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Rationale of the Normobaric Interval Hypoxic Training Method and the «Detensor» Method for Long-term-traction of the Spinal Column Combined Application in the Complex of Rehabilitation Measures for Post-COVID-19 Syndrome

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Abstract

During the first year of the new coronavirus (COVID-19) pandemic, more than 60 million people were infected. Of these, almost 20% had the consequences after it, the so-called "Post-COVID syndrome", which manifests itself in various long-term painful symptoms. The causative agent of the disease, the coronavirus SARS-CoV-2, primarily affects the lung tissues and disrupts gas exchange that leads to acute respiratory distress syndrome, systemic hypoxia, when, first of all, the blood saturation system is destroyed. Severe complications of this infection require the active development of methods to eliminate and prevent the consequences of infection with coronavirus. Therefore, the search for effective rehabilitation method, especially of the respiratory system specifically after suffering from pneumonia caused by COVID-19, is extremely urgent.

As a result of numerous studies, the possibility of using the method of normobaric interval hypoxic training was justified. At the same time, the respiratory surface and the number of alveoli in the lungs increase, the mass of the respiratory muscles increases and the neurons of the respiratory center hypertrophy occurs as a result of which the efficiency of the ventilation function increases. Inflammation in the lungs can last for several weeks and then fibrosis occurs in place of the damaged areas. This shows the absolute need for effective methods of rehabilitation, first of all, of the bronchopulmonary system after suffering from pneumonia caused by COVID-19. Interval hypoxic training, as an effective non-specific method of increasing the body's defenses is indispensable in rehabilitation after viral pneumonia. It is shown that the combined use of interval hypoxic training and the method "Detensor" for the gentle long-term traction of spinal column can reduce or eliminate ventilation and perfusion disorders in chronic obstructive pulmonary disease. This justifies the possibility of using these methods for correction of bronchopulmonary disorders as a non-invasive and non-pharmacological support in the complex of rehabilitation measures for Post-COVID syndrome.

Keywords: Post-COVID syndrome, coronavirus, SARS-CoV-2, COVID-19, normobaric interval hypoxic training, method «Detensor», gentle long-term traction of spinal column

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During the first year of pandemic more than 60 million people have been caught the new corona virus (COVID-19). Almost 20% of these people had the consequences of this disease, so-called "Post-COVID-19" syndrome, developed different long-term painful symptoms from which former patients suffer up to 12 weeks or more [1]. Post- COVID-19 syndrome is included in the International Classifier of Diseases ICD-10 "U09.9" in the wording "Health Condition after COVID-19".

The infecting agent is the highly infectious coronavirus SARS-CoV-2, primarily picks out lung tissue and interrupts gas exchange, which leads to acute respiratory distress syndrome, systemic hypoxia, when the mechanism of blood saturation is destroyed [2]. The serious complications of this infection require the active development of methods to eliminate and prevent the consequences of the virus infection. Thus, the search for effective methods of rehabilitation, especially of the respiratory system, after suffering from pneumonia caused by COVID-19, is currently relevant.

In 2019, a group of scientists from the USA and the Great Britain: G.Semenza, W.Kaelin, P. Ratcliff received the Nobel Prize in Physiology/ Medicine for a series of researches in the field of adaptation of cells to oxygen deficit and the role of hypoxia influence on different body functional systems [3]. It

is known that SARS-CoV-2 virus needs certain conditions on the part of cell membranes to penetrate into the lung tissue cell: the existence of the CE2 receptor and the membrane-bound serine protease TMPRSS2 (Transmembrane protease, serine 2). SARS-CoV-2 virus uses angiotensin converting enzyme 2 (ACE2 – membrane protein) as a receptor to enter the cell and TMPRSS2 is necessary for activation the viral S-protein of the peplomer. Without these elements, the penetration of SARS-CoV-2 virus into the cell is impossible.

As the TMPRSS2 enzyme activates the SARS-CoV-2 coronavirus, enzyme inhibitors can block the virus [4, 5]. Such an inhibitor can be hypoxytherapy, as the basis of prophylaxis and treatment of the consequences of corona virus. A hypothesis was developed about the potential usefulness of the so-called "hypoxic conditioning" for the activation of HIF-1 – induced cytoprotective signaling (HIF-1 – hypoxia-inducible factor-1) that would reduce disease severity and improve the functioning of vital organs in patients with COVID-19.

The authors suggested that activation of the HIF-1 α-signaling pathway under conditions of moderate hypoxia will decrease the activity of ACE2 and TMPRSS2 and increase ADAM17 (metalloproteinase 17) on the surface of alveolocytes and, therefore, reduce the invasiveness of SARS-CoV-2. Whereas, HIF-1a protein targets are involved in the production of proinflammatory cytokines induced by discernible hypoxia, where the inflammatory process and the cytokine storm phase of COVID-19 are then activated

In contrast, the moderate doses of intermittent hypoxia can reduce the pro-inflammatory process. Whereas the preventive measures and correction of severe hypoxemia in the treatment of patients with COVID-19 is carried out using oxygenation and mechanical ventilation. Hypoxic conditioning can be useful as a non-invasive and non-pharmacological treatment method of the corona virus consequences [2, 7]. This specific technique has entered practical medicine as "normobaric interval hypoxic training" (IGT), which most correctly determines the essence of its effecting mechanism on the human body [8].

During IHT the number of alveoli increases in the lungs, the capacity of breathing muscles expands, the activity of the respiratory center increases as the result it stimulates pulmonary ventilation and increases its efficiency and also physical and mental capacity, nonspecific resistance of the body [9, 10].

The clinical use of controlled hypoxia has confidently come into practice since the 80s of the last century. It is proven that this factor has a marked therapeutic effect in different diseases that are followed by hypoxemia. Hypoxia causes a number of changes in various body systems focused on adaptive reactions, it allows tissues to functionalize in conditions of oxygen defect. They should activate the necessary oxygen delivery to the body, facilitate its transportation to vital systems during hypoxemia and provide the ability for tissues to utilize oxygen at its low voltage [9,11].

It is known that during different health problems including viral infections, mitochondria are disordered. In this case, a number of metabolic and energy disorders appears which create an unfavorable pathological background for the regenerative process. Besides, mitochondria have a signal function, they are the primary sensors of the oxygen level, and as soon as the oxygen level changes involving these intracellular organs, adaptation mechanisms are activated. If the oxygen content changes (for example, when a person goes up the mountains), at the beginning mitochondria switch on fast signals then slower adaptation mechanisms begin to act. Ultimately, a person adapts to hypoxia after 2–3 weeks in the mountains. And when a person descends on the sea level, in such a way, the cells can already use oxygen more economically, they need less oxygen to do the same work. It was also found that when using the IHT method, this effect is increased [10, 11].

Our immunity destroys bacteria and viruses through an oxidative explosion, in other words, when the oxygen accumulates inside the cell and then mitochondria, pyroxisomes use this oxygen not for energy but for activation of free radicals that destroy bacteria, viruses and even cancer cells. This process also involves nitric oxide, a signal molecule that has an antibacterial antiviral effect and it is also a modulator of other processes – it regulates vascular tone, affects the cell wall permeability. If you strengthen the endogenous oxidative protection, increase the amount of nitric oxide, the cells will be able to resist infection more effectively. In this case, the antioxidative system is simultaneously activated by increasing the activity of catalase, superoxide dismutase and peroxidase [9, 11, 12].

The Scientists from the United States (the University of California) discovered that the catalase enzyme is able to suppress the multiplication of coronavirus in the body, regulate the production of cytokines and be effective in COVID-19. It helps to prevent cytokine storm, which ultimately increases cell resistance of internal surface of the alveoli in the lungs. It is found that the patients with asymptomatic coronavirus infection have an increased enzyme activity of antioxidant defence. These people have a powerful immune response to the infective matter, the expulsion of free radicals occurs, which leads to the viruses and bacteria elimination [7, 12, 13]. But, if the activity of the superoxide dismutase enzymes is reduced, then a powerful systemic inflammatory reaction occurs throughout the endothelium, microthrombosis and microcirculation disorders develop, a hyperergic systemic response is formed, which ultimately leads to death. To prevent a fatal case, it is just needed the presence of a large antioxidative reserve in the cells thanks to the activation of their own enzymes.

Inflammation in the lungs can last for several weeks, then fibrosis occurs in the place of the damaged areas. If there are concomitant diseases of other organs, then their recurrence is possible after recovery from a coronavirus infection, this is due to a general weakening of the body and immune response defect. The absolute necessity of valid methods of bronchopulmonary and cardiovascular rehabilitation after pneumonia caused by COVID-19 is suggested. It is noted that IHT allows to normalize status of patients faster who have been down with pneumonia. In contrast, constant hypoxia increases the disorder and activation of thrombosis, such as a stroke, heart attack, or some kind of viral infection [10, 14].

Currently, interval hypoxic training is widely and successfully used in the clinic, both preventively and for treatment and rehabilitation of many chronic diseases. However, the possibilities of this method are not fully used. In the section "Temporary guidelines. Medical rehabilitation for new coronavirus infection (COVID-19), the chapter "Medical rehabilitation of the 2nd stage ", it was recommended to conduct normobaric hypoxytherapy in stationary pressure chambers for tissue oxygenation, normalization of organ blood flow, which helps to improve tissue respiration and reduce pulmonary hypoxia15]. For IHT, a GIPO-OXI-1 device (patent No. 2301686, 2007) was developed to get gas mixtures, which can produce both hypoxic and hyperoxic gas mixtures with different oxygen content (in the range of 7–21% and up to 37% O2) from the environment air, and also it allows to diagnose many vital functional indicators.

A compact and the most powerful device for hypo-, hyperoxytherapy OXYTERRA has been created (Reg. Certificate No. 2009/06438) [16].

Having a great experience of using different methods of therapy and rehabilitation in patients with chronic bronchopulmonary pathology: chronic obstructive pulmonary disease (COPD), bronchial asthma, etc., we used the "Detensor" method besides IHT in these patients, positively assessing its effect on the state of the functional respiratory system.

The first data of its effectiveness in patients with long-term obstructive pulmonary diseases appeared by the end of the 1990s [17]. The "Detensor" system, which was developed by the German Prof. Kurt Kienlein, has been successfully used since 1981 in many countries of the world, and since 1988 it has been used in the Russian Federation. The "Detensor" system is a device consisting of inclined elastic ribs that provide long-term, gentle traction of the spinal column. The portable complex device is used both for daytime procedures and during nighttime sleep [18, 19].

The Detensor system also functions as a method of chronomedicine, it helps to maintain the circadian biorhythm of the daily physiological elongation of the vertebral column and paravertebral structures[20]. The Nobel Prize in Physiology or Medicine was got (Hall J., Rosbash M., Young M.) in 2017 for the discovery of the circadian rhythms mechanisms. Long-term gentle traction of the spine restores and holds its natural physiological bends (lordosis and kyphosis), it normalizes the body's center-of-gravity position, provides relaxation of the paravertebral and intercostal muscles [17, 18, 21], increases the amplitude of the diaphragm excursion, reduces intrapleural pressure and improves segmental innervation.

It is shown that the "Detensor" method contributes to the normalization of non-specific adaptive body reactions and increases the level of their reactivity. The obtained data on the increased reaction and quiet activation indicated a high activity of the immune system, especially its cellular component-killer T-lymphocytes. It is commonly known that the cells affected by some viruses are also their targets.

These observed changes in the immune system were the most favorable and physiologically optimal. The normalization of nonspecific adaptive body reactions with the "Detensor" method application also shows anti-stress anti-depressive effect, the improvement in subjective and objective indicators of the underlying disease [22].

Chronic obstructive pulmonary disease is a respiratory pathology characterized by constantly progressive airways obstruction and it leads to respiratory distress. This disease is quite widespread. The incidence rate all over the world, frequent disablement and heavy mortality among the patients who suffer from this disease is registered. The main pathophysiological mechanisms of COPD are bronchial patency disorders because of the initial spasm of unstriated muscles, mucosal edema and mucus hypersecretion that leads to nonreversible fibrosis and pulmonary emphysema with the changes of breath act and gas exchange accompanied by progressive ventilation-perfusion disorders.

The impairment of the spinal column has a significant effect on pulmonary ventilation in patients with respiratory pathology (bronchial asthma, COPD, etc.). The vertebral changes are most obvious in chronic use of steroids (especially if the onset of a disease was in early childhood) because of their negative effect on bone tissue and the entire musculoskeletal system. It is shown that in patients with respiratory pathology, the "Detensor" method has a positive effect on the functional state of the respiratory muscles in any age. These effects improve the external respiration state indicators which reflect the activity of the respiratory muscles, their strength and endurance [17, 21, 23].

It is noted that after the course of IHT, the inspiratory volume increase, the respiratory rate decreases and the economy of respiration increases. The hemodynamic equivalent is significantly reduced, blood circulation becomes more efficient, and the body's tissues are supplied with oxygen. The oxygen pulse increases with each cardiac beat. The hemoglobin content increases significantly. The rate of oxygen arrival to the alveoli and the oxygen delivery of arterial blood increase. Thus, interval hypoxic training is an effective nonspecific method of increasing the body's defenses and contributes to arterialization and increasing its oxygen capacity.

A comparative analysis of ICT and the "Detensor" method for lung ventilation showed that bronchial patency increases when using the "Detensor" method. Whereas, when using IHT, the gas exchange and blood circulation indicators improve. The results were more effective when using IHT and the Detensor method together than when using them separately. It is shown that the tidal volume, alveolar ventilation and diffusion surface of the lungs have increased, and in general, the state of the functional respiratory system has improved [9, 23, 24]. It is noted that the oxygen effect of the respiratory cycle has increased. It became more physiological when saturated with oxygen. The ventilation equivalent has decreased, and external breathing has become more economical. There was a decrease in the heart rate, an increase in the stroke volume and oxygen pulse, a decrease in the hemodynamic equivalent, which indicates a more rational heart function. Blood circulation indicators in patients with COPD (Chronic obstructive pulmonary disease) with a combination of ICT and the "Detensor" method indicated an increase in the saturation of arterial blood with oxygen and the speed of its spread due to improved ventilation and perfusion mechanisms.

Thus, ICT and the Detensor method have different approaches to the impact on pulmonary ventilation and ventilation-perfusion mechanisms, so their combination allowed to increase the final effectiveness in respiratory pathology. Using IHT and the Detensor method together has obvious advantages and values. They can be included in the treatment and prevention of COVID-19 coronavirus infection complications [9, 23, 24].

Moreover, according to many authors' reports, coronavirus infection damages the lungs and leads to the development of various psychosomatic complications including disabling conditions. The medical rehabilitation requires effective methods where preference should be given to non-drug methods [25, 26].

The successful simultaneous use of IHT and the Detensor method in the elimination of ventilation and perfusion disorders in COPD has a positive effect on the immune system and fully meets the requirements of the present time and gives grounds for using these methods, primarily for the correction of bronchopulmonary disorders in the complex of rehabilitation measures for Post-COVID-19 syndrome.

This model of pathogenetic treatment and respiratory rehabilitation of patients with chronic obstructive pulmonary disease using IHT and the "Detensor" method can be included in the complex of multidisciplinary measures of the rehabilitation program in Post-COVID-19 syndrome.

Both offered mechanisms of non-invasive and non-pharmacological effects are based on studies and they are awarded with two Nobel Prizes in Physiology or Medicine (in 2017 Nobel prize was awarded for the discovery of the mechanisms of circadian rhythms and in 2019 – for a series of works on the study of cells reaction to oxygen and hypoxia).

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Contribution:
Tsyganova T.N. – selection of patients, development of the program for their examination and detection of hypoxic therapy therapeutic regimen, control of patient testing, data processing, preparation of the publication; Kienlein (Balakireva) O.V., Kienlein L.K. – development of the program for examining patients with respiratory pathology and the choice of the therapeutic regimen for the "Detensor" method, control of patient testing, data processing, publication preparation; Kapustin A.V. – testing healthy subjects and adolescent patients with respiratory pathology, development of the program for their examination, control patient testing, data analysis and processing, preparation of the publication; Shushardzhan S.V. – international coordination, data analysis and editing, preparation of the publication.