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Hyperbaric Exposure Effects on Pulmonary Functions in Hyperbaric Chamber Workers

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ABSTRACT

Objective: This study aimed to investigate the effect of breathing pressurized air in two consecutive hyperbaric sessions on lung function in hyperbaric chamber inside attendants (HCIAs).

Materials and Methods: The study included 29 HCIAs working in the hospital's hyperbaric oxygen (HBO_2) therapy unit. HCIAs re-entered the HBO_2 therapy session multiple times after the break given to the internal assisted sessions due to the Coronavirus Disease 2019 (COVID-19) pandemic. We assessed the pulmonary function tests (PFTs) measurements from the first two sessions to understand whether any changes in lung function that might develop in participants at the first session were permanent and what the effect would be at the second session.

Results: There was a decrease in mean forced vital capacity (FVC) of 4.77% (p=0.003) in the first session and 4.20% (p=0.006) in the second session. Mean forced expiratory volume in one second (FEV1) decreased by 5.33% (p=0.003) in the first session and by 4.73% (p=0.001) in the second session. There was a decrease in mean peak expiratory flow (PEF) of 10.27% (p=0.001) in the second session. There was a decrease in mean forced expiratory flow (FEF) 25–75% of 9.64% (p=0.008) in the second session. No significant difference was found for any PFT parameters when comparing the pre-session values of the first and second sessions.

Conclusion: Pulmonary function in HCIAs is affected by HBO_2 therapy. There was a decrease in FEV1 and FVC in one session and all PFT parameters in the following session. This finding is important because it shows that PFT may be more affected in repeated HBO_2 therapy sessions.

Keywords: Diagnosis, hyperbaric oxygenation, occupational exposure, respiratory function tests.

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INTRODUCTION

Hyperbaric oxygen (HBO_2) therapy is a therapeutic intervention in which oxygen is delivered through the lungs at a pressure higher than standard atmospheric pressure.[1] The application has multiple indications, as defined by the Undersea and Hyperbaric Medicine Society, and its use has increased significantly in recent years.[2,3]

HBO_2 therapy can be administered in monoplace or multiplace chambers. Monoplace chambers accommodate a single patient and are typically transparent, cylindrical, and equipped with one door. The attendant observes the patient from outside the chamber and communicates via an intercom. Multiplace chambers can treat multiple patients simultaneously. A hyperbaric chamber inside attendant (HCIA) attends sessions to assist patients and manage medical emergencies. Consequently, HCIAs are exposed to the effects of the hyperbaric chamber.[1,3,4] This exposure impacts not only respiratory functions but also many other systems. Breathing compressed air under hyperbaric conditions increases respiratory effort, airway resistance, and decreases lung compliance. As a result, respiratory function, particularly airway function, may be compromised.[3] One study evaluated occupational accidents and complications among HCIAs, identifying two-thirds of these complications as "hyperbaric accidents," including decompression sickness due to direct pressure exposure.[5] Another study reviewed literature on the health status of HCIAs and noted that occupational accidents and complications can even lead to death, although this is rare.[1]

While some studies have investigated the impact of increased pressure on lung function, they have primarily focused on divers and patients. The number of studies on HCIAs is limited. This study aimed to investigate the effect of breathing pressurized air in two consecutive hyperbaric sessions on lung function in HCIAs and to draw the attention of researchers in this direction.

KEY MESSAGES

- Hyperbaric oxygen (HBO_2) therapy affects pulmonary function in healthcare workers, with decreases in FEV1 and FVC observed after one session.
- All pulmonary function test parameters (FVC, FEV1, PEF, and FEF25–75) decreased further in subsequent sessions, indicating a potential cumulative effect of repeated HBO_2 exposure.
- These findings highlight the importance of implementing proactive measures to mitigate occupational risks related to altered pulmonary function in healthcare workers exposed to hyperbaric environments.

MATERIALS AND METHODS

Participants' Selection, Power Analysis, and Ethics Committee Approval

The study began with 33 participants. One participant was excluded due to pregnancy, one due to claustrophobia, and two due to ear equalization problems. Eventually, the study included 29 HCIAs working in the hospital's HBO_2 therapy unit between August and October 2021. All HCIAs were medically fit according to the ' Undersea and Hyperbaric Medical Society (UHMS) Guidelines for Multiplace Inside Attendants Medical Fitness to Work 2018' .[6] According to these guidelines, all HCIA employees were deemed fit for work, although one reported a migraine, another a goiter, and a third gastroesophageal reflux. The race, age, sex, height, and weight of the participants were recorded. Weight and height were measured using a calibrated scale and stadiometer, respectively. The atopy history and smoking habits of the HCIAs were also noted.

A power analysis was conducted using G*Power version 3.1.9.7 (2020) for Windows 10 (University of Düsseldorf, Germany), concerning similar studies in the literature. A sample size of 29 was calculated with 80% power, a type 1 error rate of 0.05, and a moderate effect size (Cohen's d: 0.55). Ethical approval was obtained from the Non-Invasive Clinical Research Ethics Committee of Pamukkale University (Denizli, Türkiye) on 17 August 2021, with approval number 15. Informed consent was obtained from each participant after the nature of the study procedures was fully explained. The study was conducted according to the ethical principles of the Declaration of Helsinki.

Hyperbaric Oxygen Therapy Protocol and Spirometric Tests

Each HBO_2 therapy session was performed at a pressure of 2.5 atmospheres absolute (ATA) (250 kPa) for 90 minutes. As a precaution against decompression sickness, all HCIAs breathed 100% oxygen during the last 15 minutes of the isobaric phase and until exiting the chamber.

HCIAs re-entered the HBO_2 session multiple times after a break due to the Coronavirus Disease (COVID-19) pandemic. We evaluated data from the first and second sessions. Pulmonary function tests (PFTs), including spirometric tests, were assessed from the first two sessions to determine whether any changes in lung function that might have developed during the first session were permanent and to evaluate their impact during the second session. Measurements were taken on two consecutive days, immediately before and after the HBO_2 therapy sessions. To achieve standardization, PFTs were performed and evaluated immediately before and after the first and second sessions using the same machine and tools (Spirodoc, MIR Research & Development, Via del Maggiolino, Italy), by a pulmonologist, in the same room, and under the same conditions (same air, temperature, light, and noise), according to methods previously described in the literature.[7]

Spirometry was calibrated regularly before each PFT measurement according to the manufacturer's instructions. Following European Respiratory Society recommendations, all spirometric tests were performed three times, and the

Table 1. Demographic data of the participants

	n	%	Mean±SD	Min–max
Age (years)			21.14±1.66	19–26
Gender				
Male	6	20.7		
Female	23	79.3		
Height (cm)			165.03±6.57	155–180
Weight (kg)			61.24±11.29	45–88
BMI (kg/m^2)				
Normal (18.5–24.9)	23	79.3		
Overweight (25–29.9)	5	17.2		
Obese (30.0–39.9)	1	3.5		
History of atopy				
Yes	3	10.3		
No	26	89.7		
Interval between two sessions (days)			16±8	10–35
Smoking				
Yes	11	37.8		
No	18	62.2		

SD: Standard deviation; BMI: Body Mass Index.

best value was used for calculations.[7] Participants did not smoke immediately before or after the HBO_2 therapy sessions and the spirometric tests. Forced vital capacity (FVC, mL), forced expiratory volume in one second (FEV1, mL), forced expiratory flow at 25%–75% of FVC (FEF25–75, mL/s), and peak expiratory flow (PEF, L/min) were measured and recorded during spirometric testing.

Statistical Analysis

The Shapiro-Wilk test was used to assess the normality of data distribution. Data with a normal distribution were presented as mean±standard deviation (SD), and data with a non-normal distribution were presented as median (minimum–maximum). The T-test was used to compare means for data with normal distribution, and non-parametric tests such as the Mann-Whitney and Wilcoxon tests were used when data were not normally distributed. The chi-square test was used to determine the relationship (independence) between variables. All p-values <0.05 were considered significant. Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 21.0 for Windows (Chicago, IL, USA). To analyze individual PFT changes, HCIAs were divided into two groups: those with a pre- and post-session decrease of less than 5% and those with a reduction of more than 5% for each PFT value.

RESULTS

A total of 29 HCIAs were included in the study. All participants were Caucasian. The demographic characteristics of the participants are shown in Table 1.

When evaluating the PFTs of the HCIAs, the mean FVCs was 3.57±0.57 L (min–max: 2.91–4.84) before the first session and 3.40±0.53 L (min–max: 2.55–4.54) after the first session. FVC was 3.57±0.64 L (min–max: 2.67–5.43) before the second session and 3.42±0.58 L (min–max: 2.58–4.71) after the second session (Table 2). There was a decrease in mean FVC of 4.77% (p=0.003) in the first session and 4.20% (p=0.006) in the second session (Table 3).

The mean FEV1s of the HCIAs was 3.38±0.51 L (min–max: 2.71–4.53) before the first session and 3.20±0.42 L (min–max: 2.55–4.30) after the first session. FEV1s was 3.38±0.51 L (min–max: 2.63–4.56) before the second session and 3.22±0.47 L (min–max: 2.46–4.36) after the second session (Table 2). Mean FEV1 decreased by 5.33% (p=0.003) in the first session and by 4.73% (p=0.001) in the second session (Table 3).

The mean peak expiratory flow (PEF) of the HCIAs was 5.28±1.17 L/sec (min–max: 2.94–8.51) before the first

Table 2. Pulmonary function test values of hyperbaric chamber attendants before and after sessions

Variable	First session (Mean±SD)		Second session (Mean±SD)	
	Before the session	After the session	Before the session	After the session
FVC	3.57±0.57	3.40±0.53	3.57±0.64	3.42±0.58
FEV1	3.38±0.51	3.20±0.42	3.38±0.51	3.22±0.47
PEF	5.28±1.17	5.07±1.01	5.65±1.36	5.07±1.09
FEF25–75	4.32±0.76	4.15±0.73	4.46±0.77	4.23±0.73

SD: Standard deviation; FVC: Forced vital capacity; FEV1: Forced expiratory volume in 1 second; PEF: Peak expiratory flow; FEF25–75: Forced Expiratory Flow at 25–75% of FVC.

Table 3. Differences and P values of pulmonary function test variables between sessions for hyperbaric chamber inside attendants

Variable	Before the 1st session - After the 1st session % difference/P†	Before the 2nd session - After the 2nd session % difference/P†	Before the 1st session - Before the 2nd session % difference/P†	After the 1st session - Before the 2nd session % difference/P†
FEV1	**-5.33/0.003**	-4.73/**0.001**	0/0.303	**+5.63/0.003**
FVC	-4.77/**0.003**	-4.20/**0.006**	0/0.133	**+5.00/0.019**
FEF25–75	-3.94/0.096	**-9.64/0.008**	+3.24/0.290	**+7.47/0.003**
PEF	-3.98/0.157	**-10.27/0.001**	+7.01/0.072	**+11.44/<0.001**

†: Paired Samples T-Test; FEV1: Forced expiratory volume in one second; FVC: Forced vital capacity; FEF25–75: Forced expiratory flow at 25%-75% of FVC; PEF: Peak expiratory flow.

session and 5.07±1.01 L/sec (min–max: 3.78–7.27) after the first session. PEF was 5.65±1.36 L/sec (min–max: 3.93–8.95) before the second session and 5.07±1.09 L/sec (min–max: 2.96–7.27) after the second session (Table 2). There was a decrease in mean PEF of 10.27% (p=0.001) in the second session (Table 3).

The mean FEF25–75s of the HCIAs was 4.32±0.76 L/sec (min–max: 2.55–5.71) before the first session and 4.15±0.73 L/sec (min–max: 3.07–6.09) after the first session. FEF25–75 was 4.46±0.77 L/sec (min–max: 3.09–6.43) before the second session and 4.23±0.73 L/sec (min–max: 2.90–6.10) after the second session (Table 2). There was a decrease in mean FEF25–75 of 9.64% (p=0.008) in the second session (Table 3). No significant difference was found for any PFT parameters when comparing the pre-session values of the first and second sessions. Significant increases were noted in all PFT parameters after the first session and before the second session (Table 3). At the end of the first session, two participants experienced dyspnea, and one had both dyspnea and cough. At the end of the second session, two participants experienced dyspnea. The symptoms that developed in both sessions were transient.

DISCUSSION

HCIAs are in the same hyperbaric chamber as the patients during HBO_2 therapy sessions and are exposed to the same pressures as the patients. While patient treatment typically lasts 20–30 sessions, HCIAs are exposed to these conditions throughout their active working life. Additionally, patients breathe 100% oxygen, whereas HCIAs breathe pressurized air for most of the session. In this study, we examined differences in PFTs in 29 HCIAs in the first and subsequent sessions. We found significant decreases in FVC and FEV1 in the first session and in all PFT parameters (FVC, FEV1, PEF, and FEF25–75) in the second session. Furthermore, the decrease in FEV1 in the first session and the decreases in FEF25–75 and PEF in the second session were greater than 5%.

Several studies have investigated the effects of working in a hyperbaric chamber on the respiratory system of HCIAs. Ozdemir et al.[8] conducted a prospective study involving 11 HCIAs and 15 controls, followed for one year. They found differences of 2.3%, 3.7%, and 6.9% in FEV1%, the percentage of predicted FEV1, and FEF25–75, respectively, but reported that these differences were similar to those of the control group. Poolpol et al.[3] reported decreases in FEV1, FEF25–75, and the ratio of FEV1 to FVC over time after comparing two PFTs of 51 HCIAs measured

one year apart. The study reported by Demir et al.[9] included 68 HCIAs who entered the hyperbaric chamber. Their study found decreases in FVC, FEV1, FEV1/FVC, PEF, and FEF25–75 even in one session. Our study found significant decreases in FVC and FEV1 in the first session and all PFT parameters (FVC, FEV1, PEF, and FEF25–75) in the second session.

Changes of 5% or more in serial spirometric tests are considered statistically significant according to the American Thoracic Society (ATS) and the National Health and Nutrition Examination Survey (NHANES) guidelines.[7,10] In one study, the authors stated that daily changes in PFT of up to 5% can be considered normal, but for a significant change, the decrease should be 5% or greater.[11] Our study found decreases in FVC in the first and second sessions; these decreases were statistically significant, but the reductions were less than 5%. In addition, FEV1 has been found to decrease in three studies of HCIAs.[3,8,9] In our study, in agreement with the literature, we found that FEV1 decreased in the first and second session PFT measurements, and these decreases were statistically significant. We also observed that the decrease in FEV1 in the first session was more than 5%. In addition, Ozdemir et al.[8] and Poolpol et al.[3] also reported a significant decrease in FEF25–75 in their study of HCIAs. Demir et al.[9] reported a decrease in FEF25–75, but it was not significant. In our study, however, we did not find a significant difference between the FEF25–75 of HCIAs in the first session, but we did find a significant decrease in FEF25–75 in the second session, which was more than 5%. However, in our study, we did not find a significant difference between the PEF of HCIAs in the first session, but we found a significant decrease in PEF in the second session, and this difference was more than 5%. No statistically significant difference was found when comparing PFT values before our study's first and second sessions. In addition, an increase of 5% or more was observed in all PFT parameters after the first session and before the second session. This finding suggests that one session does not have a lasting effect on lung function in HCIA. This study is one of the few studies to examine the impact of HCIAs on lung function. It shows that working in a hyperbaric chamber affects lung function in HCIAs and that PFT can be further affected by repeated sessions of HBO_2. The study also showed that the decrease in lung capacity during the first session was not permanent, but a reduction in lung capacity could be observed again in subsequent sessions. Over the long term, this could lead to cumulative, permanent damage to the lungs of HCIAs. This finding may be important for future research.

Limitations of the study include a limited number of participants, analysis restricted to those working in a hyperbaric oxygen therapy room, the fact that the study was only conducted over a limited period, and the young age of the participants. There may also be uncertainty about the generalizability of the study results.

CONCLUSION

Pulmonary function in HCIAs is affected by HBO_2 therapy. There were decreases in FEV1 and FVC in one session and all PFT parameters in the following session. This finding is important because it shows that PFTs may be more affected in repeated HBO_2 therapy sessions. At the same time, there was a more than 5% decrease in FEV1 in the first session, and in FEF25–75, and PEF in the second session. This study emphasizes the need for proactive measures to address occupational risks associated with altered pulmonary function that may develop in healthcare workers in hyperbaric environments. The aim is to improve the safety and well-being of healthcare workers. Considering the limited number of studies on this topic in the literature, further studies are needed to investigate the cumulative effects of hyperbaric chamber exposure on lung function in HCIAs.

Ethics Committee Approval: The Pamukkale University Non-Interventional Clinical Research Ethics Committee granted approval for this study (date: 17.08.2021, number: 15).

Author Contributions: Concept – LD; Design – LD; Supervision – LD, MA; Resource – LD; Materials – LD; Data Collection and/or Processing – LD, MA; Analysis and/or Interpretation – LD, MA; Literature Search – LD, MA; Writing – LD, MA; Critical Reviews – LD.

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