

Effectiveness of the application of the endogenous-hypoxic breathing technique in the physical training of 13-16-year-old cyclists

NATALIIA GAVRYLOVA¹, VIKTORIIA BOHUSLAVSKA^{1,2}, MARYAN PITYN², YURIY MOSEICHUK³, OKSANA KYSELYTSIA³

¹Vinnitsia State Mykhailo Kotsyubynskyi Pedagogical University, UKRAINE

²Lviv State University of Physical Culture, Lviv, UKRAINE

³Yuriy Fedkovych Chernivtsi National University, Chernivtsi, UKRAINE

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Abstract:

The issue of perfection of functional and physical fitness of 13-16 year-old cyclists by means of application of the endogenous-hypoxic breathing techniques in the training process is investigated in the article. Due to the application of the endogenous-hypoxic breathing technique in combination with exercise loads, cyclists aged 13-16 years have positive changes in the apparatus of external respiration: the functional capabilities of the respiratory muscles are increased, the respiratory surface of the lungs increases, there is an economization of the respiratory muscles work in the relative muscular rest state, and it is also facilitated also passage of air in the area of medium and small bronchi is facilitated. The effectiveness of the complex application of normobaric hypoxia and hypercapnia, as well as the training loads on the physical fitness of adolescent cyclists, depends on the age of athletes. In the 13-14-year-old athletes, in 16 weeks after the beginning of the formative experiment, the special physical preparedness increased by the results of the cycling a 200 m flying-start heat (2.75 %, $p < 0.05$) and the cycling a 2,000 m heat with a single turning (by 5.18 %, $p < 0.01$); general physical fitness by results of running 60 m race (by 3.43 %, $p < 0.05$), running a 1,500 m race (3.16 %, $p < 0.01$) and the maximum number of squats in 15 sec (at 8, 57 %, $p < 0.005$). In 15-16-year-old cyclists, training sessions with application of the endogenous-hypoxic breathing technique contributed to an increase in overall physical fitness – according to the results of running a 1,500 m race (2.29 %, $p < 0.02$) and special physical fitness – according to the results of cycling a 2,000 m heat with one turn (5.91 %, $p < 0.005$).

Key words: hypoxia, hypercapnia, cyclists, perfection, fitness.

Introduction

The analysis of the protocols of the Olympic Games, the Winter Olympics, the World Championships and other competitions testifies to the growth of results in various sports, in particular, in cycling (Briskin, 2011, 2015; Karatnyk, 2015; Khimenes, 2015; Pityn, 2017; Sergiy, 2017). One of the reasons for this phenomenon is the improvement of the training process at all stages of the multi-year training of an athlete (Kropta, 2017; Viktoriia, 2017; Zhyrnov, 2017). Special attention should be paid to the preparation of athletes in the puberty period of ontogenesis, when cyclists have the stages of preliminary and specialized basic training, since the improvement of physical and functional preparedness in the indicated periods takes place against the backdrop of intense age-related adjustment of the body (Gavrylova, 2011, 2012; Kmyta, 2015, 2016; Khimenes, 2016; Hruzevych, 2017). The enhancement of the efficiency of training sessions by increasing the amount of loads at these stages might not bring the expected increase of sports results, and even can disrupt the balanced activities of those functional systems that are determinants of the process of improving the physical fitness of athletes at the next stages of multi-year training.

Taking into account the abovementioned, the enhancement of the physical fitness of adolescent athletes should not be due to excessive physical activity, but due to the additional use of special means that contribute to increase the efficiency of physical work in the athletes training process (Bishop, 2002; Gruzevych, 2013; Gorshova, 2017).

In order to increase the efficiency of training sessions for athletes of different specializations, it is promising to introduce special techniques in the process of sports training, which, in addition to physical activity, create the state of hypoxia in the body, which can be achieved both due to the staying in conditions of reduced atmospheric barometric pressure (in the hypobaric environment) and in conditions of normal atmospheric pressure (normobaric conditions). Economic and technical inconveniences limit the possibilities of widespread use of mountain-climatic and baro-chambered models of hypoxia in the training process of athletes. In addition, it has been established that the main factor in the mechanism of creating such models of hypoxia is the reduction

of the partial pressure of oxygen in the inhaled air, which may be accompanied by the deterioration of well-being or even the state of health of athletes. Therefore, such models of artificial creation of hypoxia should not be applied by specialists in physical education and sports in working with adolescents (Bishop, 2002; Gorbenko, 2005; Gavrylova, 2011; Kmyta, 2015; Kropta, 2017).

In our opinion, at the stages of preliminary and specialized basic training of cyclists it is promising to use an accessible and safe hypoxic model in the training process that enhance the efficiency of the training sessions not by increasing the volume of physical loads. Meanwhile, it should be taken into consideration that the specific posture and long-lasting static tension of the muscles of the upper shoulder girdle of the cyclist during the work somewhat complicate the activity of the circulatory and respiratory organs. As a compensatory phenomenon, through relaxation of the muscles of the anterior abdominal wall in a cyclist, favourable conditions are created for ventilation of the lower part of lungs due to strengthening of work of the muscles of the abdominal press and diaphragm, accompanied by a longer exhalation compared to the inspiration. Taking into account the abovementioned, it is advisable to increase the ventilation capacity of the cyclist's lungs by increasing the functionality of the above-mentioned muscles, which provide the abdominal type of respiration (Gorbenko, 2005; Gavrylova, 2011, 2012).

So, in the training process of young cyclists, an additional means of strengthening the effect of physical activity should be the use of such a hypoxic model, which would contribute not only to the improvement of the type of breathing characteristic of the cyclist, but also did not interfere with the ontogenesis process. These requirements are satisfied by the model of creation in the body of a state of pronounced hypercapnia and moderate hypoxia, which is caused by breathing through the apparatus "Endogenic-01".

Materials and Methods

Theoretical analysis and generalization of literary sources; pedagogical observation; pedagogical experiment; pedagogical testing with using methods of bicycle ergometry, pulsometry, sphygmomanometry, spirometry, chronometry; methods of mathematical statistics.

The study of physical working capacity was performed with bicycle ergometric test PWC₁₇₀ (Carpman B.L.). By the value of the PWC₁₇₀ indicator it was calculated the value of the maximum oxygen consumption VO_{2max}. The Wingate Anaerobic Test was used to determine the power of anaerobic alactatic and lactate energy supply processes. To determine the capacity of anaerobic lactate energy supply processes, it was used the method developed, which is used in mass surveys of athletes and provides for the determination of the anaerobic (lactate) performance of the body in terms of the maximum quantity of external mechanical work per 1 minute (MQEMW). For the purpose of studying the restoration of the heart rate after the metered physical load on a bicycle ergometer, it was used a pulsometry method with "TOPcom sports" and "SIGMA SPORT PS 4" heart rate monitors; the LD-91 sphygmomanometry was used to study the dynamics of the blood pressure recovery.

For the study of physical fitness, there were used the control tests which are indicated in the cycling sport curriculum for Children's and Youth Sports Schools, Olympic Reserve Junior Sports Schools, School of Higher Sportsmanship were used in the work.

The general physical fitness was evaluated according to the results of the tests that characterize the explosive strength (standing long jump), speed (running 60 m race); the speed-strength endurance (number of squats for 15 sec); the dynamic strength endurance (flexion and extension of arms in front lying support on the floor "to failure"); the static strength endurance of the extensor muscles of the back (holding "to failure" the pose "lying in the prone position with slightly extended straight arms and legs up"); the static strength endurance of the gluteus muscles (holding "to failure" the pose "lying in the prone position with legs maximum raised over the couch, extended by 10° and bent at the knee joints at a 45-degree angle, holding hands by the couch"); as well as general endurance (running 1,500 m race).

Special physical fitness was assessed by the time of cycling a 200 m flying-start heat and cycling a 2,000 m heat with a single turning

The obtained scientific materials were processed by the methods of mathematical statistics. The one-time impact of the artificially created hypoxia and hypercapnia, as well as metered physical loads on the functional state of the respiratory system of cyclists was studied by comparing the linked samples, and to establish the validity of the differences in the values obtained at the same time, the paired Wilcoxon-T test criterion was used. The effectiveness of the complex impact of the endogenous-hypoxic breathing technique and physical loads on functional and physical fitness during 16 weeks of the preparatory period of a one-year macrocycle was assessed by comparing the arithmetic linked samples, and the probability of differentiation between them was determined by the Student's t-criterion.

Results

Based on the analysis of literary sources, it is determined that cyclists' stages of preliminary and specialized basic training coincide with puberty period of human development. Improvement of physical and functional preparedness at these stages occurs during the period of intensive age biochemical, morphological and functional transformations, that must be considered in the organization of training sessions. The use of large

physical loads in order to increase the adaptation to training loads in the young athletes can cause the opposite effect - the deterioration of the adaptive reserves of the body. The data of the scientific sources indicate that various methods of artificially created hypoxia serve as means of strengthening impact of the athletes training. At the same time, the scientific information about the possibility of the application of the existing techniques for the artificial creation of hypoxia at different stages of cyclists training is controversial, and therefore requires further study (Gavrylova, 2011; Gruzevych, 2013; Gorshova, 2017).

The conducted analysis of scientific and methodological literature proves the necessity of the simultaneous experimental testing and introduction of the special techniques of creating the artificial state of hypoxia in the body, together with physical exercises into the cyclists training process. In addition, the issue of the peculiarities of the use of these techniques in the training system of athletes-teenagers remains a little studied.

After analysing the content of cycling training sessions at the stages of preliminary and specialized basic training of Children's Junior Sports schools, we came to the conclusion that in the process of preparation of young athletes insufficient attention is paid to the formation of the breathing type which is specific in the cyclists during the pedalling. Therefore, in the training sessions of athletes at these stages of multi-year training, as an additional means of improving physical fitness, the special breathing exercises should be used to create a specific type of breathing for the cyclists.

It has been established that in the training sessions of young cyclists a significant part of the work takes place in the anaerobic conditions of energy supply. In the case of abuse of such a work in the puberty period of ontogenesis, functions of those body systems that are determining for the process of perfection of athletic skills may be violated. Therefore, we applied an additional way of creating hypoxic-hypercapnic state in the body with the help of the apparatus "Endogenic-01" in the training process of the cyclists aged 13-16 years (Gavrylova, 2011).

The main task of cyclists' sports training at the stages of preliminary and specialized basic training in the preparatory period of the annual macrocycle was to increase the level of functional, physical, technical and tactical fitness. The training sessions were planned taking into accounts the age-specific peculiarities of the development of the body of cyclists-teenagers and were based on the general didactic and specific principles of sports training. The main attention was paid to the development of such physical qualities as the general and special endurance, the strength dynamic and static endurance, the speed-strength endurance, speed and the explosive strength.

The endogenous-hypoxic breathing technique was used in the cyclists training process at the general preparatory and partly at the special preparatory stages of the preparatory period of a one-year macrocycle, namely in the involving, basic and control-preparatory mesocycles for 16 weeks from December to April. The duration of a cycling training session in the preparatory period of the annual macrocycle at the stage of preliminary basic training was about 115 minutes, and the frequency of classes - 4-5 times a week. At the stage of the specialized basic training, the training session lasted about 175 minutes, with a frequency of 5-6 times a week.

The training sessions of the control and experimental cyclists groups did not differ in the content. The difference was the application by the athletes of the experimental groups of the endogenous-hypoxic breathing technique with the help of the apparatus "Endogenic-01" according to the so-called "itinerary list" at the beginning of each training session. This technique included a gradual adaptation to normobaric hypoxia and hypercapnia by increasing the amount of water in the apparatus, an increase in the time of slow exhalation, and also an increase in the duration of training sessions.

The hypoxic-hypercapnic state was created at the beginning of the preparatory part of the training session in order to increase the functional capabilities of the respiratory muscles, which are actively involved in the work of the cyclist, to form an economic stereotype of respiration, as well as to realize the functional capabilities of the body in the main part of the exercise.

One of the main tasks of training sessions for cyclists of the experimental groups at the stages of preliminary and specialized basic training was the formation of the adaptive mechanisms of the organism, not by increasing the volume and intensity of the training work, but by applying in the process of preparation of the artificially created hypoxic-hypercapnic state with the help of the device "Endogenic- 01".

The results of the conducted researches showed that the five-minute one-time application of the endogenous-hypoxic breathing technique leads to an increase in the functional capabilities of the respiratory muscles and bronchial permeability, namely: maximal ventilation of the lungs (MVL), = 30 (p <0.01); the lifetime capacity of the lungs during inspiration (IVC), T_{cr} = 44.5 (p <0.05) of the instantaneous volume velocity of air passing at the level of large bronchi (IVV25), T_{cr} = 33.0 (p <0.05) of the instantaneous volume velocity of air passing at the level of small bronchi (IVV75), T_{cr} = 44.5 (p <0.05).

A comparative analysis of the results of the spirographic study before and after the application of metered physical loads on a bicycle ergometer with a power of 1 and 2 W per 1 kg of body weight showed an improvement in the passage of air in the area of small bronchi, as indicated by the indicators of instantaneous

volume velocity ($T_{cr} = 1.0$, $p < 0.01$) and average volume velocity ($T_{cr} = 1.0$, $p < 0.01$) of air passing at the level of small bronchi.

The training sessions without the application of the endogenous-hypoxic breathing techniques during 16 weeks of the preparatory period in 13-14-year-old cyclists contributed to an increase in the relative magnitudes of the power of anaerobic alactative energy supply processes (by 6.18 %, $p < 0.05$), as well as the capacity of anaerobic lactate processes of energy supply (by 5.18 %, $p < 0.05$). Unlike 13-14-year-old cyclists, in 15-16-year-old athletes in the control group, such training sessions did not affect both the anaerobic processes of energy supply and did not cause significant changes in the physical working capacity and aerobic performance of the body.

The application of the endogenous-hypoxic breathing technique in the training process of cyclists at the stages of preliminary and specialized basic training during the preparatory period of an annual macrocycle contributed to an increase in physical working capacity, aerobic and anaerobic performance of the body.

There were revealed the age differences of the influence of the normobaric hypoxia and hypercapnia on the functional preparedness of adolescent cyclists. The integrated application of the endogenous-hypoxic breathing technique and physical exercises proved to be more effective for persons aged 13-14 years, than for 15-16 year-old adolescents. Thus, in 13-14-year-old cyclists of the experimental group, in 8 weeks after the beginning of the experiment, a significant increase in physical working capacity and aerobic performance was revealed, as evidenced by the growth of absolute values of PWC_{170} by 18.0%, ($p < 0.05$) and $VO_{2\max}$ by 8.08 %, ($p < 0.05$). In sixteen weeks after the beginning of the experiment, athletes of this age group had average values of $PWC_{170\text{ abs.}}$ and $VO_{2\max\text{ abs.}}$ increased by 28.89 % ($p < 0.005$) and 12.98 % ($p < 0.01$) respectively, compared to the baseline.

At the same time, during this period, in addition to the absolute values of the above mentioned indicators, a significant increase was found in the relative magnitude of PWC_{170} by 22.83 %, ($p < 0.05$). The integrated application of the endogenous-hypoxic breathing technique and training loads for 16 weeks in cyclists aged 13-14 years influenced not only aerobic but also anaerobic performance of the body. Thus, in comparison with the baseline there was a significant increase of the average values of relative capacities of anaerobic lactate energy supply by 6.14 %, ($p < 0.01$) and of the power of anaerobic alactative energy supply by 10.10 %, ($p < 0.05$). At the same time, the average values of the absolute and relative power indices of anaerobic lactate energy supply processes increased in average by 17.48 % ($p < 0.05$) and by 11.96 % ($p < 0.05$) respectively.

On the basis of the conducted research, it was established that the use of the normobaric hypoxia and hypercapnia in combination with training loads in 15-16-year-old cyclists significantly influenced the physical working capacity, aerobic and anaerobic performance of the organism in 16 weeks after the beginning of the experiment. Thus, the average value of the absolute value of PWC_{170} exceeded the original level by 15.84% ($p < 0.05$), and the relative - by 12.13 % ($p < 0.02$). The average magnitude of the absolute index $VO_{2\max}$ increased by 8.61 % ($p < 0.05$), and the relative magnitude increased by 5.13 % ($p < 0.05$). In addition, such training sessions contributed to the growth of the average values of such relative anaerobic performance of an organism as the capacity of anaerobic lactate energy supply processes (the value of the MQEMW increased by 4.17 %, $p < 0.01$) and the power of anaerobic lactate energy supply processes (the value of W_{anT30} increased by 6.24 %, $p < 0.05$).

It has been established that the use of normobaric hypoxia and hypercapnia in combination with training loads increases the functionality of the respiratory system of cyclists. Training sessions without application the endogenous-hypoxic breathing technique in the cyclists aged 13-14 years of the control group during the whole experiment did not affect significantly the function of external respiration. However, in 15-16-year-old athletes, such training sessions contributed to the growth of VC (5.63 %, $p < 0.05$) and IVC (6.85 %, $p < 0.05$), which indicates an increase in the respiratory surface of the lungs.

It was established that the use within 16 weeks of normobaric hypoxia and hypercapnia in the training process of both 13-14-year-old and 15-16-year-old cyclists influenced effectively on the function of external respiration, as indicated by an increase in the parameters of maximal ventilation of the lungs (MVL), respiratory reserve (RR), the ratio of the maximum ventilation of the lungs to the minute volume of respiration (MVL / MV), Inspiratory reserve volume (IRV), the vital lung capacity (VC), Inspiratory Vital Capacity (IVC), Expiratory Vital Capacity (EVC) (Table 1).

After the completion of the sixteen-week training cycle with application of the endogenous-hypoxic breathing technique, statistically significant changes in the forced lung capacity (FVC) and its components were registered. Thus, the average FVC relatively to the initial data increased in the 13-14-year-old cyclists by 3.53 % ($p < 0.05$), the volume of forced exhalation in 1 second (FEV1) - by 8.25 % ($p < 0.05$), and the instantaneous volume velocity of air passing at the level of the middle bronchi (IVV_{50}) - by 10.05 % ($p < 0.05$). In the 15-16-year-old athletes, a significant increase in FVC was registered - by 4.74 % ($p < 0.05$), FEV1 - by 6.53 % ($p < 0.05$), IVV_{50} - by 6.16 % ($p < 0.05$), peak volume velocity (PVV) - by 4.34 % ($p < 0.05$) and the instantaneous volume velocity of air passing at the level of small bronchi (IVV_{75}) - by 11.70 % ($p < 0.05$).

Table 1. The impact of the training sessions with application of the normobaric hypoxia and hypercapnia on the function of external respiration of cyclists aged 13-16 year

Indicators	Age	The average value, $\bar{x} \pm S$				
		Before the beginning	in 8 weeks from the beginning of the training	t	in 8 weeks from the beginning of the training	t
MVL, l·min ⁻¹	13-14	136.35±5.37	143.74±4.41	1.06	158.69±5.83**	2.82
	15-16	152.96±4.03	165.04±4.62	1.97	170.14±4.16**	2.97
RR, %	13-14	93.69±0.30	94.07±0.18	1.07	94.59±0.24*	2.31
	15-16	93.97±0.19	94.46±0.21	1.77	94.64±0.21*	2.37
MVL/ХОД	13-14	16.16±0.72	17.0±0.48	0.96	18.88±0.85*	2.45
	15-16	16.75±0.52	18.31±0.59	1.97	18.87±0.74*	2.36
PO вД, l	13-14	1.53±0.06	1.60±0.06	0.83	1.70±0.05*	2.19
	15-16	1.86±0.04	1.90±0.04	0.88	1.99±0.03**	2.74
VC, l	13-14	3.54±0.10	3.67±0.11	0.87	3.88±0.10*	2.36
	15-16	4.10±0.07	4.25±0.06	1.69	4.40±0.07***	3.12
IVC, l	13-14	2.21±0.07	2.30±0.07	0.92	2.48±0.07**	2.70
	15-16	2.64±0.04	2.71±0.04	1.29	2.83±0.04****	3.54
EVC, l	13-14	2.01±0.06	2.07±0.05	0.84	2.18±0.05*	2.19
	15-16	2.25±0.05	2.35±0.05	1.52	2.41±0.06*	2.19

Notes. The probability of the difference in values relatively to the value recorded before the beginning of the formative experiment:

* – p < 0,05; ** – p < 0,02; *** – p < 0,01; **** – p < 0,005

The application of the endogenous-hypoxic breathing technique in a combination with physical exercise loads for cyclists aged 13-16 years during the preparatory period of the annual macrocycle contributed to accelerating of the blood pressure and the heart rate recovery after performing physical work, as well as improving the vascular response to bicycle ergometric metered physical load with a power of 1 W and 2 W per 1 kg of the body weight according to the character of the diastolic pressure changes.

The systolic blood pressure recovery under the influence of eight-week training sessions without the application and with the application of the endogenous-hypoxic breathing technique in the cyclists aged 13-14 years with loads on a bicycle ergometer with a power of 1 W per 1 kg of body weight has significantly accelerated, however, the acceleration in the representatives of the experimental group was more intensive. It should also be noted that among the cyclists of the control and experimental groups in 8 weeks after the beginning of the experiment, the number of persons with increased diastolic blood pressure during exercise on a bicycle ergometer with a power of 2 W per 1 kg of body weight decreased. However, unlike the control group, in the cyclists of the experimental group the 16-week application of normobaric hypoxia and hypercapnia contributed to accelerating of the heart rate recovery after performing physical activity on a bicycle ergometer with a power of 1 W per 1 kg of body weight.

It was recorded a significant acceleration in the recovery of the systolic blood pressure and the heart rate after the metered physical loads with a power of 1 W per 1 kg of body weight, in the cyclists aged 15-16 years of the experimental and control groups, in 16 weeks after the beginning of the experiment. However, in the athletes of the experimental group, the positive impact of the training sessions in combination with normobaric hypoxia and hypercapnia manifested itself by a decrease in the number of persons who have diastolic blood pressure increases during performing the metered physical activity.

In the athletes aged 15-16 years of control and experimental groups compared with adolescents aged 13-14 years after performing bicycle ergometric metered loads, the systolic blood pressure recovery occurred a little faster. It has been established that 16-week-trainings without the application of the endogenous-hypoxic breathing technique of the athletes aged 13-14 years of the control group contributed to an increase in speed based on the results of the cycling a 200 m flying-start heat by 1.61 %, (p < 0.05) and the speed-strength endurance according to the maximum number of squats for 15 sec by 8.21 %, (p < 0.05). However, in the 15-16-year-old cyclists of the control group, such training sessions increased special endurance based on the results of overcoming the 2,000 m heat with a single turn by 4.42 % (p < 0.05).

The application of the endogenous-hypoxic breathing technique in the training process of cyclists at the stages of preliminary and specialized basic training contributed to a more substantial increase in general and special physical fitness (Table 2). Moreover, as a result of the study, there were revealed age peculiarities of the impact effectiveness of the normobaric hypoxia and hypercapnia on physical fitness of cyclists. The integrated application of the endogenous-hypoxic breathing technique in combination with training loads proved to be more effective for the cyclists aged 13-14 years than for 15-16 year-old athletes.

In the 13-14-year-old athletes (at the stage of preliminary basic training), the application of the artificially created hypoxia and hypercapnia in the training process during the 16 weeks helped to increase

overall physical fitness, in particular the running speed of 60 m, 1,500 m, as well as the maximum number of squats for 15 sec. In addition, the special physical preparedness has increased according to the results of cycling a 200 m flying-start heat and cycling a 2,000 m heat with one turn. In 15-16-year-old cyclists (at the stage of specialized basic training), training sessions in combination with the normobaric hypoxia and hypercapnia have increased the speed of running a 1,500 m race and the speed of cycling a 2,000 m heat with one turn.

Table 2. The impact of the training sessions with application of the normobaric hypoxia and hypercapnia on physical fitness of 13-16 year-old cyclists.

Indicators	Age	The average value, $\bar{x} \pm S$				
		Before the beginning	in 8 weeks from the beginning of the training	t	in 16 weeks from the beginning of the training	t
Running 60 m, sec	13-14	9.74±0.10	9.58±0.11	1.10	9.41±0.11*	2.25
	15-16	8.98±0.15	8.88±0.14	0.50	8.61±0.13	1.85
Number of squats for 15 sec, times	13-14	16.15±0.26	16.77±0.17	1.97	17.54±0.26****	3.78
	15-16	17.42±0.28	17.83±0.18	1.25	18.08±0.18	2.0
Running 1,500 m, min	13-14	6.35±0.05	6.19±0.05*	2.19	6.15±0.05***	2.69
	15-16	5.09±0.03	5.01±0.03	1.78	4.97±0.02**	2.75
Cycling 200 m flying-start heat, sec	13-14	15.21±0.11	15.0±0.14	1.15	14.79±0.15*	2.26
	15-16	13.09±0.15	12.97±0.11	0.66	12.70±0.14	1.94
Cycling 2,000 m heat with one turn, sec	13-14	3.09±0.04	2.98±0.04	1.98	2.93±0.04***	2.81
	15-16	2.79±0.03	2.71±0.04	1.72	2.63±0.03****	3.92

Notes. The probability of the difference in values relatively to the value recorded before the beginning of the formative experiment:

* - $p < 0.05$; ** - $p < 0.02$; *** - $p < 0.01$; **** - $p < 0.005$

Discussion

Analysis and generalization of scientific and methodological literature on the subject of research testifies to the possibility of application of the special (additional), increasing the effect of physical activity, techniques in the systemic training of athletes. To achieve the desired adaptive effect of physical activity in the process of training of the high-skilled athletes, there are used special techniques that additionally create the state of hypoxia in the body. The information on the application of such techniques is limited. In addition, not all the models of artificially created hypoxia can be used by specialists in physical education and sports when working with adolescents, due to the negative influence on the functional state of the growing organism. The most accessible and safe hypoxic method that can be used in the training process of adolescents is the endogenous-hypoxic breathing technique (Gavrylova, 2011; Gruzevych, 2013; Kmyta, 2015; Kropta, 2017).

The results of the influence of the normobaric hypoxia and hypercapnia at its one-time application on the external respiration function of the cyclists aged 13-16 years showed significant positive changes in the functional capabilities of the respiratory muscles and the ability of the large and small bronchi to pass the air. It was recorded the significant growth of such indicators, as VC ($T_{cr} = 44.5$, $p < 0.05$), IVV_{25} ($T_{cr} = 33.0$, $p < 0.05$), IVV_{75} ($T_{cr} = 44.5$, $p < 0.05$), MVL ($T_{cr} = 30.0$, $p < 0.01$). The metered physical exercises on bicycle ergometer with a power of 1W and 2 W per 1 kg of body weight of cyclists contributed to improved air passage in the area of small bronchi, as indicated by the indicators IVV_{75} ($T_{cr} = 1.0$, $p < 0.01$) and AVV_{75-85} ($T_{cr} = 1.0$, $p < 0.01$).

Training sessions under the curriculum for Children's and Youth Sports Schools, Olympic Reserve Junior Sports Schools, School of Higher Sportsmanship in cycling in 16 weeks after the beginning of the formative experiment, in the cyclists aged 13-14 years increased the power of anaerobic alactatic energy supply processes by 6.18 % ($p < 0.05$), as well as the power of anaerobic lactate energy supply processes - by 5.18 % ($p < 0.05$). It was also proved the acceleration of the period of the systolic blood pressure recovery after performing the metered physical loads on a bicycle ergometer with a power of 1W and 2 W per 1 kg of body weight of athletes. In the 15-16-year-old boys, the functional capabilities of the external respiration increased, in particular VC by 5.63 %, ($p < 0.05$) and IVC - by 6.85 %, ($p < 0.05$). Sixteen-week trainings of athletes aged 13-14 helped to increase the speed-strength endurance by 8.21 %, ($p < 0.05$) and speed by 1.61 %, ($p < 0.05$). In 15-16-year-old cyclists, such trainings have caused growth of the special endurance by 4.42 %, ($p < 0.05$).

The 13-16 year-old cyclists have applied normobaric hypoxia and hypercapnia in the preparatory period of annual macrocycle during 16 weeks and that contributed to an increase in physical working capacity, aerobic and anaerobic performance of the body. It has been revealed that the impact effectiveness of this technique on the functional fitness depends on the age of athletes. At the stage of preliminary basic training in 13-14-year-old athletes, the effect of such trainings manifested itself somewhat faster (in 8 weeks after the beginning of the experiment) than at the stage of the specialized basic training in 15-16-year-old cyclists. The increase in functional fitness in the athletes aged 13-14 years was more pronounced than that of athletes aged 15-

16 years. The physical fitness in 16 weeks increased in the 13-14-year-old cyclists at a relative magnitude of PWC_{170} by 22.83 % ($p < 0.05$), and in 15-16-year-olds - by 12.13 % ($p < 0.02$). The aerobic performance increased by the value of the indicator $VO_{2\max}$ has risen only in 15-16-year-old adolescents by 5.13% ($p < 0.05$). The capacity of anaerobic lactate productivity of an organism with a relative magnitude of the MQEMW increased in the 13-14-year-old cyclists by 6.14 % ($p < 0.01$), and in the 15-16-year-olds - by 4.17 % ($p < 0.01$). The power of anaerobic lactate performance by the value of the index $WanT_{30\text{ relative}}$ increased in 13-14-year-old athletes by 11.96 % ($p < 0.05$), and in 15-16-year-olds - by 6.24 % ($p < 0.05$). The power of the anaerobic alactative performance of the organism by the relative magnitude of the index $WanT_{10}$ increased by 10.10 % ($p < 0.05$) only in 13-14 year-old adolescents.

In the course of the research, it was confirmed that the application of additional techniques of artificially created hypoxia contributes to increasing the effectiveness of the training process of athletes of various specializations, as well as it was proved the scientific evidence of the positive impact of sports training combined with artificially created hypoxia on general and special physical fitness of athletes. At the same time, it has been supplemented the scientific information on the effectiveness of the use of various types of hypoxia in athletes' training sessions to enhance their functional fitness.

It can be considered as the absolutely new the revealed features of the influence of the normobaric hypoxia and hypercapnia on the functional and physical fitness of cyclists at the stages of preliminary and specialized basic training.

Conclusions

1. Due to the application of the endogenous-hypoxic breathing technique in a combination with training loads of cyclists of 13-16 years, positive changes have occurred in the apparatus of external respiration: functional capabilities of the respiratory muscles increase; respiratory surface of the lungs increase; there is an economization of work of the respiratory muscles in the state of relative muscular rest, and also the passage of air in the area of the medium and small bronchi is facilitated. The increase in the functional capacity of the respiratory muscles is indicated by the growth of MVL in the 13-14-year-old athletes - by 16.39 %, ($p < 0.02$), in the 15-16-year-old athletes - by 11.23 %, ($p < 0.02$), and MVL / HR (in 13-14-year-olds - by 16.82 %, ($p < 0.05$), in 15-16-year-olds - by 11.69 %, ($p < 0.05$). The evidence of an increase in the respiratory surface of the lungs is the increase in VC in the 13-14-year-olds - by 9.66 %, ($p < 0.05$), in the 15-16-year-olds - by 7.25 %, ($p < 0.01$). The economization of the work of the respiratory muscles is proved by decrease in RR in the state of relative muscular rest in athletes aged 13-14 years by 12.5 %, ($p < 0.05$), in 15-16-year-olds - by 12.35 %, ($p < 0.05$). The improvement of the bronchial permeability in the segment of medium and small bronchi is indicated by the growth of FVC indices in the 13-14-year-olds - by 3.53 %, ($p < 0.05$), in the 15-16-year-olds - by 4.74 % ($p < 0.05$) and of its components FEV1 in 13-14-year-olds - by 8.25 %, ($p < 0.05$), in 15-16-year-olds - by 6.53 %, ($p < 0.05$), IVV50 (in 13 -14-year-olds - by 10.05 %, $p < 0.05$, in 15-16-year-olds - by 6.16 %, $p < 0.05$), IVV75 (in the 15-16-year-olds - by 11.7 %, $p < 0.05$).

2. The sixteen-week trainings in combination with the artificially created normobaric hypoxia and hypercapnia in the preparatory period of the annual macrocycle have improved the cardiovascular response to metered physical activity (power of 1 W and 2 W per 1 kg of body weight), as well as accelerated the recovery of the blood pressure and heart rate after work completion. The positive influence of such trainings at the stage of preliminary basic training is evidenced by the acceleration of the recovery of the blood pressure and the heart rate, and at the stage of specialized basic training it is confirmed by a decrease in the number of athletes with the hypertonic type of cardiovascular response to the metered physical loads.

3. The effectiveness of the integrated application of the normobaric hypoxia and hypercapnia, as well as the training load on the physical fitness of adolescent cyclists depends on the age of athletes. In the 13-14-year-old athletes, in 16 weeks after the beginning of the formative experiment, the special physical preparedness increased according to the results of the cycling a 200 m fly-start heat (by 2.75 %, $p < 0.05$) and cycling a 2,000m heat with one turn (by 5.18 %, $p < 0.01$). The improvement of the overall physical fitness was confirmed by the growth of the results of running a 60 m race (by 3.43 %, $p < 0.05$), running a 1,500 m race (by 3.16 %, $p < 0.01$) and the maximum number of squats for 15 sec. (by 8.57 %, $p < 0.005$). At the stage of preliminary basic training, compared with cyclists with specialized basic training, the impact effectiveness of the normobaric hypoxia and hypercapnia on some indicators of the physical fitness was manifested somewhat faster (in 8 weeks after the beginning of the experiment). In 15-16-year-old cyclists training sessions with application of the endogenous-hypoxic breathing technique contributed to an increase in overall physical fitness according to the result of running a 1,500 m race (by 2.29 %, $p < 0.02$) and special physical fitness according to the results of the cycling a 2,000 m heat with one turn (by 5.91 %, $p < 0.005$).

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