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Original Article

Mechanisms of formation the training effects in athletes with application of swimmer's snorkel devise during the aerobic loads

RUSLAN KROPTA[1], IRYNA HRUZEVYCH[2], OLEKSANDR ZHYRNOV[3], ALLA SULYMA[4], SVITLANA SALNYKOVA[5], VOLODYMYR KORMILTSEV[6], VADYM POLIAK[7]
[1,3,6,]National University of Physical Education and Sports of Ukraine, Kiev, UKRAINE
[2,4,7]Vinnitsia State MykhailoKotsyubynskyi Pedagogical University, UKRAINE
[5,]Vinnitsia Institute of Trade and Economics, UKRAINE

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Abstract
In order to determine the peculiarities of the reaction of the cardiorespiratory system of athletes during the application of swimmer's snorkel, the research of indicators of activity of the cardiorespiratory system was performed. It was found that the use of such devices, both in a state of relative rest and in conditions of cyclic loading of aerobic nature, is an influential additional factor in increasing the capabilities of the cardiorespiratory system of athletes. The basic functional effects of the use of such devices are established: early activation of the expiratory muscles, reduction of the gradients of concentration of O_2 and CO_2.
Key words: aerobic training, swimmer's snorkel devices, cardiorespiratory system, swimming, amateur athletes.

Introduction

At all stages of the all over the year training of athletes for increasing their athletic results provides for the implementation of the physical work of large volume and intensity, that requires maximum mobilization of functional reserves of the body (L.M. Kuzmina, 2012; A.A. Pryimakov, R.V. Kropta, 2003; I. Hruzevych, V. Bohuslavska, R. Kropta, Y. Galan, I. Nakonechnyi. M. Pityn,2017). The practice of the sports training requires constant search, development, and substantiation of the new ergogenic sports training tools, which simultaneously enhance the effect of physical exercises and improve the adaptation level of the athletes to high-intensity exercises. (A.D.Gething, M. Williams,B. Davies, 2004; A.K. McConnell, M. Lomax, 2006; A.K. McConnell, 2009).

In the scientific publications of the recent years, a certain attention was taken to the introduction of a wide range of tools of influence on the respiratory system in the training process of the athletes, there are followed: artificial hypoxia and hypercapnia, breathing through additional vacuum space, respiration with increased resistive and elastic resistance, arbitrary hypoventilation, etc. Followed researchers(as the L.M. Kuzmina, 2004; I. Hruzevych, V. Bohuslavska, R. Kropta, Y. Galan, I. Nakonechnyi. M. Pityn, 2017; AK. McConnell, 2009;JD. Witt, JA. Guenette, JL. Rupert, DC. McKenzie AW. Sheel, 2007; Y. M.Furman, I.V.Hruzevych, 2014), is talking about the attraction of the effective, modern and scientifically substantiated tools that can significantly increase the efficiency of physical exercises without increasing the amount of training work, especially in sports, requires a domination of the endurance (A.A. Pryimakov, R.V. Kropta, 2003; J.A. Wylegala, D.R. Pendergast, L.E. Gosselin, D.E. Warkander, C.E. Lundgren, 2007;A.W. Sheel, 2002; R.V. Kropta, 2004; BJ. Taylor, SC. How, L.M.Romer, 2006)

For the practical activity, devices using right during the physical loads has a particular importance, there are followed: respiratory tubes for swimming, respiratory masks for use in running, classes in uniforms, and other (C.A. Harms, TJ. Wetter, CM. St Croix, 1998; AK.McConnell, M. Lomax, 2006; AK.McConnell, 2009, AW.Sheel, 2002).The main feature of the impact of such devices is linking with the regulation of mechanical resistance of air flow, low frequency vibration of exhaust air, as well as the possibility of their use during physical activity as an additional load regulator (AD. Gething, M. Williams, B. Davies, 2004; BJ. Taylor, SC. How, L.M. Romer, 2006; J.A Wylegala, D.R. Pendergast, L.E. Gosselin, D.E. Warkander, C.E. Lundgren, 2007).

At the same time, the information about the physiological component of the using of complex devices for the respiratory system in the conditions of training and competitive activities of athletes is rather limited. In a lot of the scientific publications, only the educational component is presented, the mode of application and the effectiveness of the process of sports training, based on the results of pedagogical experiments (AK. McConnell,

Corresponding Author: RUSLAN KROPTA, E-mail: y_kropta@ukr.net

LM. Romer,2004;AK. McConnell, 2009; AW.Sheel, 2002; BJ. Taylor, SC. How, L.M. Romer, 2006; J.A Wylegala, D.R. Pendergast, L.E. Gosselin, D.E. Warkander, C.E. Lundgren, 2007).

The importance of determining the physiological mechanisms of the influence of the devices of additional influence on the cardiorespiratory system of the athletes in the conditions of training became the basis for research, the results are the content of this publication.

Purpose of the research

To research the physiological mechanisms of the formation of training effects from the using of the swimmer's snorkel device during the aerobic exercise in swimming.

Materials & Methods

Participants

In the research participated 10 athletes, specialized in swimming, aged 19-21 years, having completed swimming competitive and training seasons from 1 to 3 years.All participants received informed consent for participation in this research, all athletes were previously trained in the testing procedure.

Procedure/Test protocol/Measure/Instruments

The research of the peculiarities of the reaction of the cardiopulmonary resection system was carried out in a rest condition (in the sitting position) and in conditions during the physical activity (manual bicycle ergometry). The bike "TECHNOGYM" was used for hand-tanning, which allowed the muscles of the upper extremities and upper shoulder girdle to be used in a mode that simulates the movements of the swimmer.

Fig. 1.Illustration of the testing process: hands are handled with measurements of the activity of the cardiopulmonary resuscitation system during the normal breathing (on the left picture) and during the breathing act with a swimmer's snorkel device (on the right picture)
(source: photos of the authors, Kropta R. and Hruzevych I.)

Registration of indicators of external respiration, gas composition of exhaled air and blood circulation was carried out with the gas analyzer of exhaust air with a spirometer "JEAGER Oxicon Mobile" (Germany),the heart rate was studied by the registrar"POLAR".

Measuring the performance of the cardiopulmonary resuscitation system during the rest condition was according to the followed scheme:

10 minutes – surveyed performing the arbitrary breathing through the mask of the analyzer,

20 minutes – surveyed performing the random breathing through the mask of the analyzer with the attached swimmer's snorkel device (at this stage, the gas composition of exhaled air was alternately measured directly near the mask of the analyzer and at the end of the swimmer's snorkel device).

10 minutes –surveyed performing the random breathing through the mask of the analyzer.

For the measurement of the cardiopulmonary resuscitation system performance during the physical activity, athletes performed a motor test PWC-170. The choice of the test was due to the level of physical capacity level of the participants who took part in the testing. The test consisted of two loads:

1) 5 minutes of pedaling, power was 1 $W \cdot kg^{-1}$, the tempo was arbitrary;
2) 4 minutes of pedaling, with power, that was selected by the results of the first load and was about1,5$W \cdot kg^{-1}$, the tempo was arbitrary.

The test was performed twice, for the first time with breathing in the mask of the analyzer, the second time - in the mask of the analyzer with the attached swimmer's snorkel device. The time taken for the restoring of the condition between tests was 60 minutes.

Statistical analysis

The data obtained during the experiment were processed using descriptive statistics methods. We used the method of averages. Average values of the studied indicators were determined ($\bar{x}$) and a standard deviation (σ).The statistical processing of the materials of the research was performed with using a software package Microsoft Excel 2010.

Results

Investigating the indicators of a cardiorespiratory system of the athletes during the rest condition and with an additional load from the swimmer's snorkel device, has shown that breathing through the swimmer's snorkel device forms the gas composition of the air, inhaled by an athlete has a difference with an ordinary atmospheric air: $F_IO_2$level decreased by a 2,08%, $F_ICO_2$indicator increased on a 2,1% (Table 1).Reducing of the gradients concentration caused by and additional vacuum space has an effect on pulmonary ventilation due to increasing of respiratory of the muscle activity (Table 2). It has been determined that within 10 minutes of breathing with the swimmer's snorkel using, the respiration rate is increased mainly due to an increasing of characteristics of the reduction of inspiratory muscles, as evidenced by a decrease in inspiratory time and an increase in the duration of exhalation. After 10 minutes of breathing, both parameters of the duration of the breath phases are reduced, the activity of the expiratory muscles also begins to increase.

Table 1.The content and partial pressure of the respiratory gases in the free breathing of athletes during the rest condition and with using theswimmer’s snorkeldevice($\bar{x}$±σ)

Gas content (partial gas pressure)	Random breathing	Random breathing through swimmer’s snorkel	
		near the analyzer mask	at the end of swimmer’s snorkel
F_IO_2	20,76 ± 0,06	18,68 ± 0,06	20,81 ± 0,02
F_ICO_2	0,20 ± 0,06	2,30 ± 0,08	0,35 ± 0,02
F_EO_2(P_EO_2)	17,0±0,35 (16,06±0,33)	16,82±0,2 (15,85±0,19)	18,2±0,2 (17,22±0,21)
F_ECO_2 (P_ECO_2)	3,63±0,17 (3,42±0,16)	3,97±0,09 (3,74±0,0,8)	2,42±0,1 (2,28±0,1)
$F_{ET}O_2$ ($P_{ET}O_2$)	15,7±0,39 (14,79±0,37)	15,6±0,3 (14,76±0,28)	16,3±0,2 (15,42±0,27)
$F_{ET}CO_2$ ($P_{ET}CO_2$)	4,89±0,18 (4,61±0,17)	4,94±0,14 (4,66±0,13)	4,33±0,13 (4,08±0,12)

Comment.F_I– inspiration gas fraction, %;F_E – expiration gas fraction, %; F_{ET}– end-tidal gas fraction, %; P_E – pressure gas in expiration, кPa;P_{ET}– pressure end-tidal gas, кPa.

Table 2.Indicators of external breathing of athletes during the rest condition and with using the swimmer’s snorkel device($\bar{x}$±σ)

An indicator of external respiration	Random breathing during the rest	Random breathing through the swimmer’s snorkel on the 10 min	on the 20 min
V_T, l	0,90 ± 0,12	1,02 ± 0,09	0,92 ± 0,08
f, l·min^{-1}	13,2 ± 1,42	13,93 ± 1,24	16,34 ± 1,04
$\dot{V}_E$, l·min^{-1}	11,79 ± 2,99	14,21 ± 0,42	14,56 ± 1,16
$t_{(E+I)}$, sec	4,79 ± 0,45	4,55 ± 0,46	3,74 ± 0,46
t_E, sec	2,39 ± 0,2	2,45 ± 0,23	2,06 ± 0,15
t_I, sec	2,40 ± 0,19	2,10 ± 0,2	1,68 ± 0,18

Comment.V_T– tidal volume on expiration; f –breathing frequency; $\dot{V}_E$ –minute ventilation; $t_{(E+I)}$- total time respiratory cycle; t_E- time expiration; t_I- time inspiration.

Performing the test PWC-170 allowed to identify the effects of breathing with a swimmer's snorkel device during the aerobic exercise (Table 3). Comparison of indicators of the cardiorespiratory system of athletes during the physical activity, as during the rest, indicates on the creation of additional stress from the swimmer's snorkel device either on an external respiration system, or a gas exchange and the efficiency of transport of oxygen.

As during the relative rest, during the loading of power as 1 W·kg^{-1} with using the swimmer’s snorkel deviceis observed increased indicator of $\dot{V}_E$, by increasing the breathing frequency and reducing the time of the respiratory cycle, especially by increasing the expiration rate (Table 3). The created additional voltage on the respiratory muscles, that’s also reflected in the gas exchange rates, also increased, compared with physical work without the using of the swimmer's snorkel device.With the increasing power to 1,5 W·kg^{-1}, the difference in external respiration rates during the using of swimmer's snorkel device was not observed in the comparison with its absence, while the rates of gas exchange and blood circulation were even more different (Fig. 1).

Table 3.Indicators of external respiration and gas exchange of the athletes during the aerobic exercise ($\bar{x}\pm\sigma$)

Indicator	Manual pedaling, P/m=1 W·kg^{-1}; SR= 53-54 1·min^{-1}		Manual pedaling, P/m=1,5 W·kg^{-1}; SR= 62-63 1·min^{-1}	
	Random breathing	Random breathingthrough swimmer's snorkel	Random breathing	Random breathingthrough swimmer's snorkel
V_T, l	1,47 ± 0,25	1,48 ± 0,16	1,71 ± 0,23	1,67 ± 0,22
f, 1·min^{-1}	23,45 ± 2,7	26,23 ± 2,77	33,47 ± 5,53	33,75 ± 5,64
$\dot{V}_E$, l·min^{-1}	34,23 ± 7,97	38,70 ± 7,74	57,91 ± 16,9	57,03 ±16,31
$t_{(E+I)}$, sec	2,62 ± 0,31	2,34 ± 0,26	1,87 ±0,4	1,83 ± 0,35
t_E, sec	1,39 ± 0,11	1,25 ± 0,11	0,98 ± 0,22	0,95 ± 0,19
t_I, sec	1,24 ± 0,12	1,08 ± 0,11	0,88 ± 0,19	0,88 ± 0,16
$\dot{V}O_2$, l·min^{-1}	1327,7 ± 177,7	1518, 78 ± 286,24	1839,2 ± 244,16	1988,5 ± 551,0
$\dot{V}O_2/m$, ml·min^{-1}·kg^{-1}	15,64 ±2,07	18,1 ± 3,43	21,84 ± 2,68	23,67 ± 4,27
$V\dot{C}O_2$, l·min^{-1}	1188,4 ± 282,46	1302,65 ± 375,7	1771,41 ± 451,8	1861,03 ± 432,92
RQ, r.u.	0,89 ± 0,11	0,84 ± 0,11	0,95 ± 0,14	0,92 ± 0,14
HR, 1·min^{-1}	127,2 ± 9,2	136,53 ± 8,99	159,72 ± 13,1	161,4 ± 14,8
$\dot{V}O_2/HR$, ml·1^{-1}·ming^{-1}	10,41 ± 0,82	11,13 ± 1,58	11,51 ± 0,53	12,53 ± 1,17
SpO_2, %	91,2 ± 3,09	97,48 ± 0,43	92,92 ± 5,8	89,53 ± 1,2

Comment. $\dot{V}O_2$–O_2-uptake; $\dot{V}O_2/m$– O_2uptake per 1 kg of body weight; $V\dot{C}O_2$ – CO_2-output$_2$; RQ–respiratory exchange ratio; HR–heart rate; $\dot{V}O_2/HR$- oxygen pulse; SpO_2 – O_2-saturation of the blood.

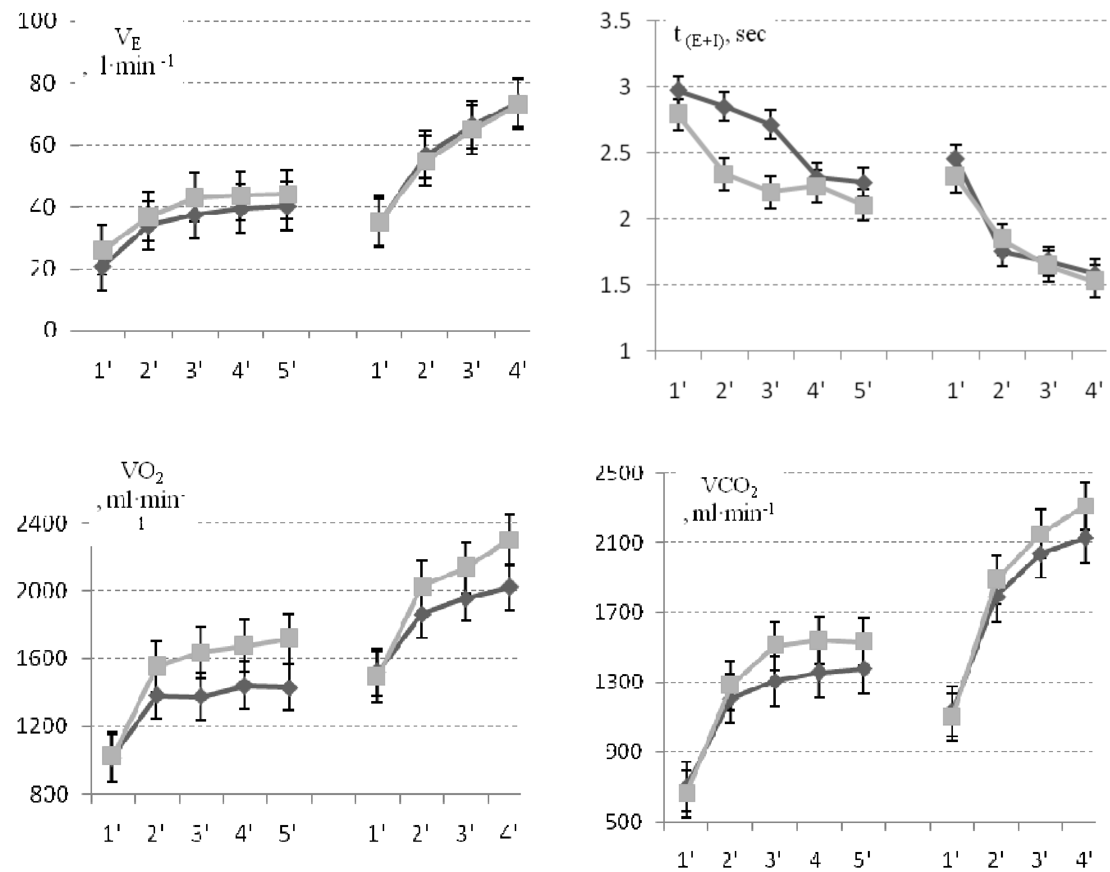

Fig. 1. Dynamics of indicators of the minute ventilation($\dot{V}_E$), total time respiratory cycle($t_{(E+I)}$), oxygen uptake($\dot{V}O_2$) andcarbon dioxide output ($V\dot{C}O_2$) during the test PWC-170 performed by the amateur-athletes:there are average data of two loads are presented, duration of 5 minutes (1'-5') and 4 minutes(1'-4'). Dark bars indicate the dynamics of indicators during performing the test without the use of swimmer's snorkel device; light bars - while using swimmer's snorkel device.

The foregoing data are confirmed by the dynamics of ventilation equivalents for O_2 ($\dot{V}_E/\dot{V}O_2$) and CO_2 ($\dot{V}_E/\dot{V}CO_2$), reflected the effectiveness of ventilation of the lungs in relation to the transport of respiratory gases. Absence of differences in the values of ventilation equivalents under load conditions by power 1 $W \cdot kg^{-1}$ during the using the swimmer's snorkel device, in comparison with its absence, indicated that in purely aerobic conditions, as in the relative rest condition, the coordination of external respiration with respect to the needs of gas exchange is sufficiently effective, without interfering with additional resistance to breathing and changes in the gas composition of inhaled air. When power is increasing to the $1{,}5 W \cdot kg^{-1}$, during the breathing through the swimmer's snorkel device, the ventilation equivalents are reduced. So with the same indicators of the $\dot{V}_E$on the level nearby 57 ± 16$l \cdot min^{-1}$, $\dot{V}_E/\dot{V}O_2$ indicator was 29,71± 5,7r.u.,during the breath without swimmer's snorkel device, same indicator decreased to 27,43 ± 3,35 r.u., that's associated with an increase in the level of oxygen consumption. The difference in the dynamics of the $\dot{V}_E/\dot{V}CO_2$indicatorwas not observed at all stages of the testing.

An important functional effect observed in exercise conditions with the using the swimmer's snorkel device was an increase in the minute volume of blood (determined by the index of perfusion – $\dot{Q}tc$) at the expense of a significant increasing in the hit stroke volume of blood (SVc), in the absence of a significant difference in athlete's$\dot{HR}$indicator (Fig. 2). The$\dot{Q}tc$indicator during the pedaling power1 $W \cdot kg^{-1}$ and during the swimmer's snorkel device using was 12,02 ± 1,3 $l \cdot min^{-1}$ (without using the swimmer's snorkel device same indicator was 9,91 ± 0,7 $l \cdot min^{-1}$) but during the power holding on the 1,5 $Вт \cdot кг^{-1}$ this indicator was 13,47 ± 1,2 $l \cdot min^{-1}$ (without using the swimmer's snorkel device same indicator was 12,24 ± 0,64 $л \cdot хв^{-1}$).

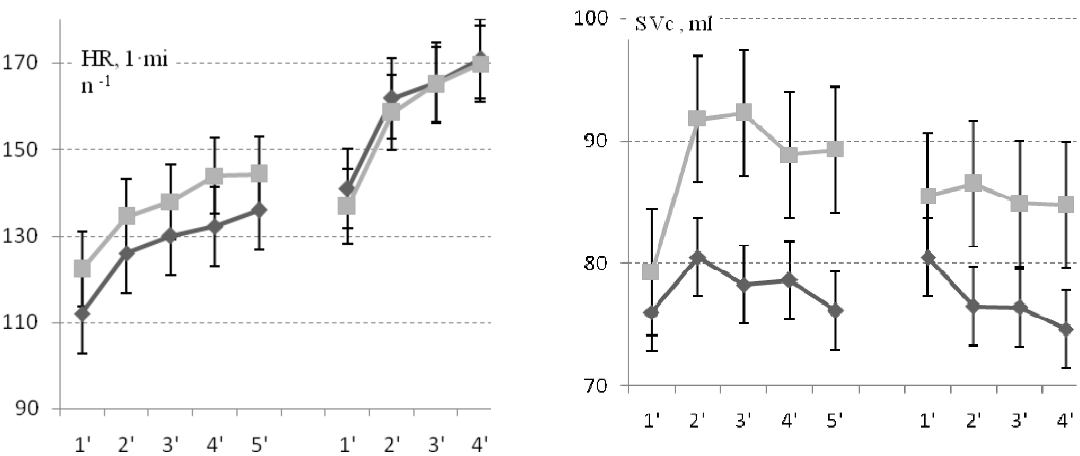

Fig. 2. Dynamics of indicators of heart rate ($\dot{HR}$) and shock volume of blood (SVc) during the PWC-170 test, performed by the amateur-athletes:there are average data of two loads are presented, duration of 5 minutes (1'-5') and 4 minutes (1'-4'). Dark bars indicate the dynamics of indicators during performing the test without the use of swimmer's snorkel device; light bars - while using swimmer's snorkel device.

Discussion

The studying of the indicators of the cardiorespiratory system of athletes in a rest condition and with additional loading by swimmer's snorkel device confirms the data obtained from McConnell&Lomax (2006), Kuzmina, (2004) about the regarding of the physiological mechanism of breathing through a swimmer's snorkel device. The mechanism consists of the formation of an excellent gas composition of air from ordinary atmospheric, with unreliably decreasing the volume of $O_2$and a fairly significant increasing the volume of CO_2.It is the CO_2 level is themain factor, influencing the athlete's breathing. Data from Harms, Wetter&St Croix (1998), McConnell, (2009), indicate that the reason for such changes is the presence of additional vacuum space, in which at low speed of air in a relative rest condition (there are sitting posture, air temperature about 26°C, arbitrary breathing) formed gas composition is negative from atmospheric. Therefore, the using of the swimmer's snorkel device in a rest condition creates the frameworks for the additional chemical stimulation of the respiratory center.The results are consistent with the data obtained from Sheel, (2002), How &Romer, (2006) that the breath with swimmer's snorkel device using in a relative restrain condition gradually increases the activity of the inspiratory muscles and activates the expiratory, for providing relatively forced respiration and increasing the lungs respiration, as the physiological reactions that are not inherent to the relative calm condition.

At the same time, aerobic loads are bringing to the increased activity of the respiratory center and cause a significant increasing of the strength and rate of muscle contraction, both during the inhalation and exhalation, actually reduce the effect of the additional vacuum space in the swimmer's snorkel device. Thus, the using of theswimmer's snorkeldevice in the aerobic loading conditions is not a factor in limiting the flow of gas and stimulation of external respiration. Forced breathing during aerobic exercise performing creates such a velocity of exhaled air that does not provide the formation of an atmosphere other than the gas mixture that is inhaled by an athlete, and the record in the study of an increased level of oxygen consumption is associated with the oxygen supply with increased muscular effort and an oxygen demand from both skeletal and respiratory muscles.

We assume that in conditions of loading with an increase anaerobic energy supply (with a power above the anaerobic threshold), the appearance of non-respirable $CO_2$and an increased request of O_2will bring a more active respiratory system reaction on the using of a swimmer's snorkel device.Based on the obtained data, we can say that the increase of theSVcindicator became the main compensatory mechanism for providing an increased oxygen demand for an identical response of the external breath to the using of the swimmer's snorkel device, as compared with the performance of the test load without its application.

Conclusions

The using of the devices of additional influence on the breathing system (swimmer's snorkel and others) both in a relative rest condition and in the conditions of cyclic loading of an aerobic exercises, is an influential additional factor of increase of possibilities of a cardiorespiratory system of athletes.

The main functional effects of the using such devices in a rest condition were in the early activation of expiratory muscles, reduction of concentration gradients of$O_2$and CO_2indicators due to the creation of a different atmospheric gas mixture in an additional vacuum space.The accumulation effect of the devices of additional influence on the respiratory system is noted: the first manifestations of the effect are observed after 10 minutes of application and tend to increase the effect in the future.In the conditions of aerobic loading of low intensity (as the 1 $W \cdot kg^{-1}$) the functional effects inherent in rest, become more pronounced.

The using of the devices of additional influence on the respiration system under conditions of aerobic loading of medium intensity (as the 1,5 $W \cdot kg^{-1}$) causes more stressing on the cardiorespiratory system of athletes, compared to the work without swimmer's snorkel device, that's compensated by the increasing the shocking volume of blood.

The prospect of further research is connected with the determination of the impact of swimmer's snorkel device on the activity of the cardiorespiratory system of athletes under conditions during the aerobic-anaerobic performance and anaerobic physical activity.

Credit

The work was carried out in accordance with the thematic plan of the Ministry of Education and Science of Ukraine for 2016-2020 years on the topics: 2.8. «The Features of the Somatic, Visceral and Sensory Systems of the Qualified Athletes at the Different Stages of the Preparation Process» (No of the State Registration is 0116U001632); «Theoretical and Methodological Foundations of the Programming and Simulation of the Athlete's Training of the Different Qualifications» (No of the State Registration is 0116U005299); 2015-1 «The Using of the Ergogenic Factors in the Practice of Training of the Qualified Athletes» (No of the State Registration is 0115U000902).

Conflicts of interest–If the authors have any conflicts of interest to declare.

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