

NORMOBARIA – PHYSIOLOGICAL CONDITIONS AND POSSIBILITIES OF APPLICATIONS

Gabriela Henrykowska¹⁾, T. Wójtowicz²⁾, Weronika Czuj³⁾, Ewa Zieliński⁴⁾, Piotr Siermontowski²⁾

¹⁾ Medical University of Łódź, Department of Epidemiology and Public Health, Poland

²⁾ Department of Underwater Works Technology, Naval Academy, Gdynia, Poland

³⁾ Individual Specialist Medical Practice in Stalowa Wola, Poland

⁴⁾ Department of Emergency Medical Services, Collegium Medicum in Bydgoszcz, Nicolaus Copernicus University in Toruń, Poland

ABSTRACT

The article discusses the impact on the human body of breathing in an atmosphere of normobaric or slightly hyperbaric conditions, as well as breathing a mixture with an increased content of oxygen with the addition of carbon dioxide. The positive and negative effects breathing with an increased content of oxygen of hyperbaric conditions were compared with normobaric conditions and indications for their use were presented.

Keywords: normobaria, hyperoxia, hyperbaric oxygenation, hypercapnia, vasodilation, oxygenation.

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INTRODUCTION

Being in a hyperbaric environment or an environment with an altered composition of the breathing mixture compared to air is never indifferent to the human body. Changes in the composition and pressure of the atmosphere can have positive or negative effects. While the effects of increased pressure (hyperbaria) carry numerous risks related to physical properties of gases and the impact of hyperbaria on the body [1], normobaria does not pose such significant hazards [2,3].

Normobaria; literally translates to 'normal pressure.' It denotes the effect on the human body of breathing air of altered composition while maintaining, or only slightly deviating (upwards) from, atmospheric pressure [4].

Oxygen therapy has been used for over a hundred years, which involves supplying more oxygen to the body, which accelerates the treatment of various ailments and supports regeneration. This may mean breathing oxygen-enriched air or even pure oxygen. Hyperoxia, i.e. the effect of increased oxygen content or breathing pure oxygen, has been used in emergency and therapeutic procedures for over a century [5,6]. Despite significant and precisely described complications and consequences of this type of therapy, it is widely used in medicine due to the predominance of positive effects over negative ones [7,8,9,10].

In medicine, although less frequently in recent times, a two-component mixture consisting of pure oxygen with the addition of carbon dioxide is also used [11]. This mixture takes advantage of the vasodilatory effect, particularly on cerebral vessels, of carbon dioxide, which counteracts the narrowing of brain vessels caused by high concentrations of oxygen [12].

The therapeutic benefits of hyperbaric and normobaric conditions have also been appreciated outside of medicine. They are used in training routines for athletes, effort optimization [13,14], and even in cosmetology, although in the latter case, the effects are often opposite to the intended outcome [15]. Other numerous 'applications' of hyperbaric and normobaric conditions are not worth mentioning, as there is no evidence supporting their positive effects [16,17].

NORMOBARIA

The claims encouraging the use of normobaric chambers that make reference to a "return to the atmosphere in which the human species originated," are not only unfounded but also unnecessary, as the positive effects of the method in terms of recreation and well-being speak for themselves. However, the reference to Earth's atmosphere is indeed valid, though the timeline is shifted by a few million years; the applied atmosphere is closer to the one that existed during the formation of the planet's crust and a period of intense volcanic activity, rather than the much later period when hominids emerged [18,19].

The essence of the hyperoxia effect in normobaric conditions is the improvement of oxygenation in the body. Hyperoxia occurs when the partial pressure of oxygen in the blood exceeds 300 mmHg [5,20]. To achieve such a partial pressure of oxygen in the blood, its partial pressure in the breathing mixture should be at least 480 mmHg, which means the

oxygen concentration in the mixture must be at least 44% at sea level. Such an oxygen concentration is at the threshold for negative and highly adverse effects of oxygen on the human body, particularly with prolonged or cyclical exposure, which implies its use only in specific, strictly defined indications and under medical supervision [21,22,23].

In the atmosphere used in recreational normobaric chambers, enriched with oxygen and carbon dioxide, the partial pressure of oxygen capable of causing negative effects is never reached. However, the positive effects, especially with incidental and short-term use, are worth considering [11,14,24].

The second, aside from oxygen, component of the breathing mixture, whose content differs from that in air is carbon dioxide. Hypercapnia or an elevated level of carbon dioxide in the blood occurs when its partial pressure reaches 45 mmHg or more [25]. To achieve such a value, the carbon dioxide content in the breathing air would need to be 0,24 mmHg. However, the main source of carbon dioxide is not the breathing air but the body's metabolism. In the atmosphere used in recreational normobaric chambers, the amount of CO₂ never reaches levels that could be harmful to the human body [2].

Promotional materials describing normobaric therapy also mention a small addition of hydrogen to the breathing mixture. This gas, similarly to helium, nitrogen and argon, can be found in the same part of the periodic table. Under normobaric conditions it does not enter into any chemical reaction, nor does it participate in cell metabolism [26]. Therefore, it holds no physiological significance, and adding it to the mixture only worsens safety conditions; as highly explosive and flammable gas stored in cylinders, it poses a significant risk of explosion or fire during transfer [27]. The addition of hydrogen can only be considered in terms of its extremely low density, which theoretically improves breathing efficiency. However, this is undetectable due to its trace content in the mixture.

The last important parameter is the proper selection of humidity - the water vapor content in the breathing mixture preventing the drying out of the respiratory tract [28].

A properly balanced breathing mixture allows for the full utilization of inhaled oxygen without reaching harmful partial pressures for the tissues, thanks to the synergistic effect of carbon dioxide [7,25]. The body's defense mechanisms against hyperoxia include reflexive vasoconstriction, especially in cerebral blood vessels, in response to increased partial pressure of oxygen in the blood, as well as reflexive constriction of the trachea and bronchi during the inhalation of pure oxygen [28,29].

In the human respiratory system, carbon dioxide plays a more significant regulatory role than oxygen. Its presence limits or completely negates the above-mentioned vascular protective mechanisms against hyperoxia. An elevated level of carbon dioxide is also the main factor stimulating the respiratory center [11,25]. Thus, increasing the carbon dioxide content in the breathing mixture or increased retention of carbon dioxide produced during the body's metabolic processes ensures proper gas exchange in lungs, and most importantly, in the large vessels supplying blood to the brain [11,12]. Here, the cross-sectional area of the individual cerebral arteries and the condition of their inner walls are key factors, closely linked to the coefficient of blood flow laminarity/turbulence, which, in

physical terms, is treated as a dynamic, heterogenous fluid. This is directly related to the so-called 'momentary blood transfer volume/capacity' - to simplify, it is an easily assessed arithmetic factor referred to in intensive care and transfusion medicine as 'how much does it carry? how much can it carry?' Unfortunately, carbon dioxide is not a guarantee of maintaining a normal width of the bronchi and trachea; the effect of bronchoconstriction remains. Additionally, prolonged exposure to such an atmosphere (though fortunately extremely rare) can result in changes to the structure of bronchial mucus [30,31]. However, this deterioration in the physical conditions of ventilation is of little significance, as individuals in 'normobaric chambers' tend to engage in meditation more often than in intense physical exercise.

Special attention should be given to the so-called Bohr effect [32]. This physiological response to a drop in blood pH (i.e., its acidification) also affects the process and outcome of oxygen transport in blood. Oxygen in the blood is transported in two forms: as a physical solution in the plasma and bound to hemoglobin in erythrocytes. The evolution of this mechanism was driven by the increased oxygen demand of warm-blooded organisms, which have large body mass, highly efficient muscles, and as evolution progressed, an increasing demand for oxygen by the nervous system. Oxygen physically dissolved in the blood plasma alone is insufficient for proper functioning at atmospheric pressure, hence the need for oxygen molecules to bind to hemoglobin in red blood cells during oxygenation in the lungs and to detach during oxygen release in tissues. This process is also regulated by carbon dioxide, which as an anhydride of weak carbonic acid, dissolves in the plasma, acidifies the blood, lowers its pH, and facilitates the release of oxygen molecules from hemoglobin in the tissues [33]. Under physiological conditions, this effect occurs during intense physical exertion, where a large amount of metabolites, including carbon dioxide, is produced in the muscles. The second "part" of this physiological mechanism is the formation of a phosphate ester of glyceric acid in erythrocytes during anaerobic metabolism, which has an effect compatible with that of carbon dioxide. Of course, exposure in a normobaric chamber utilizes only the first part of the Bohr effect, related to pH reduction. However, facilitating oxygen release in tissues is important for improving oxygenation [32].

ACTION

The positive effects of utilizing elevated levels of oxygen as well as carbon dioxide in normobaric conditions, which have physiological foundations and clinical confirmation, can be divided into two groups: those similar to classical hyperbaric therapy, which involve specific medical conditions, and the second group of effects related to relaxation and rest [16,17]. The first group includes promoting wound healing, reducing the severity of infections, particularly purulent ones, bactericidal action, and a recently confirmed vasogenic effect [34,35,36]. The second group undoubtedly involves a broad spectrum of muscle relaxation within the active musculoskeletal system, increased oxygenation of the body, and stimulation of erythropoiesis, which increases the supply of red blood cells, and consequently enhances the body's efficiency by increasing the oxygen-carrying

component of the circulating blood volume [14,16]. One should not forget about the faster and easier achievement, as well as the longer maintenance, of the balance in pre-enzymatic and enzymatic plasma activators, which are crucial for neurotransmission in the receptor-coordinator-effector chain of peripheral nerves, especially their efferent fibers, which are more susceptible to relative hypoxia [37,38].

Pressure 1500 hPa = 150 kPa, including: oxygen 37% = 421,8 mmHg = 56,24 kPa, while basic conditions required = max. 100 mmHg = 13,33 kPa carbon dioxide 1,079% = 12,3 mmHg = 1,64 kPa.

As demonstrated in the calculations above, where the composition of the atmosphere at sea level ("ordinary air") was used as the baseline, the available oxygen pressure in therapeutic conditions is more than four times higher. The presented figures clearly indicate the expected physiological benefits.

Exposure to the above atmosphere of oxygen-rich air with a small amount of carbon dioxide under slightly increased pressure allows for numerous positive effects, such as relaxation and acceleration of rest, and even therapeutic ones, without exposing the users to the negative effects of oxygen at increased pressure [16,17,37,38]. The partial oxygen pressure values achieved in the intended conditions are far from the levels defined as hyperoxia, which cause acute damage to cells and tissues, and they do not pose a risk of oxygen-related damage to lung parenchyma during prolonged exposure [4-6].

The so-called 'oxygen lung clock', a unit of pulmonary oxygen toxicity, corresponds to breathing pure oxygen at atmospheric pressure (90,066 kPa) for 1 minute. Lung damage occurs after exceeding 800 units of pulmonary toxicity, i.e., after approximately 13 hours of exposure. Naturally, under conditions of increased pressure of the breathing mixture, according to Dalton's Law, the pressures of its individual components also increase, so the toxic effect on the lungs increases proportionally [1,23].

Multi-center studies indicate that the potential for lung parenchyma damage arises when the oxygen pressure in the breathing mixture exceeds 50 kPa. The composition of the proposed breathing mixture and the suggested working pressure are close to this threshold value; however, the proposed exposure time (2 hours) is several times shorter than the time required to raise concerns about potential lung parenchyma damage. This highlights the safety of the method compared to the competing approach of hyperbaric oxygen therapy, which is used for the same purposes [23].

The health benefits of staying in normobaric conditions (with increased oxygen and carbon dioxide levels in the breathing air) include improved tissue oxygenation, which means:

- acceleration of lactic acid metabolism - regeneration after long-term physical exertion. This effect is the strongest, allowing for a significant reduction in recovery time and enabling quicker resumption of activity [14];
- enhanced exercise tolerance, making it ideal for integration into physical training cycles [13, 39];
- faster metabolism of aldehydes, promoting recovery after ethanol poisoning [37];
- short-term mood improvement due to increased oxygen availability to the brain [3,38,39];

- similarly, short-term enhancement of mental performance [40,41];
 - improvement of tissue blood supply in individuals with cardiovascular diseases [4,5];
 - improvement of tissue blood supply in individuals with diabetes (in cases of diabetic microangiopathy) [42,43];
 - relief of symptoms in cases of vascular migraines [24];
 - improvement of preconditions for short-term physical exertion [13,14,39];
 - acceleration of regeneration after injuries and trauma involving blood vessel damage in muscles and parenchymal organs (multiple exposures required) [17].
- Less obvious, though observed benefits include:
- increased resistance to fatigue after multiple exposures [17];
 - potential treatment of chronic fatigue syndrome and depression [44].

A highly significant advantage of the normobaric chamber is the ability to move freely during exposure without the restriction of mask hoses, which are required for breathing in hyperbaric oxygen chambers. Additionally, it is easier and more cost-effective to adapt the normobaric chamber for use with gym or training equipment, as it does not require 'oxygen purity' certification necessary for placement in hyperbaric chambers, which significantly increases acquisition costs. Similarly, electronic devices used inside the normobaric chamber (such as LCD displays or hard drivers) do not need to be resistant to elevated pressure, which broadens the range of devices that can be used in normobaric conditions inside the chamber.

Normobaria in an oxygen-rich atmosphere is free from many health risks associated with hypoxia and hyperbaria, especially oxygen hyperbaria. Essentially, aside from excluding individuals suffering from claustrophobia, only one health consequence should be considered. This relates to the increased generation of reactive oxygen species and free radicals due to the higher availability of oxygen compared to atmospheric air [45]. This phenomenon, which is harmful to cells (including DNA), is inextricably linked to hyperbaric oxygen or hyperoxia. It may contribute, among others: to the development of circulatory system diseases, respiratory diseases, certain eye diseases or increase the risk of carcinogenesis [46].

Taking the above into account, one may be tempted to say that exposure in hyperbaric chambers may have a "pro-aging" effect instead of the widely advertised "anti-aging". However, in normobaria, the increase in the production of free radicals will be small due to the partial pressure of oxygen in the proposed breathing mixture [47]. For this reason, it will be easy to completely eliminate the negative effect with a proper, balanced diet used in parallel with normobaric exposures [48].

CONCLUSIONS

Due to the safety of use, lack of side effects, health benefits, lower requirements for the qualifications of service personnel and availability, normobaria in a changed gas mixture environment seems to be a rational choice. It is also worth mentioning the significantly lower costs when achieving similar effects, especially in the field of non-medical applications.

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dr n. med. Gabriela Henrykowska
Zakład Epidemiologii i Zdrowia Publicznego,
Uniwersytet Medyczny w Łodzi
gabriela.henrykowska@umed.lodz.pl

