Effects of interval hypoxic training to the cognitive, emotional and physiological indicators of students

Abdrazak Babashev[1*], *Ainur* Yerlan[2], *Erbolat* Makashev[3], *Dinara* Baytilesova[4], and *Gulshat* Atanbayeva[1]

[1]Al-Farabi Kazakh National University, Almaty,050040, Kazakhstan
[2]Caspian International School of Medicine, Almaty,050000, Kazakhstan
[3]Institute of Genetics and Physiology, Almaty,050090, Kazakhstan
[4]Kazakh-Russian Medical University, Almaty,050000, Kazakhstan

Abstract. Currently, noninvasive medicine is used more widely due to its safety and naturalness. One of the promising tools of noninvasive medicine is the interval hypoxia training. This method has an extensive corrective effect on the human organism. In this article we present the results of study of the influence of hypoxic training on the cognitive, emotional and physiological functions. Before and after each of 14 sessions lasting one hour, students performed tests to determine the features of memory, level of anxiety and the lung capacity. The study involved 40 male students aged 19-20 years. It was established that hypobaric adaptation is accompanied by positive changes in the indicators of cognitive, emotional and physiological functions. Indicators of memory capacity and lungs vital capacity increased whereas the levels of situational anxiety decreased. Thus the course of interval hypoxic training has a multifaceted positive effects. It is suggested that beneficial impact of hypobaric adaptation on psychological and physiological functions is explained by ricing and mobilization of organism's reserve capacity

1 Introduction

Life in the modern digital world is full of stressors such as physical inactivity, high information load, busy schedule and others, which can cause a decrease in cognitive performance, deterioration of the emotional state and physiological functions and negatively affect the organism's ability to adapt to the constantly changing external demands [1,2]. In this regard, students experience a lot of mental load and are in other stressful conditions, such as staying in a sitting position for many hours and regular exams [3,4].

To support subject's mental and physical health a variety of evidence-based noninvasive interventions are available. And one of the promising tool of noninvasive treatment is the interval hypoxia training. Despite the fact that the method has long been effectively used for optimizing a functioning of respiratory, genitourinary and other body's autonomic systems

* Corresponding author: Abdrazak55@mail.ru

[5,6], the prospects for using hypoxic training to improve particular cognitive functions, such as different types of memory, which is especially important for students, as they are constantly learns new knowledge, have not yet been assessed. It has been shown that hypoxia training had a positive effect on the general condition of students, as well as the psycho-emotional status with a predominance of improving the brain cognitive functions [7]. It is assumed that the beneficial effect is associated with a limited effect of stress on the expression of brain-derived neurotrophic factor (BDNF) in the hippocampus and an increase in capillary density, which optimizes the functional state of the brain due to the training course, which can have a complex effect on the psycho-emotional mediated by the limbic system, which is the center of memory [8,9]. We aimed to estimate the influence of elaborated variant of protocol of interval hypoxic training to the cognitive, emotional and physiological indicators in students.

2 Material and Methods

2.1 Ethical statement and Participants

The legitimacy of the research is confirmed by the conclusion of the independent Ethical committee at the Institute of Human and Animal Physiology of the Ministry of Education and Science of the Republic of Kazakhstan (02.09.2021. №07-05/95). Volunteer participants signed informed consent. 40 physically active , young-aged (19±2) years males volunteered to participate in the present investigation.

2.2 Hypoxic training procedure

The studies were carried out at an altitude of 3,000 meters to 4,000 meters in a special hypoxic chamber using hypoxic in automatic mode using bicycle ergometric, a pressure chamber is used, where it is regulated the number of students training, quickly and at any time to create and maintain a stable hypoxic atmosphere. it is possible to maintain altitude and balance between temperature and humidity with this pressure chamber by creating high altitude conditions. All testing was conducted in a simulated hypoxia chamber (“Jiangyin Safe Import and Export Co., LTD”, China ISO13485:2016, Declaration of Conformity: EAEU KG417/024. D.0008745) in laboratory of hypoxia in Institute of Physiology Human and Animal MES RK. Hypoxic effects were performed in courses lasting 14 sessions. The training was conducted in a cyclically fractionated mode with a hypoxic mixture containing 10-15% oxygen and 85-90% nitrogen for 10 minutes. The course training was started from a height of 3000 m for the first three sessions, then after the third, sixth, ninth and twelfth sessions, the "height" in the chamber increased stepwise by 500 m. The last three sessions were performed at an "altitude" of 4000 m.

2.3 Measurement of cognitive, emotional and physiological indicators

The assessment of cognitive, emotional and physiological indicators was conducted before and after each of 14 sessions of interval hypoxic training. To resolve the issue of admission to hypoxic training, applicants provided data on their health status and only after receiving admission by doctor of laboratory , the participants were tested of each session .

Lung capacity was determined using using a dry spirometer SSP brand by method of Sokolov A.D (Spyrometr SSP, NV-MED , Russian,Moscow) [10].

Quantitative assessment of mechanical and logical memory was provided by test Methodology "Study of logical and mechanical memory" [11,12], personal and situational

anxiety was assessed using the Spilberg-Hanin's test (State-Trait Anxiety Inventory, STAI) (Russian adaptation by Hanin Y.L) [13].

2.4 Statistical analysis

During the observation, indicators of the level of average personal and average situational anxiety were measured by points, lung volume was measured before (on the first day) and after sessions of interval hypoxia in ml. Data on the calculation of logical and mechanical memory were indicators before (on the first day of training and after) the measurement of the word count unit. The results of the study were compared with each other (before and after), the values of the indicators were averaged. All quantitative results are presented as mean ± standard deviation (SD). Paired t-test using Microsoft Excel were applied for the analysis. Differences were considered significant at p values less than 0.05.

3 Results and Discussion

Data analysis revealed three groups of students with different levels of personal and situational anxiety. The first group with low personal and situational anxiety (0-7 points) included 11 people, the group with average level of anxiety (8-14 points) included 12 students, and the group with high level (15-20 points) of anxiety 17 people. In the middle group changes in the anxiety level in response to IHT was not significant. It was shown that both groups (low and high) allowed us to identify the following specifics of student anxiety: Students with a "high index" of anxiety have a high index of both situational and personal anxiety. The average indicator of "high" personal anxiety before the IHT sessions was 12 ± 0.05 points ($p < 0.05$) and situational anxiety 16 ± 0.05($p < 0.05$) points, after the IHT session the level of "high" personal anxiety decreased to 5.98 ± 0 .05. points ($p<0.05$,), and the level of "high" situational awareness decreased by 3.66±0.05 points ($p<0.05$,) compared to the IHT session. At the same time, the level of "low" personal activity increased to the level of 12 ± 0.05 points ($p < 0.05$), and situational anxiety increased to the level of 16.2 ± 0.05 points ($p < 0.05$) compared to the level before IHT sessions.

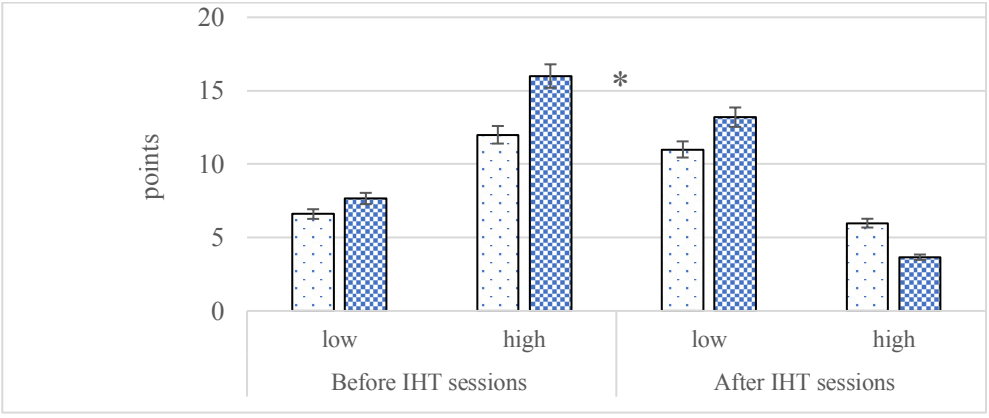

Fig1. Students' anxiety level before and after IHT sessions, *p≤0.05.

Thus, it can be assumed that the indicators of students with a low level of anxiety predominate after IHT sessions .It is noted that IHT sessions can have a twofold effect according to opinion`s of students in a timely manner and also have an effect after a long period. It was revealed that more positive results are noted (behavior improves students

become more calm, balanced, adequate, attention improves, sleep normalizes, and perception of educational material increases). These data were also confirmed when observing children suffering from epilepsy, seizures of epilepsy became less frequent [20]. A confirming fact of the positive effect of IHT sessions is the change in volume indicators in the respiratory system, which demonstrates the organism's reserve capabilities for prolonged exposure to hypoxia (Fig.2). For example, the total lung capacity of the lungs (TLC) after interval hypoxic therapy increased by 3686 ml ± 0.05 ml, but the reserve volume of inspiration increased.

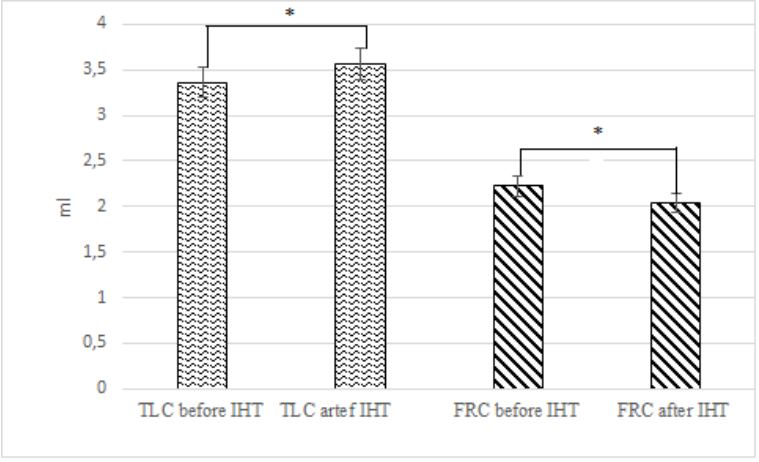

Fig.2. Respiratory capacity of lung, before and after IHT .(TLC-total lung capacity , FRC-functional residual volume, IHT- Intermittent hypoxic training), *p≤0.05.

Thus, it can be assumed that the functional respiratory system reacts first to a decrease in oxygen in the inhaled air and compensates for an increase in lung volume. Thus, an increase in the efficiency of the circulatory function is combined with an increase in the functional capabilities of external respiration when adapting to periodic hypoxia. This set of shifts seems to play a role in increasing performance at maximum load. One of the criteria for resistance to physical activity is the degree of enzymemia, i.e. the release of enzymes into the blood due to the labialization of cell membranes. It is known that the occurrence of this kind of membrane labialization and enzymemia under stress and during physical exertion in untrained people is largely determined by the activation of lipid peroxidation (POL). This kind of activation is a factor limiting the intensity of physical activity, and the introduction of antioxidants to people, suppressing the activation of lipids, increases the intensity and duration of physical activity [21].

After a course of interval hypoxic training , students showed an improvement in memory (logical and mechanical) by test "Study of logical and mechanical memory" [11,12] (Fig.3). Based on the results of testing the volume of logical and mechanical memory, it was revealed that in the “before IHT” group, the majority of students had a number of words of logical memory below 5±0.05 words, which is due to the fact that they were unable to establish an associative connection between the proposed conditions. The number of words of mechanical memory before IHT was 6±0.05 p≤0.005, which indicates memorization of words without understanding the meaning. After sessions of interval hypoxia in students, the number of words of logical memory was above 9±0.05 p≤0.005 words, and the number of words of mechanical memory was below 5±0.05 p≤0.005. Thus, based on the result, it can be assumed that perhaps more logical memory develops, and the function of mechanical memory decreases.

Sessions of interval hypoxia increase the humoral function of oxygen transport, which increases aerobic and anaerobic capabilities. This contributes to the appearance of the effect of training, eliminates violations of homeostasis and, as a result, the stress reaction disappears, which has become unnecessary [14].

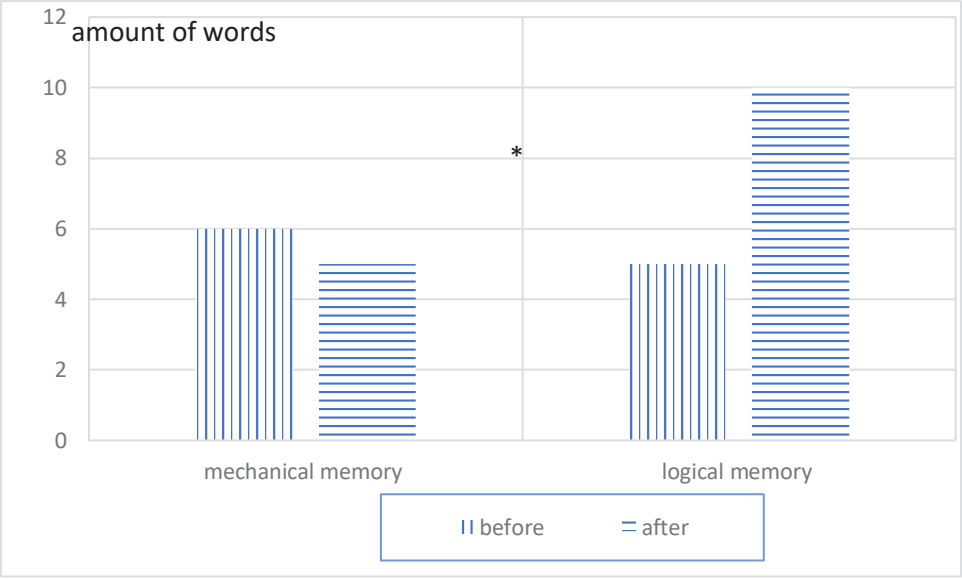

Fig.3. Types of memory before and after IHT (1-mechanical memory, 2-logical memory), *p≤0.005.

Relatively short-term interventions can improve cognitive function, confirmed by Niedermeier et al., which shows an improvement in visual attention after a brief intense physical activity [15]. Thus, IHT improves the initial functional state by increasing the overall vegetative function of the organs [16]. At the same time, respiratory volumes and lung capacities increase, respiratory regulation improves, resistance to mixed hypercapnia and hypoxia increases, and, consequently, the organism becomes more adapted to physical exertion. The conducted IHT sessions showed that during the period of IHT training, the students' performance significantly increased with a decrease in muscle mass.

4 Conclusion

Under the influence of interval hypoxic training, the reaction to adequate differentiation of positive and inhibitory stimuli in time-deficient conditions is significantly improved. This has also been proven by a number of works by scientists who have confirmed the facts of a positive impact normobaric hypoxic training on the effectiveness of cognitive activity parameters [5,6,7]. Hypoxia acts indirectly on the smooth muscles of the bronchi, eliminating spasm.This is also facilitated by the stimulation of beta adrenergic receptors , which occurs under the influence of oxygen deficiency . Under stress, there is a decrease in energy consumption during passive work, as well as increased oxygen utilization during active work [17]. It was found that the effect of hypoxia sessions directly activates the expression of brain-derived neurotrophic factor (BDNF) in the structures of the hippocampus, which affects the centers of memory and awareness [18, 8, 9]. Despite the data on the effect of adaptation to interval hypoxia on the structural and functional characteristics of the brain, the specific mechanisms of which have not been fully disclosed. Similar researchers suggest that the mechanism activating under the action of hypoxia may be associated with the synthesis of

nitrites, stimulation of antioxidant function and an increase in capillary tones in the brain [8,19]. Intermittent hypoxia thus activates the cross mechanism , prevents damage to the heart, activates the "structural systemic trace", i.e. activation of protein and nucleic acid biosynthesis [20]. In addition to the beneficial effects on physiological performance described, increasing evidence indicates that moderate treatment increases hippocampal neurogenesis, synaptogenesis, and BDNF expression and improves spatial learning and memory abilities of organism. A variety of protective effects on the respiratory system, cardiovascular system, nervous system, and other organs, and then counteracts the damage of hypoxia to organisms through complex defense mechanisms [4,8-10,17].

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