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Influence of Hyperbaric Oxygen on Pulmonary Functions in Post COVID-19 Patients

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Abstract

BACKGROUND: The new coronavirus SARS-CoV-2 produced the COVID-19 pandemic. Acute respiratory distress syndrome (ARDS) is caused by this highly infectious virus, which infects both the lower as well as the upper respiratory tracts. Even with COVID-19 patients, the HBOT has proven to be an effective means of treating hypoxia**. PURPOSE:** to examine the impact of hyperbaric oxygen on forced vital capacity (FVC), forced expiratory volume (FEV1) in addition to oxygen saturation in post- COVID-19 patients. **DESIGN:patients were assigned randomly in to two equal groups by** randomized controlled trial. **SETTING:** Patients with post Covid-19 from inpatient Clinic ZagaZig Chest Hospital sharqia governate Ministry of Health. **SUBJECTS:** seventy-two patients (21 to 66 years old) previously infected with SARS-CoV-2. **METHODS:** Patients were randomized into two equivalent groups utilizing a computer-generated block randomization program, Hyperbaric Oxygen therapy in addition to breathing exercises and traditional medical treatment were given to **Experiamental group "A**", and the same traditional medical treatment program were given to **Control group "B"** throughout the course of an 8-weeks of intervention. The patients' pre- and post-treatment evaluations were performed using body weight and height scale for measuring weight and height then calculating BMI, Spirometry for measuring FVC, FEV1, Pulse Oximeter for Oxygen. **RESULTS:** Mixed design MANOVA comparisons revealed statistically significant differences among pre- and post-treatment for all variables in both groups as p-value <0.05. Between both groups, analysis revealed that the study group had statistically significant improvement over the control group (p-value <0.05) when comparing the two groups. **CONCLUSION:** HPOT has a positive effect on the Pulmonary Functions in Post COVID-19 Patient.

Keywords: Hyperbaric oxygen therapy, Pulmonary function, Covid-19, Post Covid-19

Introduction

Worldwide, SARS-CoV-2, also known as Coronavirus Disease 2019 (COVID-19), was identified as a pandemic by the World Health Organization (WHO) on March 11, 2020. There were 2,149,551 reported cases in the UK by the end of 2020. When patients were assessed by pulmonary or infectious disease specialists four to six weeks after being discharged from a post-COVID clinic, they were found to have long-term problems such as dyspnea, cough fatigue, and disturbances of taste and smell **(Kjellberg et al., 2020).**

Some patients report symptoms months after recovering from the acute stage of referred to as 'long-COVID', a syndrome that is difficult to characterize, and there is growing anecdotal data regarding this (Carfì et al., 2020). When SARS-CoV-2 enters a host's respiratory system, it infects type 2 alveolar cells. Once inside, the virus binds to certain angiotensin-converting enzyme 2 (ACE2) receptors, multiplies, as well as triggers an inflammatory reaction. This reaction can lead to vasodilatation, a higher permeability of pulmonary capillaries, destruction of endothelial cells, as well as, in extreme instances, acute systemic inflammatory reaction and a flood of cytokines **(Asokan et al., 2020).**

In hyperbaric oxygen therapy (HBOT), patients inhale 100% oxygen gas intermittently in pressured chambers, following the principles of gas physics as they relate to pressure. The majority of research has focused on administering oxygen at concentrations between 1.5 to 3.0 ATA, which is an ideal level where side effects are minimal and therapeutic benefits are still achieved. Camporesi and Bosco (2014) found that HBOT raises the partial pressure of oxygen in both plasma and tissues.

A hyperbaric chamber, which is compressed to a specific degree, is used to administer the HBOT treatment. Within the chamber, the patient is positioned, and the internal pressure is raised to a therapeutic level above 1 bar of absolute air pressure. Throughout the course of the treatment, the patient is required to breathe only oxygen. According to Fracic et al. (2011), there are two main types of hyperbaric chambers: monoplace and multiplace. According to autoptic and pathologic research, pulmonary microcirculation malfunction and catastrophic inflammation can arise when platelets activate and collect in the lungs. However, daily HBOT treatments may alleviate this problem **(Xu et al., 2020).**

The HBOT relies on the pressure-related laws of gas physics and entails breathing in 100% oxygen inside pressurized chambers at irregular intervals. To achieve therapeutic results with little risk of adverse reactions, most research have used oxygen administration within 1.5 and atmosphere absolute (ATA). The partial pressure of oxygen in tissues and plasma is increased with HBOT **(Camporesi and Bosco, 2014).**

The HBOT treatments, like all medical treatments are an added expense and although can be offered in a safe environment still have side effects and potential risks. Individual clinicians and patients are encouraged to look at HBOT like other clinical recommendations with a risk-benefit analysis grounded in the best available evidence to choose the best available treatment options to optimize clinical outcome **(John et al., 2019).**

There are some widely accepted indications for HBOT treatment: severe or symptomatic CO poisoning, clostridial myositis as well as gas gangrene, certain crush injuries, compartment syndromes, along with other acute traumatic ischemias; decompression diseases; specific vascular insufficiencies, such as central retinal artery obstruction; and the improvement of healing in certain problem wounds. Severe otherwise not treatable anemias are also considered for HBOT treatment (Kindwall and Whelan, 2008).

The new coronavirus SARS-CoV-2 produced the COVID-19 pandemic. ARDS is caused by this highly infectious virus, which infects both the upper as well as the lower respiratory tracts (Carfi et al., 2020). Patients receiving rehabilitation who experience a hyper-inflammatory reaction that lasts longer than 14 days should seek out appropriate medical, physical, and psychological care **(Hasichaolu et al., 2020).**

According to a recent study by VanDamme-Ostapowicz et al. (2022), patients with COVID-19 can benefit from the well-established HBOT technique for treating hypoxia. Similar registered clinical trials like "HBOT in post-COVID-19 Syndrome" as well as "HBOT in the management of Long COVID-HOT-LoCO Syndrome" were present when this report was written. Nevertheless, just one study was actively seeking participants, even though there is a requirement to treat post-COVID syndrome. Clinical experiments have demonstrated that HBO can ease oxygen debt and lessen inflammatory reactions, thus this is especially interesting. But how exactly HBOT therapy lowers inflammation remains unknown (Cannellotto et al., 2021).

To increase the likelihood of a full recovery, it appears important to develop a multidisciplinary and holistic rehabilitation strategy that takes into account respiratory therapy that is individualized to each patient's needs. Pulmonary rehabilitation is recommended for patients recovered from SARS-CoV-2 infection, despite respiratory rehabilitation's initial goal to treat chronic lung disorders (Barker-Davies et al., 2020). Patients undergoing respiratory rehabilitation hope to experience a marked improvement in their symptoms of dyspnea, anxiety, depression, difficulties, dysfunctions, morbidity, as well as their quality of life **(Zhao et al., 2020).**

Regarding the current literature, there is a lack of data concerning the impact of HBOT on pulmonary functioning in individuals who have recovered from COVID-19. This study aims to examine the effects of HBOT on FVC, FEV1, as well as oxygen saturation in individuals who have recovered from COVID-19. Physiotherapists working in public and private hospitals and clinics may find this study useful because HBOT has a number of positive effects, is safe, and is efficient in treating chronic diseases; consequently, it can be an additional component of physical therapy for patients recovering from COVID-19.

Subjects

This study was conducted to detect the impact of HBOT on pulmonary functions in post-COVID-19 patients from March to June 2022 at physiotherapy inpatient department at Zagazig Chest Hospital, sharqia, Egypt.

The study followed the guidelines laid out in the Helisiniki declaration, which is the World Medical Association's code of ethics. With the number P.T.REC/012/003546, the Ethical Committee of the Faculty of Physical Therapy at Cairo University in Egypt gave their approval to the study's protocol. The study processes could not begin until all patients had their parents' or legal guardians' signatures on a written consent form authorizing their participation.

Participating in this study were 72 individuals, including both sexes, who had a history of SARS-CoV-2 infection. Thirty-one males and forty-one females took part in the research. They were chosen from the Zagazig Chest Hospital Department in Cairo, Egypt. The investigators included all patients who had received hospital treatment and whose physical indices met the criteria for discharge set by the national "Diagnosis and Treatment Protocol for Novel Coronavirus Pneumonia" in this study, which was based on a sample size calculation utilizing G-power test with an effect size of 0.67, power of 0.8, and $\alpha = 0.05$ **(Zhao et al., 2020).**

Design of the study: Randomized controls trail as patients were a signed randomly into two equals groups based on inclusion and exclusion criteria.

Sample size calculation: Patient were selected randomly and distributed in two groups by computer generation. Utilizing G*Power (version 3.0.10), the sample size calculation was done. The F-test MANOVA was chosen for both the within- and between-interaction effects. With α=0.05, G*Power = 80%, and effect size = 0.67, a minimum of 38 individuals per group and an overall of 72 subjects were needed for the obtained sample size. This study included 72 male and female patients who had a history of SARS-CoV-2 infection. Participants were

found in the physiotherapy outpatient clinic and laboratory department of Zagazig Chest Hospital in Sharqia, Egypt. Discharge criteria according to the national "Diagnosis and Treatment Protocol for Novel Coronavirus Pneumonia" were used to determine whether a patient could be discharged from the hospital after receiving treatment **(Zhao et al., 2020).**

Subject's selection :Seventy-two patients from both genders aged from 21 to 66 years with a BMI between 25 to 29.9 kg/m² diagnosed as two-week post recovery from covid-19 who had Patients had decline in both FEV1 and FVC (<80%), Low oxygen saturation (90% to 95%) **(Hasichaolu et al., 2020).** During the eligibility assessment, twelve patients were excluded because six didn't fulfill the eligibility criteria and six declined to take-part in the study.

Randomization Method: We used a computer-generated block randomization method that you can find at http://www.randomization.com/ to carry out the randomization. A 1:1:1 allocation ratio was used to randomly assign participants to blocks of 6 or 9. Sealed, opaque envelopes were numbered consecutively for concealed allocation. A blinded researcher who wasn't engaged in any way with recruitment, data collecting, or treatment performed the randomization.

(A) Criteria for selection:

The criteria for patient's selection were classified into two main categories: Patients to be admitted to the study should have the following inclusive criteria: Patients had decline in both FEV1 and FVC (<80%), Low oxygen saturation (90% to 95%) (90% to 95%); All participants were clinically and medically stable; Age ranged from 21 to 66 years **(Hasichaolu et al., 2020).** The body mass index (BMI) of all patients was from 25 to 29.9 kg/m^2.

(B) Exclusion criteria:

If the subject met any of the following conditions, they were not included: neurological disorder; mental illness; COPD or another respiratory condition; Patients in critical care who require intubation. Individuals who are smokers or were unable to accurately administer the PFT tests; A condition affecting the inner ear as well as pregnancy **(Hadanny et al., 2019).**

They were assigned into two groups

- **Group A (Experiamental group):** This group involved 36 patients who was given traditional medical treatment, breathing exercises and HBOT daily in the morning.
- **Group B (Control group):** This group included 38 patients who was given the same traditional medical treatment of group (A).

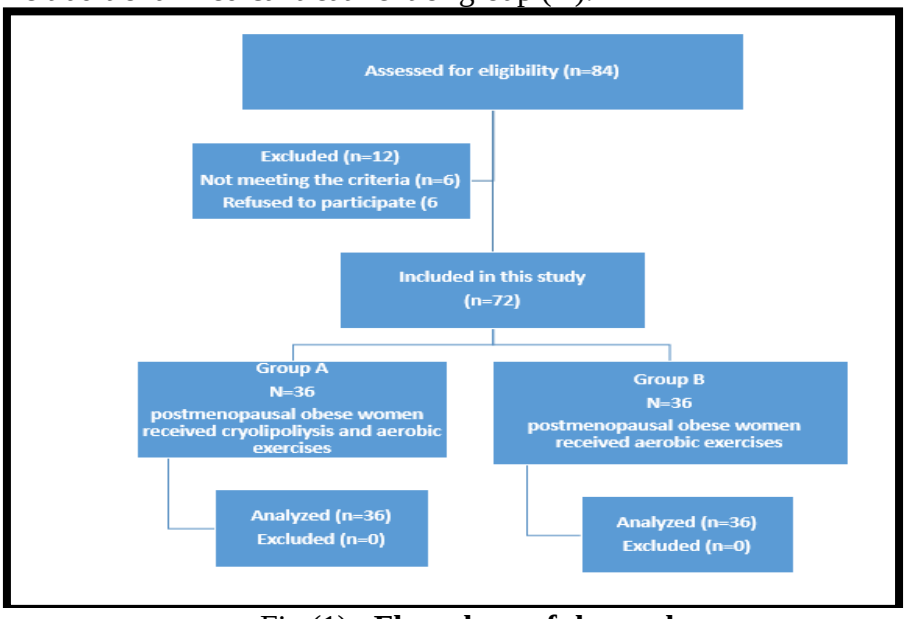

Fig.(1): **Flow chart of the study.**

III- Instrumentations:

A- Instruments for evaluation:

1- Body weight and height scale:

It is used for height measuring stand with weighting scale, for measurement the subject's weight and height for calculate the BMI**.**

2- Spirometry (Spirometer SMP 21/01 RD):

Digital spirometer SMP 21/01 RD (Russian) offers the subsequent functions:

- The measurement of four VC parameters, nineteen FVC parameters, twenty-six "flow-volume loop" parameters, seven MTV parameters, and three MVV parameters; Analysis of adult and pediatric lung volumes as well as peak expiratory flows using the Klement/Shiryaeva, ITS, ECCS, KNUDSON, Zapletal, and Polgar standards Russian and ATS method parameter evaluation; Making use of a colored TFT display to show measurement data; Producing a report detailing spirometry findings using the in-built thermoprinter; Making use of an external laser printer's USB interface to create a report detailing spirometry findings; Evaluation after drug administration; Operate using the internal battery; Managing patient records in a database; The device's adaptability to both stationary and mobile settings; Simple gadget control knob **(Vanhan Graham et al., 2019)**

Among pulmonary function tests, it is the most prevalent. Its objective data is useful for diagnosing lung disorders and keeping track of lung health, making it a popular tool for evaluating lung function. Reliable and valid findings allowed for more precise measurements, a more limited range of acceptable values for populations, and easier identification of outliers. FVC, measured as the volume released during expiration with maximal force and completion beginning at full inspiration, and FEV1, measured as the volume delivered in the initial second of an FVC maneuver, are the two most crucial components of spirometry **(Anastasio et al., 2021).**

3- Pulse oximeter (Finger pulse oximeter): When compared to other pulse oximeters in clinical trials, this one constantly came out on top for accuracy and reliability.

Specifications:

Quickly and accurately measure oxygen saturation and heart rate on the go with this small, lightweight sensor; Light-emitting diode (OLED) display; For your convenience, it can be shown in four different orientations; Optical detecting technology, rapid measuring, and a single button for operation Presents vital signs including blood oxygen saturation (%SpO2), pulse rate (PRbpm), as well as perfusion index (PI%); environmentally friendly and energy efficient; turns off in five seconds if not in usage; The screen will display numbers when the alert value is reached; Includes a miniature lanyard and Not involved: two AAA batteries. The source is Herradura et al. (2020). While

This test evaluates the blood's oxygen saturation level in a noninvasive manner. Rapid detection of even minute oxygen level changes is possible. These readings indicate the degree to which your blood is delivering oxygen to your legs and arms, which are located farthest from your heart. The pulse oximeter looks like a little clip. It connects to a finger or other body component **(Herradura et al., 2020**)

B- Instruments for treatment:

1- Hyperbaric oxygen therapy (HBOT) (OXY JOURA):

It is a valid and reliable method which can continue to be an opportunity for clinicians to better manage a variety of clinical problems. According to Kirby et al. (2019), hyperbaric medicine departments are required to adhere to strict infection control protocols when treating patients throughout this pandemic. By paradoxically increasing levels of anti-oxidative elements, intermittent HBOT protects lungs against oxygen poisoning. For the

duration of the recommended treatment, worries about pulmonary toxicity are purely speculative **(Moon and Weaver, 2020).**

Following a unique treatment plan, it is carefully designed to meet stringent medical and technological standards, allowing each patient to experience the healing benefits of oxygen and its components include: Chamber body, Window, Pressure system and Computer control.

a) Chamber body:

The chamber is 4 mm in thickness and weighs 90 kg; the material is aluminum; it is lightweight. Environmentally safe and resistant to corrosion; Constructed from a single thick aluminum sheet with no center welding; The total strength of the chamber is greater, and its material thickness is 4 mm.

b) Window:

Manufactured and moulded from polycarbonate in Japan; Was 250 times more resistant to impact than glass; Comes in a range of adaptable quality levels; Resistant to thicknesses of 10 mm and greater.

c) Pressure system:

Pressure system with automatic control; The user can easily adjust the compression as well as decompression speeds, treatment pressure levels, and session duration through the simple touch screen interface; Documentation of session duration, start and end times, and total sessions recorded daily. Modern barometer stabilization technology strives for a pressure differential as near to zero as feasible; To achieve and sustain the desired air pressure, the microprocessor system mechanically adjusts the pumping system's as well as the air intake's speeds; Japanese company SMC produces pneumatic controllers.

d) Computer control:

Compression/decompression speed; Treatment pressure level; Chamber temperature and Session time.

IV) Procedures:

A- assessment procedures:

1-Assesment of BMI:

All patients in both groups had been assessed by the weight and height scale to detect the BMI according this equation weight/hight^2. They were asked to wear thin layer of clothes. After that they were asked to stand on the right place on the standing board with both hand in front of them with fisted hand beside their body, and looking forward, then stand for while till the analogue stop moving. Then the height was measured by asking the patient to stand erect on the stand board without shoes, feet straight ahead, face was looked forward and the stadiometer was lowered so that the hair pressed down, and the height was scored in meter^2.

2-Spirometry:

Patients are advised to remove any jewelry, tight clothing, or other anything that could potentially interfere with the process. It is essential that patients wear their dentures during the treatment. Prior to the procedure, patients were asked to sit down and empty their bladders. After having a gentle clip placed on their nose, patients were told to breathe in through their mouths instead of their noses. under close observation as the patient breathes in as deeply and as quickly as possible, maintaining this pattern until no more air can be exhaled, to measure FVC and FEV1 **(Miller et al., 2005).**

3- Pulse oximeter: Within seconds of inserting his finger securely into the oximeter (the majority of which require the nail side up), the device lit up with figures that showed the patient's blood oxygen level. A blood oxygen saturation level of 95% to 98% was the norm for healthy individuals. A typical value drops to about 93 or 92 or even lower for certain individuals with preexisting health issues **(Fmichard et al., 2020).**

B- Procedures for treatment: 72 patients who fulfilled the preceding criteria were randomized into two groups of equivalent number (A and B):

Group A (Experimental group): which included 36 patients who were given conventional medical treatment, breathing exercises and HBOT daily in the morning for 3 weeks:

1) Conventional medical treatment includes:

Vitamin D: For adults under the age of 70, the daily recommended dosage of vitamin D is 600 international units; In the case of anticoagulation medications, such as low-molecular-weight heparin (enoxaparin) (30 mg), which is often administered subcutaneously every twelve hours, the recommended daily dosage is 200 mg of vitamin C. **(Fowler et al., 2021)**.

2) Breathing exercises:

Diaphragmatic breathing*:* The patient should sit up straight on a chair, rest their neck and shoulders, and support up their feet. The therapist gently suggested that the patient place both hands on their abdomen and take a deep breath in through their nose as if trying to enlarge their belly button. When the patient's abdomen rose, they could feel it in their hands. The next step was to have the patient totally exhale through their mouth. At the beginning of each session, there are three repeats. Each repetition consists of an intervention round that is repeated 10-15 times, which is followed by a short rest period of less than one minute for each repetition. We started with three repetitions and gradually worked our way up to ten (equivalent to one session) by the end of the week. A total of three sessions per day, lasting between ten and twenty minutes each, were practiced by the participants in this way. **(Lu et al., 2020); *Pursed lip breathing****:* The patient should sit up straight on a chair, rest their neck and shoulders, and support up their feet. The therapist instructed the patient to take deep breaths in through their noses as if they were planning to whistle, smell roses, purse their lips, etc. Then, after three rounds of inhalation, have the patient exhale slowly via pursed lips, as if blowing out a candle. Aim to hold their breath for twice as long as they inhaled. Each round of intervention was performed 10-15 times, with a brief rest period of less than one minute between each round, during which participants breathed normally. We started with three repetitions and worked our way up to ten (equivalent to one session) by the end of the week. A total of three sessions per day, lasting between ten and twenty minutes each, were practiced by the participants in this way **(Lu et al., 2020).**

3) Methods of application of HBOT:

Placing the patient within the chamber and exposing them to 100% oxygen at 2 ATA with 5-minute air breaks every 20 minutes is how the treatment is administered. There were sixty minutes in each session. The initial and final sessions of the day are when the measurements are taken **(Kjellberg et al., 2020).**

Group B (Control group): This group involved 36 patients who were given the same conventional medical treatment and breathing exercises of group (A) for 3 weeks.

Data collection and statistical analysis

The data was tested for normality utilizing the Shapiro-Wilk test before analysis. The homogeneity of variances among groups was tested using Levene's test. A homogeneity of variance was observed, and the data followed a normal distribution.

Descriptive statistics: For every variable, the mean and standard deviation of every group were determined; The mean of X is equal to the sum of all X divided by the total number of X (or x); Get the standard deviation (SD) by taking the square root of the variance.

A. Interferential Statistics:

To compare the groups based on age and BMI, we used an independent t test; to compare the groups based on genders, we used chi-squared tests. To examine the impact of time (before and after treatment), treatment (across groups), and the interaction of the two on FVC, FEV1, as well as O2 mean values, a mixed MANOVA was performed. Subsequent multiple

comparisons were corrected using Bonferroni; All statistical tests were conducted with a significance level of $p < 0.05$, and the statistical analysis was carried out using SPSS version 25 for Windows.

Statistical analysis

When comparing groups based on age and BMI, an independent t-test was employed; when comparing groups based on sex distribution, a chi-squared test was employed. We used the Shapiro-Wilk test to make sure the data was normally distributed. The homogeneity of variances among groups was tested using Levene's test. To examine the effects within and across groups on FVC, FEV1, and O2 saturation, a mixed MANOVA was used. For the subsequent multiple comparison, Bonferroni corrections were applied. A significance criterion of $p < 0.05$ was established for all statistical tests. All statistical analysis was carried out using SPSS version 25 for Windows, which is a program developed by IBM SPSS in Chicago, IL, USA.

- Results

- Subject characteristics:

The subjects in both Group A and Group B are shown in Table (1). The distribution of ages, BMI, and sexes didn't vary significantly ($p > 0.05$) among the groups.

Table 1. Comparison of subject characteristics among group A and B:

	Group A	Group B	Statistics	p-value
Age, mean ± SD (years)	43.36± 12.13	44.33 ± 11.89	(t = -0.34)	0.73
BMI, mean ± SD (years)	28.55 ± 1.04	28.24 ± 1.18	(t = 1.20)	0.28
Sex, n (%)				
Female	19 (53%)	22 (61%)	(χ^2 = 0.51)	0.47
Male	17 (47%)	14 (39%)		

SD, Standard deviation; t, unpaired t value; χ^2, Chi squared value; p value, Level of significance.

Effect of treatment on FVC, FEV1 and O2 saturation:

The results of the mixed MANOVA showed that the treatment and time variables interacted significantly ($F = 8.05$, $p = 0.001$, partial eta squared = 0.26). $F = 634.89$, $p = 0.001$, partial eta squared = 0.96) indicates that time is a significant main impact. The treatment had a main impact that was statistically significant ($F = 18.05$, $p = 0.001$, partial eta squared = 0.44).

Within group comparison

Groups A and B showed a significant improvement in FVC, FEV1, and O2 saturation after treatment when compared to before treatment ($p < 0.001$). Group B's percentage changes in FVC, FEV1, and O2 saturation were 16.19, 19., and 4.45%, whereas group A's were 20.28, 21.09, and 6.17%, respectively (Table 2).

Between group comparison

Before treatment, there was no statistically significant difference among the groups ($p > 0.05$). After the treatment, group A had significantly higher FVC, FEV1, and O2 saturation levels than group B ($p < 0.01$) (Table 2).

Table 3. Mean FVC, FEV1 and O2 saturation pre and post treatment of group A and B:

	Group A	Group B		
	Mean ±SD	Mean ±SD	MD	p value
FVC (%)				
Pre treatment	74.22 ± 2.97	73.42 ± 2.77	0.8	0.23
Post treatment	89.27 ± 3.78	85.31 ± 3.13	3.96	0.001
MD	-15.05	-11.89		
% of change	20.28	16.19		

	p = 0.001	***p = 0.001***		
FEV1 (%)				
Pre treatment	74.44 ± 2.74	73.69 ± 2.57	0.75	0.24
Post treatment	90.14 ± 3.95	87.69 ± 3.81	2.45	0.009
MD	-15.7	-14		
% of change	21.09	19		
	p = 0.001	***p = 0.001***		
O2 saturation (%)				
Pre treatment	91.44 ± 1.11	91.08 ± 0.91	0.36	0.13
Post treatment	97.08 ± 1.13	95.13 ± 1.62	1.95	0.001
MD	-5.64	-4.05		
% of change	6.17	4.45		
	p = 0.001	***p = 0.001***		

SD, Standard deviation; MD, Mean difference; p value, Probability value.

Discussion

This study was carried-out to investigate the influence of hyperbaric oxygen therapy on (FVC, FEV1 AND O_2 saturation) on pulmonary functions in patients with post covid-19. The findings revealed that a statistically significant differences has been detected among both groups in FVC, FEV1, and O_2 after 3 weeks of treatment, with more favor to the study group.

A week following the start of the disease, dyspnea as well as hypoxemia are experienced by the majority of patients with severe COVID-19 pneumonia. As a result of lung inflammation, hyaline membrane formation, airway obstruction from excessive secretions, and progressive hypoxemia, some of these conditions quickly develop into septic shock, ARDS, coagulation diseases, metabolic acidosis that is difficult to be corrected, and failure of numerous organs (Hanley et al., 2020).

A strong physiological basis and Henry's Law provide validity to the use of HBOT in the treatment of COVID-19 pneumonia and hypoxemia. Gas exchange in the lungs typically occurs according to Henry's Law. It asserts that the pressure that exists of an interface gas (oxygen in the alveoli of the lungs) is directly proportional to its concentration within a liquid (pulmonary blood). Transport of dissolved oxygen from the alveolar wall-pulmonary interstitium-capillary wall-blood plasma-red blood cell membrane-red blood cell cytoplasm-hemoglobin constitutes the final step in the process of oxygen intake and binding in lung capillary red blood cells. Reduced oxygen-hemoglobin binding occurs at any stage of this process where interference occurs. The Chinese COVID-19 patients showed consistent enhancement following every daily HBOT session, suggesting that the treatment was effectively addressing pulmonary and systemic hypoxia, inflammation, along with additional pulmonary pathophysiologic targets. Additionally, HBOT reversed oxygen debt and modulated gene expression in a short and long term **(Zhong et al., 2020).**

According to Hadanny (2019), the recently introduced intermittent repeated HBOT regimen may enhance lung function as measured by PEF, FVC, as well as oxygen saturation.

The baseline FVC value is the primary focus, with group A having an FVC of 74.22 ± 2.97% before treatment and 89.27 ± 3.78% after treatment. With a percentage of change of 20.28%, the mean change from before to after treatment was -15.05%. Group A's FVC increased significantly after therapy compared to before.

In this study there was an increase of FVC that was agree with the study of **Voortman et al., (2016**) who analyzed pulmonary function in 1,260 navy divers and detected an improvement within vital capacity about 73 mL after usage the same program of HBOT.

Our result disagrees with the study of Pougnet et al., 2013 that was concluded that no difference in FVC was observed over time after treatment with HBOT. And with study **of**

Poolpol et al., (2019) who found that there was no change in the value of FEV after treatment when compared to pretreatment with HBOT.

The present study also found that there was a 3.96 percentage point difference in FVC across the groups after therapy. After therapy, FVC was significantly higher in group A than in group B.

These findings are against with a study performed by **Skogstad et al. (2008)** who demonstrated that no difference in FVC among groups. Focusing on percentage, these diiference may be that this study work with healthy participants while our study work with postCOVIDE-19 patient who complain from pulmonary disorders.

The results revealed that FEV1 mean value pretreatment of group B was 74.44± 2.74% and that after treatment was 90.14 ± 3.95%. With a percentage of change of 21.09%, the average change from before to after treatment was -15.7%. When comparing group A's FEV1 before and after treatment, a statistically significant improvement was noted.

While Thorson and colleagues did observe a reduction in FEV1 when following the HPO program of 21 daily 90-minute sessions at 2.4 ATA (243 kPa), our results show the opposite **(Hadanny et al., 2019).** Also our results disagree with a study done by **Demir and Avci , (2022)** 68 attendees with an average follow-up of nearly 10 years reported small declines in FEV1, FVC, FEF25-75, as well as peak expiratory flow, however the clinical relevance of these findings is uncertain. These disagreements may be due to that our HBOT program is not the same as these previous studies they were different in the frequency as well as duration of HBOT exposure. **while Burrows et al., (1996), concluded that,** an effect HBOT result in an increase in FVC and FEV1 but these increase was small that may be due to the HBOT for one month.

The present study found that after treatment, there was a mean change of 2.45% in FEV1. Group A's FEV1 increased significantly more than group B's after treatment.

Possible explanations for the observed difference in outcomes between the groups include the fact that mild to moderate lung function impairments were more prevalent at the beginning in patients with pre-existing pulmonary illness and current or former smokers. Similarly, there was a higher degree of moderate deviation at baseline in all three metrics, with FEV1% being the most prominent, demonstrating variations in major airway function at baseline. It is not yet obvious why this is occurring, but it could be because physicians were more cautious with patients who had high-risk characteristics or whose pulmonary function was impaired to begin with **(Brenna et al., 2023).**

Possible differences in the average number of sessions between our study and others could explain why the proportion of expected values for FEV1 changed differently. Another probable explanation could be that the study's limited sample size led to more variation in the pattern of changes in lung function. Future study should be done on Post COVID HBOT with the same program Concerning FEV1 parameters to determine the real effect of HBOT.

The results of this research showed that group A's mean ± SD O2 saturation value before treatment was 91.44 ± 1.11% and after treatment, it was 97.08 ± 1.13%. There was a 6.17 percentage change as well as a mean difference of -5.64% between the two groups before and after therapy. Group A's O2 saturation levels were much higher after treatment than they had been before.

These findings are consistent with a study conducted by **Oliaei et al., (2021)** who revealed that patient with COVID-19 symptoms who underwent HBOT. This type of oxygen delivery reduced COVID symptms, along the correction of hypoxia and elevation of O_2 saturation.

Our results indicate that patients with COVID-19 who were severely hypoxaemic were able to increase their SpO2 levels with the help of oxygen supplementation by HBO2 treatment, and there were no major side effects. This is in line with the findings of Cannellata

et al. (2022), who discovered that, for the majority of sessions, there was a statistically significant change between arterial saturation before and after HBO2 treatment.

The after-treatment mean difference in oxygen saturation levels across the groups was 1.95 percent. Following treatment, group A's O2 saturation was much higher than group B's. The HBO2 therapy group reportedly achieved hypoxaemia correction (measured as a rise in SPO2) with a greater rise in arterial saturation than the control group (Cannelloto et al., 2022). The treatment group had less time to recover from post-COVID hypoxaemia in comparison to the control group.

In conclusion, our results provide support for the idea that HBO2 is a safe and effective treatment for COVID-19 as well as severe hypoxemia.

Findings

Both the study and control groups showed statistically significant improvements in FVC, FEV1, and O2 saturation; nevertheless, the study group was found to be superior.

Conclusion

In individuals with COVID-19, HBOT appears to be an efficient and safe oxygenation therapy. despite this, there is a lack of information and data concerning the impacts and process of HBOT in the treatment of COVID-19.

Implementations

HBOT should be a part of Physical therapy rehabilitation of the Pulmonary system on post COVID-19.

References

1) Kjellberg A, De Maio, A and Lindholm A (2022): Can hyperbaric oxygen safely serve as an anti-inflammatory treatment for COVID-19? Med Hypotheses. 144: 110224.
2) Asokan I, Rabadia SV, Yang EH. (2020): The COVID-19 pandemic and its impact on the cardio-oncology population. Curr Oncol Rep.22(6):60-64.
3) Camporesi EM and Bosco G (2014): Mechanisms of action of hyperbaric oxygen therapy. Undersea Hyperb Med 41(3):247–252.
4) Fracica PJ, Knapp MJ, Piantadosi CA, et al. (2011): Responses of baboons to prolonged hyperoxia: physiology and qualitative pathology. Journal of Applied Physiology. 71(6): 2352–2362.
5) Xu P, Zhou Q, Xu J. (2020): Mechanism of thrombocytopenia in COVID-19 patients. Ann. Hematol. 99, 1205–1208.
6) Camporesi EM and Bosco G (2014): Mechanisms of action of hyperbaric oxygen therapy. Undersea Hyperb Med 41(3):247–252.
7) John PK, Snyder J, Douglas JE. et al. (2019): Essentials of Hyperbaric Oxygen Therapy. SMo Med. 116(3): 176–179.
8) Kindwall EP and Harry WT. (2008): Hyperbaric Medicine Practice. 3rd Ed.Flagstaff, AZ; Best Publishing Co:3rd chap3: p. 26.
9) Hasichaolu L, Zhang X, Li X, et al. (2020): Circulating Cytokines and Lymphocyte Subsets in Patients Who Have Recovered from COVID-19 Biomed Int; 40:7570981.
10) Carfì, A., Bernabei, R., & Landi, F. (2020). Persistent symptoms in patients after acute COVID-19. Jama, 324(6), 603-605.
11) Krajewska-Kulak, E., Kulak, W., VanDamme-Ostapowicz, K., Lukaszuk, C., Lewko, J., Lankau, A., ... & Rozwadowska, E. (2012). Evaluation of the students' knowledge about sunbed and solar radiation. Progress in Health Sciences, 2(1), 28.

12) Cannellotto M, Duarte M, Keller G, et al. (2021): Hyperbaric oxygen as an adjuvant treatment for patients with COVID-19 severe hypoxaemia: A randomised controlled trial. Emerg. Med. J.39:88–93.
13) Barker-Davies, RM, O'Sullivan O, Senaratne KPP, et al. (2020): The Stanford Hall consensus statement for post-COVID-19 rehabilitation. Br. J. Sports Med.54: 949–959.
14) Zhao JY, Yan JY, Qu JM (2020): Interpretations of "Diagnosis and Treatment Protocol for Novel Coronavirus Pneumonia (Trial Version 7)" Chinese Medical Journal. 133 (11): 1347 – 1349.
15) Hasichaolu L, Zhang X, Li X, et al. (2020): Circulating Cytokines and Lymphocyte Subsets in Patients Who Have Recovered from COVID-19 Biomed Int; 40:7570981.
16) Hadanny A, Zubari T, Tamir-Adler L, (2019): Hyperbaric oxygen therapy effects on pulmonary functions: a prospective cohort study. BMC Pulm Med. 19(1):148.
17) Odynets, T., Briskin, Y., Zakharina, I., & Yefremova, A. (2019). Impact of a 12-week water program on the respiratory function in breast cancer survivors. Advances in Rehabilitation, 33(2), 5-11.
18) Anastasio, F., Barbuto, S., Scarnecchia, E., Cosma, P., Fugagnoli, A., Rossi, G., ... & Parravicini, P. (2021). Medium-term impact of COVID-19 on pulmonary function, functional capacity and quality of life. European Respiratory Journal, 58(3).
19) Pretto, J. J., Roebuck, T., Beckert, L., & Hamilton, G. (2014). Clinical use of pulse oximetry: official guidelines from the T horacic S ociety of A ustralia and N ew Z ealand. Respirology, 19(1), 38-46.
20) Fowler AA, Truwit JD, Hite RD, et al. (2019): Effect of vitamin C infusion on organ failure and biomarkers of inflammation and vascular injury in patients with sepsis and severe acute respiratory failure: the CITRIS-ALI randomized clinical trial. JAMA. 322 (13): 1261 - 1270.
21) Hanley B, Lucas SB, Youd E, et al. (2020): Autopsy in suspected COVID-19 cases. J Clin Pathol. 0:1-4.
22) Zhong X, Tao X, Tang Y, et al. (2020): The outcomes of hyperbaric oxygen therapy to retrieve hypoxemia of severe novel coronavirus pneumonia: first case report. Zhonghua Hanghai Yixue yu Gaoqiya Yixue Zazhi, 74:613-615.
23) Voortman M, Ooij PJ, Hulst RA, et al. (2016): Pulmonary function changes in Navy divers during their professional careers. Undersea Hyperb Med. 43(6): 649–657.
24) Poolpol P, Sithisarkul P, Rattanupong T (2019): Lung function change in hyperbaric chamber inside attendants. Int Marit Health. 70, 2: 125–131.
25) Skogstad M, Skare O, Skogstad M, (2008): Pulmonary function among professional divers over 12 years and the effect of total number of dives. Aviat Space Environ Med. 2008; 79(9): 883–887.
26) Efe, C., Kulkarni, A. V., Beretta-Piccoli, B. T., Magro, B., Stättermayer, A., Cengiz, M., ... & Wahlin, S. (2022). Liver injury after SARS-CoV-2 vaccination: Features of immune-mediated hepatitis, role of corticosteroid therapy and outcome. Hepatology, 76(6), 1576-1586.
27) Burrows B, Lebowitz MD, Camilli AE, et al. (1996): Longitudinal changes in forced expiratory volume in one second in adults. Methodologic considerations and findings in healthy nonsmokers. Am Rev Respir Dis 133: 974–980.
28) Brenna CT, Khan S, Djainai G, et al. (2023): Pulmonary function following hyperbaric oxygen therapy: A longitudinal observational study. PLoS ONE 18(5): e0285830.
29) Nalbandian, A., Desai, A. D., & Wan, E. Y. (2023). Post-COVID-19 condition. Annual Review of Medicine, 74, 55-64.

30) Cannellotto, M., Duarte, M., Keller, G., Larrea, R., Cunto, E., Chediack, V., ... & Estrada, E. (2022). Hyperbaric oxygen as an adjuvant treatment for patients with COVID-19 severe hypoxaemia: a randomised controlled trial. Emergency Medicine Journal, 39(2), 88-93.