Research Advances of Low Oxygen Training Stimulus to Individual’s Certain Physiological Indices

Chang-Zhuan SHAO\textsuperscript{a} and Hong-Ke JIANG\textsuperscript{b,\textsuperscript{*}}

Department of Sport, Shanghai Maritime University, Shanghai 201306, China

\textsuperscript{a}scz1971@126.com, \textsuperscript{b}jianghk88@yeah.net

\textsuperscript{*}Corresponding author

Keywords: Low Oxygen Training, Respiratory System, Cardiovascular System.

Abstract. The low oxygen training (LOT) was characterized by improving exercise capacities, enhancing cardiovascular functional performances due to the stimulus of insufficient oxygen and a series of physiological adaptations post-LOT. However, it is still unclear of the detailed research advances and potential new study hotspot. In the current study, we hacked the regulatory effects of LOT stimulus on individual’s certain physiological performances and elaborated intrinsic mechanisms by focusing on changes of physiology and biochemistry with literature consultation, thereby exploring new study spot.

Introduction

Hypoxia training refers to the continuous or intermittent use of the plateau natural hypoxic environment during the exercise training cycle, and with the exercise training to increase the degree of hypoxia of the motor body, resulting in a series of physiological response and adaptability to improve the body's anti-anoxia. To mobilize the body's potential, and thus to improve the ability to exercise and the body under hypoxia conditions in the synthesis of trisphenate gland training methods [1-3]. With the continuous development of competitive sports and the improvement of the level of sports technology, hypoxia training has been paid more and more attention by domestic and foreign sports circles. The research and practice of hypoxia training have been paid attention to and perfected. At present, China through the hypoxia training such as "high and low training", "high live low training low training", "low live high practice" and "gap hypoxia training" and other forms of research, as to improve the athletes Physical fitness, heart, lung function training methods and means. In this paper, through the hypoxia training on the physiological response and physiological indicators of the review, that hypoxia training on the body's physiological indicators constitutes a good impact, play a catalytic role.

The Body's Physiological Response Caused by Hypoxia Training

Effects of Hypoxia Training on the Respiratory System

Hypoxia training can increase the respiratory muscle strength, lung ventilation, tidal volume have increased significantly, and increased lung ventilation, can ensure that the oxygen
in the low external environment, the number of red blood cells increased and enough oxygen can be taken by the blood.

In hypoxic conditions, hypoxia can stimulate the carotid body and aortic body of the chemical receptors, and then stimulate the respiratory center, so that accelerated breathing to compensate for the impact of hypoxia on the body. Repeated stimulation was indicated to improve respiratory system.

Increased respiratory rate and depth caused an increase in pulmonary ventilation, which is one of the initial reactions in hypoxic environments. Hypoxia and pulmonary ventilation can increase alveolar oxygen partial pressure, increase arterial oxygen pressure and oxygen saturation, oxygen dissociation hemoglobin dissociation curve is also left, the increase in respiratory rate may be the reason for increased lung ventilation. Hypoxia is controlled by the peripheral and central chemoreceptors and depends on the sensitivity of the individual to hypoxia [4, 5]. The increase in lung ventilation, although resulting in an increase in oxygen consumption, does not have a significant effect on the increase in oxygen saturation. According to reports, the general subjects in the hypoxic environment training after 5 weeks, hypoxia ventilation increased [6]. The increase in pulmonary ventilation during hypoxia training can make breathing more effective, which will be conducive to the improvement of plain athletic ability. However, poor athlete hypoxia ventilation response weakened, weakened hypoxia ventilation reaction can reduce the respiratory muscle work, reduce the respiratory muscle oxygen consumption, and so excellent athlete’s hypoxia ventilation response to this feature is conducive to the improvement of plain athletic ability[7]. At present, the hypoxia training can change the excellent athletes hypoxia ventilation reaction is still controversial, athletes hypoxia training after hypoxia ventilation increased, which will be due to increased respiratory oxygen consumption is not conducive to the improvement of plain athletic ability.

**The effect of Hypoxia Training on the Cardiovascular System**

As a stressor, hypoxia can cause sympathetic nervous excitation, increased renal β-adrenoceptors, causing sympathetic adrenal axis of the reflex enhancement, so that myocardial contractility increased, stroke volume increased, heart rate, peripheral vasodilatation, and peripheral circulation resistance decreased, increasing cardiac output to speed up blood flow, thereby enhancing the ability to transport oxygen. After 5 days of hypoxia training, the stroke volume increased significantly. After 10 days of hypoxia training, the cardiac output increased, cardiac output, heart rate index and cardiac index were also significantly increased, and the heart rate change was not obvious[8]. Oxygen training can significantly improve the athlete's heart function, which is mainly achieved by increasing the stroke volume.

In the hypoxic environment, quiet and exercise heart rate, heart rate increases can compensate for the decline in oxygen transport capacity, but the maximum heart rate and cardiac output have declined. Studies have shown that, with the maximum oxygen uptake, the maximum heart rate also increases with the height of decreasing, more than a certain altitude above the maximum heart rate that is significantly decreased, the maximum heart rate in Mount Everest when the sea level of about 70%, the largest heart rate decline is to adapt to hypoxia. There are also studies found that at a certain height, the maximum heart rate and sea level no difference. With the adaptation to the hypoxic environment, quiet heart rate gradually restored to the level of the plain or even lower. The decrease of heart rate after hypoxia is related to the
proliferation of capillaries [9]. The decrease in \(\beta\)-adrenal gland is the main reason for the decrease of cardiac output, and the hypoxia may also be the influencing factors during exercise in hypoxic environment. Changes have a negative effect on cardiac function. The use of low-pressure chambers to simulate a height of 4000 to 8000 m shows that the increase in cardiac output decreases with height, but studies have also found that cardiac output does not change or even increase at the same level. These studies suggest that cardiac output can be maintained despite the decline in blood volume and cardiac filling after altitude. There is no data to explain the cause of increased left ventricular contractility caused by hypoxia training, myocardial energy utilization may be the improvement of left ventricular systolic force increase in the reasons [10].

**Influence on the Body of Certain Physiological Indicators of Hypoxia Training**

**Effects of Hypoxia Training on Heart Rate**

The heart rate increases significantly from the plain to the hypoxic environment (plateau or simulated plateau), but the slow heart rate can be roughly the same as that of the plains in a few years after hypoxia. Long-term migrants lived in the plateau and the world who have heart slowly. At the altitude of 4,500 ~ 4,700m pastoral areas, the majority of Tibetan herdsmen heart rate less than 60 times / min, the total population of 50.9%, but no corresponding symptoms. The reduction in oxygen content in the blood is compensated by increasing the heart rate when resting on the plateau and performing sub-maximal exercise and training. In order to provide enough oxygen for the muscles, the frequency of cardiac contraction increases. But in the maximum intensity of exercise and training, the heart rate in the upper plateau after 9 ~ 21d may drop about 5 to 10 times / min. The decrease in maximal heart rate may be related to a decrease in myocardial oxygen supply. Studies show that the same batch of subjects from the plains stationed in the plateau region, quiet when the heart rate increased by 45% over the plains, but in the same intensity of physical labor in the plateau region increased by an average of 7% to 8%. There was no significant difference in the rate of heart rate increase between the two groups, but the intensity of cardiac stress was 7% to 8% higher than that of the plain, and the intensity of heart load was equal Heart rate to the same level), the heart to do power than the plains reduced by 8% [11].

**Influence on the Blood of Hypoxia Training**

The effect of hypoxia on blood is mainly about the hemoglobin in the blood, which is related to the blood flow of the organ. The blood flow of the organ depends on the pressure of the blood perfusion (ie, the pressure of the arteriovenous) and the blood flow of the organ. The latter mainly depends on the size of the open blood vessels and the size of the inner diameter. Acute hypoxia, the skin, abdominal organ due to sympathetic nerve excitement, vasoconstrictor effect prevails, so that blood vessels to clean up and heart cerebrovascular due to local tissue metabolites vasodilator effect of blood flow increased. This change in blood flow distribution is clearly beneficial for ensuring the supply of vital organs oxygen.

In the hypoxic environment due to the stimulation of respiratory alkalosis, erythrocyte 2, 3-DPG content increased, leading to blood oxygen dissociation curve shift to the right, is conducive to the release of oxygen. In the plateau to stay, with the recovery of acid - base balance, erythrocyte 2, 3 - DPG content decreased. When the number of young erythrocytes in
the blood increased, the average erythrocyte age decreased and the content of 2, 3 - DPG in young erythrocytes was higher, and the content of 2, 3 - DPG in erythrocytes was longer in the long period after returning to the plains. In addition to 2, 3 - DPG in young red blood cells, the acid - base buffer capacity and rheology are better than those of senescent erythrocytes. Blood viscosity is the core of hemorheology research. The main influencing factors include cell hyperemia, erythrocytes Deformation, etc. due to the ability of deformability of red blood cells to a large extent affect the blood supply capacity of the organization and the co2 and other substances transport capacity. Therefore, the deformability of red blood cells athletes have a significant impact on athletic ability, hypoxia stimulation of erythrocyte deformability will have a complex and profound impact [12]. This has a positive effect on the improvement of athletic ability.

Effects of Hypoxic Training on Pulmonary Vasoconstriction

Pulmonary vascular wall cells and extracellular matrix due to hypoxia training occurred vascular structural changes, pulmonary vascular wall endothelial cells, smooth muscle cells and fibroblasts increased, differentiation and extracellular matrix synthesis increased and accumulation of changes in pulmonary vascular structural values The response to hypoxia stimulation, accompanied by a compensatory response to pulmonary wall thickening and reduced compliance. Pulmonary vascular response to hypoxia and body blood vessels, alveolar hypoxia and mixed venous blood oxygen pressure reduction are caused by pulmonary artery contraction, so that hypoxic alveolar blood flow decreased. The reduction of alveolar vasoconstriction caused by local pulmonary vasoconstriction is conducive to maintaining the appropriate proportion of alveolar ventilation and blood flow, so that through this part of the alveolar blood can still get more oxygen, which can maintain a high oxygen partial pressure. In addition, when hypoxia causes a wider range of pulmonary vasoconstriction leading to increased pulmonary motility, the upper pulmonary blood flow increases, the upper pulmonary alveolar ventilation can be more fully utilized [13].

Effects of Hypoxic Training on Capillary Hyperplasia

Long-term hypoxia can promote hair follicle hyperplasia, especially the brain, heart and skeletal muscle capillary hyperplasia more significant. Increasing the density of the capillaries can shorten the distance of blood oxygen to the cells and increase the ability to supply oxygen to the cells.

Effects of Hypoxic Training on Vital Capacity

In hypoxic conditions, due to reduced oxygen partial pressure, causing increased respiratory rate, resulting in increased acute hypoxic pulmonary ventilation, but little increase. However, in the chronic hypoxia, due to the collective respiratory regulation system has some adaptation, increased lung ventilation increased. But continued over-ventilation, body carbon dioxide content decreased, pH increased, causing respiratory alkalosis on the human body have a negative impact. At the same time, in the hypoxic stimulation, the lung gas diffusion capacity is also greatly enhanced, thereby increasing the oxygen saturation in the lungs to compensate for the impact of hypoxia on the body to improve the respiratory function, so that alveolar ventilation increased, Alveolar oxygen partial pressure increased, oxygen partial pressure also increased. Studies have shown that, after hypoxia training, subjects per minute ventilation, tidal
volume and respiratory rate did not materially change, but the intake air volume, maximum lung ventilation / vital capacity and maximum lung ventilation / tidal volume significantly improve sex. At the same time, the pulmonary function, vital capacity / time vital capacity, and maximum lung ventilation / vital capacity were significantly higher than those of the normal pulmonary function. It can be seen that hypoxia exercise can improve the lung function reserve of the subjects and improve the power and maximum oxygen uptake of the respiratory muscles and promote the pulmonary function.

Effects of Hypoxic Training on Alveolar Gas Diffusion, Oxygen Transport and Gas Exchange

The environment faced by hypoxic training is that the atmospheric pressure is lower than that of the plain, resulting in a decrease in the oxygen partial pressure of the inhaled air in the human body, which in turn reduces the oxygen uptake in the blood and decreases the oxygen partial pressure and oxygenation hemoglobin saturation. Through the increase in lung ventilation to compensate for the organization's oxygen supply. The body of hypoxia oxygen partial pressure reduction is an important mechanism to increase the red blood cells and hemoglobin content, in order to improve the oxygen transport capacity. On the other hand, increase lung ventilation, so that the intake of oxygen to increase breathing. However, some studies have shown that the maximum ventilation in the initial phase of the hypoxic environment did not increase but decreased after a period of hypoxia training, the lung capacity showed a significant increase. Plateau and plain athletes in the blood buffer system in the early hypoxia training are acidic, to the end of the state out of the state of acid. After hypoxia training, the blood buffer ability to improve, PH value is stable, no acidosis phenomenon occurs, athletes in hypoxic environment, the ability of blood to transport oxygen increased. Performance for the lung capacity, capillary open more, more blood flow is conducive to increased lung dispersion, alveolar and arterial pressure difference was progressive increase.

In hypoxic conditions, exercise can make the body oxygen demand doubled. In the hypoxic environment, exercise can increase the body's degree of hypoxia, which further caused the body's physiological compensatory response. People or animals into the hypoxic environment, hemoglobin increased, after the resulting continued increase. And the increase in red blood cells is also very obvious. The number of red blood cells and the pressure is significantly higher with the plains. The increase of hemoglobin content increases the oxygen capacity, which is beneficial to the transmission of oxygen to the tissue, and is more conducive to the gas exchange in the muscle. It is one of the adapting mechanisms of the organism adapting to hypoxia.

Effects of Hypoxia Training on Maximal Oxygen Uptake

In addition to blood changes in the oxygen transport capacity of the blood circulation, but also depend on the necessary conditions for blood circulation. The maximum oxygen uptake is the blood circulation oxygen transport capacity of an important symbol. The maximum oxygen uptake is the maximum amount of oxygen that can be used to transport the active muscle per unit of time. The maximum oxygen uptake depends largely on the maximum cardiac output. According to research reports, the maximum oxygen uptake was heightened. 2w is still significantly lower than the plain value, the decline increases with altitude and increase, the extent of women than men. On the plateau, atmospheric pressure decreased (580mmHg), causing oxygen partial pressure drop, resulting in alveolar oxygen tension and oxygen
saturation decreased [14]. Due to the maximum heart rate \ stroke volume and cardiac output decreased, these factors have a direct impact on the maximum oxygen uptake and aerobic work capacity. When the athletes returned to plain 2W by hypoxia training, the maximum oxygen uptake was increased by 3%, the maximum aerobic power increased by 5.6%, and the heart rate and blood lactate decreased significantly at the limit and sub-limit load. Hemoglobin and arterial blood after exercise Oxygen partial pressure and oxygen saturation increased, indicating that altitude training after cardiac function (increased stroke rate), blood oxygen capacity improved [15]. At the same time, in the same power movement, the oxygen function ratio increases, the glycolysis is delayed. Therefore, the maximum oxygen uptake by hypoxia training showed an increasing trend.

**Effects of Hypoxia Training on Hemolysis**

Plasma accounts for 55% of total blood. In the early plateau, the plasma volume decreased by 16 to 21% within 14 days. The degree of plasma reduction depends on the intensity and duration of training and the balance of intake and exclusion of liquid substances. Most of the loss of plasma capacity is lost by perspiration and urination, as well as excessive ventilation. The decline in plasma capacity has led to a decline in the number of people per stroke in the plateau.

**Effects of Hypoxia Training on Cardiac Output**

Hypoxia on the human heart output reported increase, unchanged and reduce the three cases, these reports are not consistent. This is different from the measurement method and height, gender age and different relationship. Chronic hypoxia can be increased by ATP / ADP + P potential or pulmonary artery increased, right ventricular load increased, blood catecholamines caused by increased myocardial protein synthesis, resulting in cardiac hypertrophy. Myocardium is very sensitive to hypoxia, in addition to heart rate; the electrocardiogram also appears hypoxia performance and right heart load increase in the change. In the highland area physical labor 3 to 6 months, ECG Q-T interval prolonged, QRS axis right deviation. The higher the altitude, the greater the strength of physical labor, the higher the incidence of ECG deviation. The detection rate of right ventricular voltage was higher than that of altitude and labor intensity, and the detection rate of right ventricular hypertrophy increased with altitude.

Chinese national men's road bike athletes altitude training research shows that at an altitude of 1, 890 m and 2, 366m period of 3 to 4 months period, the early plateau, the morning and systolic blood pressure generally increased, 4 ~ 5d after the decline, the plateau 2 ~ 3 w morning pulse to maintain the level of the plain, basically not affected by the amount of exercise and strength, but there are individual differences. The pulse and systolic blood pressure were significantly lower in the morning than 2 ~ 3 weeks after the return to the plain. The left ventricular pressure of the athletes was significantly higher than that before the training. The area of the X-ray was significantly increased and recovered after two weeks. This may be related to the increase of the load before and after the heart caused by the high intensity load in the hypoxic environment. The change range increases with the increase of the load. Plateau hypoxia and exercise load increased, so that the heart compensatory function gradually increased, when left the plateau than the plateau training before the heart function significantly increased. Plateau residents under hypoxia sustained effect, pulmonary vascular resistance and pulmonary arterial pressure rise can form hypoxic pulmonary hypertension, resulting in increased right ventricular load and right ventricular hypertrophy, severe cases can be further
developed for right heart failure. The cardiac output is reduced at maximum intensity of training, which is due to cardiac output and maximum heart rate drop. The decrease of maximal cardiac output is one of the factors influencing the maximal oxygen uptake under hypoxia.

Conclusions

Hypoxia training is the application of natural or artificial methods to make the body in a low oxygen content of the environment under normal movement of a method. It increases the body's lung ventilation and blood erythrocyte volume, improve the body's ability to transport oxygen, improve the athlete's athletic ability, and enhance the body's aerobic capacity. Hypoxia training through the respiratory system, circulatory system and other physiological indicators, proved in the physiological function of the body to enhance the ability of aerobic metabolism, it has been a high level of our athletes to improve endurance of a training method, is a line The effective scientific training method can provide a new basis for the scientific training of sports training.

Acknowledgement

This research was financially supported by the National Science Foundation.

References


