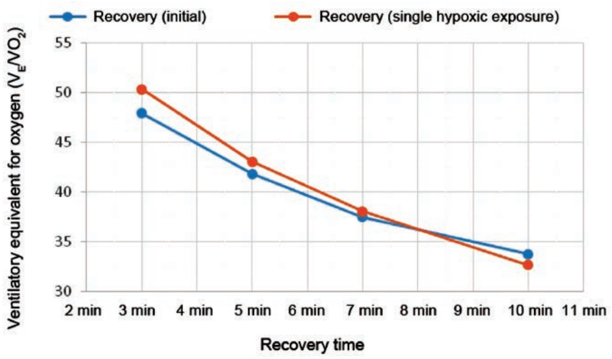

Fig. 3. *Dynamics of changes in V_E/VO_2 depending on time of recovery after aerobic load with single hypoxic exposure*

the single 30-min hypoxic exposure indicated a trend towards higher HR and lower blood oxygenation in EG (see Table).

The dynamics of changes in HR and SO_2 under 30-min hypoxic exposure (±Δ) before and after the single hypoxic exposure amounted to +10.5 and -10.3, respectively.

The measurement of the blood oxygenation levels and HR showed that the single normobaric hypoxic exposure leads to a decrease in SO_2 and an increase in HR due to a certain degree of tension in the cardiorespiratory system and a decrease in oxygen transport in the body. As oxygen delivery decreases, the share of anaerobic glycolitic processes in energy supply increases, as evidenced by the growth of excess non-metabolic carbon dioxide ($ExcCO_2$).

It is shown that during the single hypoxic exposure, the average t_{work} on the cycle ergometer increased slightly, by only 1.8%, while HR and the relative W_{work} at all test stages decreased significantly. The anaerobic exchange threshold dropped by 7.5%, and VO_2 decreased.

The analysis of the dynamics of changes in the blood lactate concentrations showed that it decreased at all test stages and significantly reduced at the 7th and 10th minutes in the recovery period, which may be due to greater substrate and oxidative phosphorylation activation and intensification of aerobic synthesis of adenosine triphosphoric acid.

Figures 1-3 illustrate the dependence of lung ventilation, O_2 consumption and ventilatory equivalent for O_2 on the time of recovery after the aerobic testing with and without hypoxic exposure.

It is shown that these physiological indicators decreased significantly during the recovery period at the 5th, 7th, and 10th minutes of the recovery period. The lung ventilation and oxygen consumption rates under hypoxic exposure reached a constant level at the 5th-7th minutes, which was especially significant under the influence of the single hypoxic exposure, while the ventilatory component – at the 10th minute.

Therefore, the analysis of the obtained parameters shows that single normobaric hypoxic exposure may contribute to the improvement of tolerance to hypoxia when working in the aerobic and anaerobic-aerobic power zones.

Conclusion. The findings showed an ambiguous reaction of the biochemical and physiological characteristics of the swimmers' body to the single hypoxic exposure when working in the aerobic mode. The efficiency of hypoxic exposure on the body and individual hypoxic tolerance rate, when coupled with load hypoxia, is largely determined by the rate of recovery of all the body functional systems involved. The single hypoxic exposure in the aerobic mode does not inhibit the adaptation mechanisms, and this variant of exposure may help improve physical working capacity at the specified power.

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