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Research article

Effect of hyperbaric chamber on saturation and heart frequency

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Abstract: Introduction: (1) Background: The use of oxygen under pressure greater than atmospheric represents progress that can be measured in terms of importance with the introduction of blood transfusion and antibiotics in therapy. The aim of the research was to determine the impact of using a hyperbaric chamber (HC) on muscle, arterial saturation and heart rate.; (2) Methods: Twelve respondents who engaged in recreational exercise. HC Macy Pan O2 801 was used for oxygen delivery. Muscle saturation was assessed with the IDIAG Moxy device. Arterial saturation was monitored with an Omron OM-35 device, and intraventricular heart rate with a Polar FT2 device. All parameters were monitored before and after HC treatment for 50 min. and constant pressure of 2.5 ATA.; (3) Results: There was a significant increase in saturation in the pectoralis, (+8.99%) p=.038, hamstring (+8.62%) p=.042. In capillary saturation (+1.42%) p=.008. Heart rate was reduced on average by about 8.5 beats p= .003. In the region of the latissimus do not record a statistically significant change in oxygen (+6.64%) p=060, however, numerical differences were determined.; (4) Conclusions: HC is an effective means of achieving positive physiological effects. It needs to be determined whether a higher ATA or duration of treatment gives better effects.

Keywords: Oxygen, MacyPan, Moxy, IDIAG, Heart Rate, Muscle.

1. Introduction

The representation of oxygen in the body is about 65% taking into account the total body mass [1, 2]. Oxygen is transported through hemoglobin as a chemical form and as a physical form, dissolved in plasma. Arterial saturation in healthy individuals ranges from 94-98% [3]. A drop in saturation below 90% is considered life-threatening [4]. Arterial saturation is measured by a simple method using a pulse oximeter [5]. We define reduced saturation as a lack of normal oxygen in the body, which can cause a number of unwanted phenomena such as anxiety states, dizziness, visual disturbances, ringing in the ears, rapid breathing and the like. Such a condition is called hypoxia [6]. Using a pulse oximeter, we detect the amount of oxyhemoglobin and deoxygenated hemoglobin in arterial blood and display it as oxyhemoglobin saturation (SpO2), [7] which is an indirect assessment of arterial oxygen saturation [8, 9].

In contrast to the pulse oximeter, the Idiag Moxy device can be used in addition to the pulse oximeter to measure local oxygen saturation. Namely, in order to maintain the state of cellular metabolism, tissues in a state of rest use about 60 ml of oxygen per one liter of blood [10]. The amount of oxygen in the muscles depends on many parameters, the most important of which are: partial pressure of inhaled oxygen, ventilation and gas exchange, hemoglobin concentration and binding of hemoglobin molecules to oxygen [11]. Exercising physical activity leads to a significant decrease in saturation [12-14]. One of the important parameters of current muscle saturation is body temperature [15, 16].

In addition to the natural amount of oxygen, it is also possible to affect the total amount of oxygen artificially using HC [17, 18]. The application of HC to increase saturation is one of the less researched areas, although the first scientific publications appeared more than 50 years ago. The positive effects of HC have been recorded in various areas of traumatology. The beneficial effects of HC in muscle inflammation, contusions [19-21], neurological damage and wound healing [22, 23]. HC can also be used for therapeutic purposes in people suffering from diabetes [24] by improving glucose tolerance. HC supplies the body with oxygen and increases oxygenation in the bloodstream. In this way, additional oxygen is introduced, which dissolves in the blood plasma. Inside the HC, the atmospheric pressure increases by 2 to 3 times compared to the normal environment, so the amount of oxygen in the body cells also increases [25]. The oxygen that is inhaled in HC is 100%, and the aforementioned pressure ranges from 2-2.5 atmospheres. The level of oxygen and its content in these conditions increases compared to the physiological state [26, 27].

Many studies indicate an increase in saturation under the influence of HC [28-30], however there is little information under which atmospheric pressure the best blood oxygen saturation occurs. Gonzales and associates [17] used HC treatment with different pressure settings and found that arterial oxygen saturation increased with HC application. The pressure was variable and ranged from 0.2 to 1.3 ATA. The measurement was performed five times for 10 minutes, a total of 50 minutes for the entire procedure. Similar results were obtained by Weaver and associates [31], concluding that HC promotes cardiorespiratory changes with an increase in peripheral oxygen saturation and an additional decrease in heart rate. The decrease in heart rate after HC treatment was confirmed by the authors: Lund and associates [32] (pressure 2.5 ATA, multiple treatments), Al-Waili and associates [33] (pressure between 2 - 2.5 ATA, 60 - 90 minutes, number of treatments 15 - 30), Kozakiewicz et al., [34] (pressure 2.96 ATA, 30 minutes). Some of the authors came to the conclusion that the minute pulse was reduced by 16 beats after 35 minutes of using HC, while the peripheral saturation was increased compared to the control group [36]. A certain group of authors points out that during recovery from activity through HC (30 min./2.5ATA) there is also a decrease in heart rate, on average by 2.2 beats [56]. Faster recovery as a by-product of inhalation of pure oxygen, but also of increased pressure compared to atmospheric pressure, was also recorded by other authors [57]. Weaver and associates [31] conducted research on a sample of 10 subjects who underwent HC treatment, significantly increased oxygenation by 37%. Hodges and associates [35], found no effect of a single 2.5 ATA pressurized HC on VO2max within a 90-min procedure. Martinelli and associates [36] determined that the oxygen saturation of the experimental group significantly increased due to the application of HC compared to the control group of subjects.

Most studies have confirmed an increase in arterial oxygen saturation, however, not a single study has dealt with the measurement of muscle saturation. The lack of research greatly affects the provision of more information about HC and its impact on the human body. This study will be a small contribution to the elucidation of this and similar thematic entities. For the sake of validity, muscle saturation was assessed in three independent muscle groups. In accordance with that, the goal of the research was formed, to determine the effects of HC application on muscle, arterial saturation and heart rate.

2. Results

In this study, it was assumed that during the application of HC for a duration of 50 min. and a pressure of 2.5 ATA in combination with an integrated mask for a better delivery of pure oxygen, statistically contribute to an increase in arterial and muscle saturation, and have a certain effect on the heart rate.

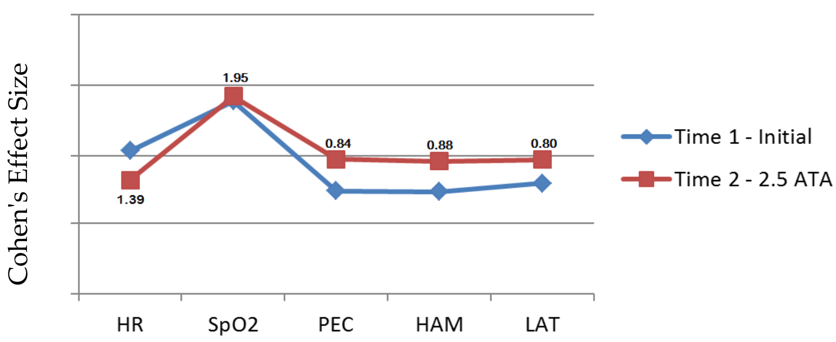
Table 1 shows certain descriptive parameters, their statistical significance and the size of the effect after the applied treatment.

Variables	Time1	Std. Dev. 1	Time2	Std. Dev. 2	Mean differences	Std. Dev. differences	p
HR	81.50	7.20	73.17	4.44	-8.33BPM	-2.76	**.003**
SpO2	95.58	1.31	97.00	1.04	+1.42%	-0.27	**.008**
PEC	70.15	12.28	79.14	8.90	+8.99%	-3.38	**.038**
HAM	69.90	9.69	78.52	9.84	+8.62%	+0.15	**.042**
LAT	72.36	8.69	79.00	7.67	+6.64%	-1.02	.060

By analyzing Table 1, numerical differences can be observed in all tested variables. Heart rate decreased by slightly more than 8 beats per minute (81.50 vs 73.17), and arterial saturation increased in percentage. Muscle saturation also underwent certain changes in numerical and percentage ratio (PEC 70.15 vs 79.14; HAM 69.90 vs 78.52), however, only in one variable, LAT (72.36 vs 79.00), no statistically significant differences were found at the .05 level, which would some of the subsequent research would be interesting to examine in more detail.

Figure 1 graphically shows the size of the effect before and after the use of HC. The size of the effects before and after the applied treatment is shown in Figure 1.

Figure 1. Effect sizes before and after HC treatment



We can state that a large effect is present in two variables, cardiac frequency (HR 1.39) and arterial saturation (SpO2 1.95). In the three variables in which oxygen saturation in muscle tissue was tested, a moderate effect was found (PEC 0.84), (HAM 0.88) and (LAT 0.80). Taking into account that statistical significance was not confirmed in the LAT variable, it would be desirable to additionally test it in research studies in order to clarify the obtained result.

3. Discussion

The first documented use of hyperbaric therapy is associated with a British physician who placed patients in an improvised container filled with oxygen under pressure in 1662 [27]. However, later in 1972, Paul Bert is considered the father of hyperbaric technology used for medical purposes [37].

By applying HC, the pure form of oxygen is delivered with additional atmospheric pressure. HC enables a beneficial effect in all cellular oxygen carriers, starting from the lungs and alveolar oxygen exchange to hemoglobin levels and oxygen delivery to other tissues [38].

The reason for such a statement is supported by similar studies, which also increased oxygen delivery using HC, but for different purposes [39]. The primary use of oxygen was aimed at reducing muscle swelling and faster recovery of injured muscle tissues accompanied by painful conditions [40].

A large number of studies support the results of this study regarding the reduction of heart rate under the influence of additional delivery of pure oxygen using HC. In the work [33] using HC for 60-90 minutes at a pressure of 2-2.5 ATA resulted in an average HR reduction of 13.4 beats. Under the same circumstances of the ATA study Martinelli and associates [36] the heart rate was reduced by 16.9 beats in the applied treatment of 120 minutes. The most similar results were obtained in the study [41] where the heart rate was reduced by 8 beats, as is the case in our research. However, in some of the studies under the influence of HC and a pressure of about 2.4 ATA for a duration of 90 minutes, there was no statistical significance in terms of HR, however, a numerical decrease in HR of 2 beats per 60 seconds was confirmed.

In terms of arterial saturation (SpO2) due to the use of HC in this research, there was an increase of 1.42%. In a study Gonzalez and associates [17], on a similar sample of subjects and a procedure duration of 63 minutes with adjusted pressure varying from 1.3 - 2.5 ATA, SpO2 increased by 2.9%. These differences in results may arise from a number of factors, including variations in study protocol, demographic characteristics of subjects, or specifics of procedural approach. Our analysis provides an additional perspective on this issue, highlighting the specifics of the target population and the procedures used in the research. Recent studies are particularly noteworthy and also support the effects of HC on SpO2 in patients with COVID-19, who represent a population with increased oxygen demand [42-45].

The greatest attention is focused on the grouped variables of muscle saturation. The initial search did not identify studies that specifically measured muscle tissue oxygen saturation, especially using newer devices. A positive effect on the saturation of the pectoral muscle and the muscle of the back of the thigh was recorded, and since there was no statistical significance at the marker point of the back muscle, it is necessary to determine the reasons why it was not due to equal vascularization of the tissues with oxygen. Some of the assumptions could be that a certain pressure was exerted on the treated back muscles due to the lying position inside the chamber.

If we consider that the application of HC contributes to faster recovery of muscle tissue [19,46-48], we can make the assumption that oxygen is very much present in the muscle environment, considering that it represents the main product of accelerated rehabilitation. Through the analysis of certain studies related to hypoxia and training at higher altitude, we can further support our findings. Although the direct focus is not on the increase of VO2max and hemoglobin, these studies provide support for the claim that even in natural conditions there is an increase in the body's oxygen saturation [58-60]. With this approach, we aim to additionally emphasize the wider picture of the organism's adaptation to increased oxygen availability and contribute to the understanding of the benefits of hyperbaric therapy.

This research represents a pioneering approach to the study of oxygen saturation in muscles, exploring aspects that have not been addressed in relevant studies so far. Due to this unique methodology, we are not able to directly compare our results with previous studies, given the lack of literature dealing with this specific aspect. Our analysis provides original insight into this area, laying the groundwork for future research and expanding the understanding of muscle oxygen saturation.

Realized studyhas certain limitations. Limitations of the study refer to the small number of subjects, however, due to the duration of the procedure, this information is largely justified. Conscious limitation of the number of subjects was applied for ethical reasons that prevented the inclusion of a control group, the need for patient safety and the impossibility of exposing certain groups of people to certain conditions was created. In addition to the above, considering that it is a research conducted in a private laboratory, there were also time and resource limitations, and at the same time they were insurmountable during your research. Despite the lack of a control group, this research contributes to the understanding of important aspects and can serve as a starting point for future research involving a broader methodology. This research indicates the positive physiological effects of using a hyperbaric chamber, especially in increasing muscle saturation and reducing heart rate. Its results may contribute to the optimization of future treatments or therapies using hyperbaric chambers, with a focus on determining the optimal pressures or duration of treatment to achieve the best effects.

4. Materials and Methods

A cross-sectional study and a non-invasive method of data collection were presented. The research was conducted in the private Master Physics laboratory in East Sarajevo. Before the start of the experiment, the purpose of the study and the measurement protocols were explained to the subjects. Each of them gave written consent to participate in the research. A short medical examination, arterial blood pressure and ECG screening were performed with all subjects. Everything was done with the aim of creating a clear clinical picture and preventing unwanted outcomes during the research. Before carrying out the treatment, virtual points were marked on the tested muscle groups for the accuracy of the output information. The research was approved by the Ethics Committee of the Faculty of Physical Education and Sports of the University of East Sarajevo.

All procedures were carried out in accordance with the provisions of the Declaration of Helsinki on work with human subjects [49].

4.1 Respondents

The sample consisted of twelve subjects (10 men, 2 women; height = 181.1 ± 4.1 cm; weight 82.5 ± 8.2 kg; BMI 25.2; age 34 ± 13 months). All participants engaged in recreational exercise 2-3 times a week and represented a suitable sample for performing the protocol. In the process of selecting respondents, attention is focused on certain factors, including the defined age frame prescribed by the study. This ensured that the sample was representative of the target population. Also, in order to ensure the relevance of the results, the participants had to regularly practice recreational exercise. In this way, a more homogeneous group was created that reflects specific activities of interest for research. This research approach achieved a high degree of precision in the selection of participants, which further contributes to the credibility and validity of the results.

4.2 Instruments and variables

A Macy Pan O2 801 hyperbaric chamber (Shanghai, China) was used for research purposes. For better oxygen delivery, integrated masks were used inside the HC.

The measurement of muscle saturation in real time (SmO2) is monitored by the infrared device IDIAG Moxy (Idiag AG, Switzerland) on the area of the pectoralis major (PEC), hamstring (HAM) and the central part of the latissimus dorsi (LAT) at the level of Th11-Th12 [50].

Arterial saturation (SpO2) was monitored with an Omron OM-35 (Kyoto, Japan) device [51].

Heart rate inside the chamber was monitored with a Polar FT2 heart rate monitor (Kempele, Finland) [52].

4.3 Treatment

Muscle and arterial saturation was measured before treatment and after 50 min. of using HC. Heart rate was monitored during the stay in HC, and the final result for all variables was recorded for 5 min. after leaving the chamber. The pressure inside the chamber was constant and was 2.5 ATA. A certain group of authors indicates that the pressure inside the chamber should be from 250 to 280 kPa, which is equivalent to a pressure between 2.46 - 2.76 ATA [10]. However, the hyperbaric and medical society points out that in clinical practice a pressure between 2 - 3 ATA is applied and that this pressure must be equal to or greater than 1.4 ATA [53]. Considering the scope of activities and the duration of the procedure for each respondent, the research was carried out within 3 working days (four respondents per day). After the end of the study, the subjects were given instructions for home care and to contact the clinic and the researcher if they notice any abnormal changes in their health status.

4.4 Statistical data processing

The results of the research were determined by the statistical method ANOVA Repeated measures in order to determine the impact of the application of the hyperbaric chamber. The data were processed with the statistical program IBM SPSS Statistics (Version 21.0, New York). In order to determine the differences between the initial and final conditions, an analysis was applied to determine the size of the effect in repeated measurements Cohen's Effect Size [54]. Effect size criteria were: <0.2 trivial effects, 0.2–0.6 small effects, 0.6–1.2 moderate effects, 1.2–2.0 large effects, and >2.0 very large effects [55]. These statistical methods focus on the actual size of the effect, helping to interpret the practical importance of the results. Also, it enables better generalization of results to the population and facilitates interpretation, expressed in standard units. This approach was chosen because it aligns with the goal of measuring effects and relevance in practice, supporting research reproducibility.

5. Conclusions

Taking into account the obtained results, it can be concluded that the additional delivery of oxygen inside the HC can cause changes in arterial and muscle saturation, which results in a decrease in heart rate. It is necessary to investigate whether the longer duration of the procedure and higher ATM contribute to better oxygenation of muscle tissue and whether oxygenation is present in smaller muscle regions.

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involved in the study.

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