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A Prospective, Observational Program Evaluation of Hyperbaric Oxygen Therapy for Veterans With Posttraumatic Stress Disorder

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Objective: The objective of this program evaluation was to evaluate the effects of hyperbaric oxygen therapy (HBOT) on posttraumatic stress disorder (PTSD) symptoms in U.S. veterans. ***Method:*** A prospective, single-arm, longitudinal design was used for this program evaluation. Eighty-seven veterans receiving HBOT at three Florida treatment centers were invited to complete anonymous online surveys. PTSD symptoms were assessed with the PTSD Checklist for the *Diagnostic and Statistical Manual of Mental Disorders*, fifth edition. Participants were White (90%), male (90%), and aged 30–59 years (76%). ***Results:*** Fifty veterans (57%) completed baseline, midpoint, and posttreatment surveys. Mean PTSD Checklist for the *Diagnostic and Statistical Manual of Mental Disorders*, fifth edition, scores decreased from 51.00 to 20.62 (Cohen's $d = -1.91$, 95% confidence intervals [−2.5, −1.4]), reflecting a clinically significant reduction from diagnostic to subthreshold levels. Improvements were sustained at 1-, 3-, and 6-month follow-ups. HBOT was also associated with reductions in depression, anxiety, somatization, sleep disturbance, impulsivity, and stress, alongside increases in resilience and positive ideation. ***Conclusion:*** HBOT produced durable, clinically, and statistically significant reductions in PTSD symptoms (mean difference > 10, $p < .001$). Findings support the need for rigorous controlled trials to further examine HBOT as a potential treatment for PTSD in veterans.

Clinical Impact Statement

This was a program evaluation of hyperbaric oxygen therapy, which involves breathing 100% oxygen in a pressurized chamber, administered by community providers to veterans with symptoms indicative of a diagnosis of posttraumatic stress disorder. There were clinically significant reductions in posttraumatic stress disorder symptoms for the 50 participants who completed the program, and importantly, these improvements were maintained for at least 6 months after treatment. While these results suggest the treatment is effective, it will be critical to perform a more rigorous controlled clinical trial with a larger sample size to definitively determine the extent to which this treatment works.

Keywords: posttraumatic stress disorder, U.S. veterans, hyperbaric oxygen therapy, traumatic brain injury

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Prevalence estimates for posttraumatic stress disorder (PTSD) vary widely; lifetime PTSD rates in U.S. military populations range from 7.7% to 17.0%, while civilian populations range from 3.4% to 26.9% (Schein et al., 2021; National Center for PTSD, n.d.). These figures underscore PTSD as a major public health concern, particularly among service members exposed to decades of armed conflict. According to the *Diagnostic and Statistical Manual of Mental Disorders*, fifth edition, text revision, a diagnosis of PTSD requires a set of specific criteria. First, there must be exposure to a traumatic event. Next, there are four symptom clusters that must be present—intrusive reexperiencing of the trauma, avoidance of trauma-related stimuli, negative alterations in cognition and mood, and hyperarousal and reactivity. Finally, symptoms associated with these clusters must persist for more than 1 month, cause significant functional impairment, and not be attributable to other conditions (American Psychiatric Association, 2022). Given multiple symptom options within each cluster, more than 600,000 unique symptom combinations can meet diagnostic criteria (Galatzer-Levy & Bryant, 2013). The phenotypic complexity of PTSD may be a function of the multifactorial pathophysiology of PTSD that involves structural and functional alterations in limbic and prefrontal regions, neurotransmitter dysregulation, genetic and epigenetic vulnerabilities, mitochondrial dysfunction, inflammatory cascades, and cerebrovascular changes (Aliev et al., 2020; Dmytriv et al., 2023; Fenster et al., 2018; Rasmusson & Pineles, 2018; Zhang et al., 2025). These processes interact dynamically; for example, FKBP5 polymorphisms are linked to reduced cingulum integrity and impaired hypothalamic–pituitary–adrenal axis regulation (Fani et al., 2016), illustrating how genetic variation converges with stress-response circuitry.

Hyperbaric oxygen therapy (HBOT) consists of inhalation of 100% oxygen at a pressure greater than one atmosphere absolute (ATA). HBOT has traditionally been used to treat decompression sickness, infections, and wound healing (Wattel, 2006). Evidence suggests HBOT may counteract multiple of the underlying pathologies associated with PTSD. Neuroimaging demonstrates restoration of fronto-limbic connectivity and hippocampal activity (Doenyas-Barak et al., 2022), while animal studies show normalization of infralimbic cortex catecholamine efflux and plasma corticosterone levels (Lin et al., 2019). Reviews highlight HBOT's capacity to enhance mitochondrial function, angiogenesis, neurogenesis, synaptic plasticity, and brain-derived neurotrophic factor release (Bin-Alamer et al., 2024). Systematic review analyses further report reductions in C-reactive protein, tumor necrosis factor-α, and interferon-γ, via NFκB suppression, alongside increased vascular endothelial growth factor and balanced oxidative stress responses (De Wolde et al., 2021). Collectively, these findings suggest HBOT exerts multimodal effects across cellular, vascular, and neurocircuit domains that are implicated in PTSD pathophysiology.

Given the overlapping PTSD pathophysiology with suggested HBOT targets, the goal of this program evaluation was to gather data on whether community providers that deliver HBOT to veterans with symptoms indicative of PTSD observe sustainable decreases in these symptoms. This was an independent evaluation of community-based HBOT providers that was contracted by the Florida Department of Veterans Affairs. The University of South Florida's role was to evaluate the service delivered by the community providers while they engaged in their regular standard of care. This will also allow us to gain insight into the viability of HBOT as a potential treatment.

Method

This program evaluation used a prospective, observational design to assess HBOT in U.S. veterans with PTSD. Ninety-five percent of veterans that volunteered for this project had a prior PTSD diagnosis, but only 85% had received prior treatment. Many of these veterans were receiving pharmacotherapy for pain (51%), depression (54%), anxiety (53%), sleep disturbances (60%), or seizures (9%). The Veterans Affairs, support groups, or medical professionals referred the veterans to the HBOT clinics.

HBOT was delivered by three community providers following their standard protocols. Although the literature reports pressures from 1.2 to 2.4 ATA with 100% oxygen (Andrews & Harch, 2024; Doenyas-Barak & Efrati, 2024), all participants received forty 60-min sessions at 1.5 ATA, once daily, 5 days per week, for 8 weeks. Survey participation was voluntary and not required for treatment. The University of South Florida's Institutional Review Board determined that, due to the de-identified nature of the data, formal informed consent was not necessary.

Psychometric Testing

Participants completed Qualtrics surveys via a link from their provider. Participants were asked to complete surveys before (baseline or 0 treatments), during (midpoint or 20 treatments), and after (post, 40 treatments) HBOT sessions and then at three follow-up time points—1, 3, and 6 months after the last treatment (1M, 3M, and 6M). Surveys included demographic questions, procedural questions, and a psychometric battery of tests. The psychometric battery included seven self-report measures, all using Likert scale questions to measure different phenomena relevant to the population being studied. The PTSD Checklist for the *Diagnostic and Statistical Manual of Mental Disorders*, fifth edition (PCL-5), was used to measure symptom clusters of PTSD (National Center for PTSD, 2016a); the PCL-5 was scored according to symptom clusters (intrusion, avoidance, negative alterations in cognition and mood, arousal) as well as a total symptomatic score. The Brief Symptom Inventory (BSI-18) was used to measure symptoms of depression, anxiety, and somatization (Derogatis, 2000). SLEEP was a composite sleep quality questionnaire that used questions from both the Insomnia Severity Index and the Pittsburgh Sleep Quality Index (Bastien et al., 2001; Buysse et al., 1989). The Perceived Stress Scale–10 was used to help measure a person's self-reported stress levels (Cohen & Williamson, 1988). The Positive and Negative Suicide Ideation–Positive Index examined protective factors against suicidal behavior (Osman et al., 2002). The Connor-Davidson Resilience Scale–10 measured resilience or recovery from a trauma (Campbell-Sills & Stein, 2007). Since PTSD and traumatic brain injury (TBI) are often comorbid (Blakey et al., 2018), the veterans also completed the Brief Traumatic Brain Injury Screen (Schwab et al., 2007).

Survey data were de-identified at collection using participant-generated identifiers composed of birth month (two digits), the first initial of the middle name, and two middle digits of the social security number. Upon receipt by the University of South Florida's team, these identifiers were replaced with four-digit participant numbers to enhance anonymity. Eleven irregularities were identified during data review and resolved through cross-checking identifiers, demographic information, and submission timelines. Partial survey responses were excluded from analysis to ensure data integrity.

Demographics of the Sample Population

The 87 veterans who participated in this evaluation were homogenous in terms of race (90% White) and gender (90% male; Table 1). Seventy-six percent of veteran participants in our sample population were in their 30s, 40s, or 50s; since age data were only recorded in predefined categories, it was not possible to calculate mean age or age-adjusted analyses. However, the mode of age was the 40–49 years of age category. Most participants were married (61%). Years of education ranged from fewer than 12 to greater than 19, with the majority having college experience.

The total number of survey responses at each collection time point were as follows: baseline, 87; mid (17–23 sessions), 64; post (after 40 sessions), 54; 1M, 36; 3M, 35; and 6M, 27 (Table 2). Of the 87 participants that started this program evaluation, 50 participants (57%) completed baseline, mid, and post HBOT surveys. Of those, only 22 participants completed all consecutive measures (base, mid, post, 1M, 3M, 6M).

Data Analysis

Data are reported as means ± standard deviation. Analyses were conducted in R Studio. Within-subject changes across time points were assessed using the Friedman test (Q), with post hoc comparisons performed using the Wilcoxon signed-rank test (W) and Bonferroni correction. Percentage change scores and effect sizes (Cohen's d with 95% confidence intervals [CI]) were calculated for each psychometric measure. Baseline PCL-5 scores of program completers versus noncompleters were compared using heteroscedastic two-sample, two-tailed Student's t tests. The same method was applied to examine differences across demographic subgroups (race, gender, TBI status). Chi-square analysis was used to evaluate differences in PTSD severity based on TBI status. For both the PCL-5 and BSI-18, global and subscale scores were calculated and percentage changes compared.

Table 1
Baseline Characteristics of Veterans Participating in This Program Evaluation

Characteristic	%	*n*
Gender		
Male	89.7	78
Female	10.3	9
Race		
Black/African American	5.7	5
White	89.7	78
Asian	2.3	2
Pacific Islander	0	0
Native American	2.3	2
Age		
18–29	5.7	5
30–39	25.3	22
40–49	29.9	26
50–59	20.7	18
60–69	8	7
70+	10.3	9
Relationship status		
Married	60.9	53
Single	13.8	12
Separated	5.7	5
Divorced	18.4	16
Widowed	1.1	1
Years of education		
<12	1.1	1
12–14	37.9	33
15–16	27.6	24
17–18	16.1	14
>19	17.2	15

Table 2
Posttraumatic Stress Disorder Symptoms Measured With the PCL-5 Decreased Over Time

PCL-5	Base	Mid	Post	1M	3M	6M
M	50.15	27.97	21.19	19.36	19.77	22.07
SD	19.14	17.22	16.63	15.49	16.02	15.12
n	87	64	54	36	35	27

Note. PCL-5 = Posttraumatic Stress Disorder Checklist for the *Diagnostic and Statistical Manual of Mental Disorders*, fifth edition; 1M = 1-month follow-up; 3M = 3-month follow-up; 6M = 6-month follow-up.

Disclosure of Artificial Intelligence

Microsoft Copilot was used in the final editing phase of article preparation in accordance with APA artificial intelligence guidelines to ensure the article met the required length. It also corrected spelling, grammar, and document clarity issues.

Results

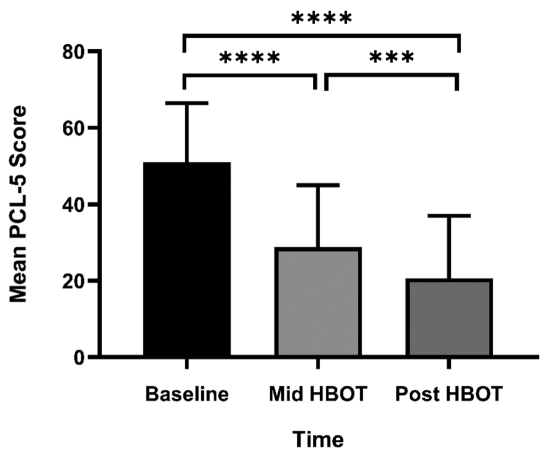
The goal of this program evaluation was to examine whether veterans receiving HBOT through community providers showed symptom changes on self-report measures of PTSD and related symptoms as measured with a series of self-report psychometric tests. The standard industry protocol of 40 HBOT sessions, each lasting 60 min in 100% oxygen at 1.5 ATA, was used. Participants had one session per day, 5 days a week, for 8 weeks. The dropout rate over this 8-week period was 38%; by the 6-month follow-up, only 27 of the original 87 veterans completed all surveys. Based on this loss of participants, we only included veterans in the analysis if they completed baseline, middle, and post surveys with no missing data points ($n = 50$). When we examined demographic characteristics and baseline psychometric test scores between completers and noncompleters, there were no significant differences between the two groups (Supplemental Tables 1 and 2).

HBOT Effects on Core Symptoms of PTSD

The PCL-5 was our primary measure of PTSD symptoms. Veterans' scores from pre-HBOT to 6 months of follow-up showed reductions over time (Table 2). The 50 participants who completed the 40 HBOT treatments had a mean score at baseline of 51.0 ± 15.5 compared to 20.6 ± 16.4 after 40 treatments (Figure 1). The changes in PCL-5 scores for these 50 participants at the three different time points were statistically significant, Friedman's $Q(2) = 69.7$, $p < .001$. The post hoc tests (Wilcoxon with Bonferroni adjustment) revealed significant differences between all three time points (baseline, midpoint, and post) with $p < .001$. The effect size for PCL-5 scores as calculated using Cohen's d was −1.91 with a 95% CI of [−1.4, −2.5] (Table 3). This represents a 60% decrease in PCL-5 scores after HBOT. Of the 50 veterans who completed the treatment, only 22 completed the follow-up PCL-5 survey. During

Figure 1

PCL-5 Baseline, Middle, and Posttreatment Means, Standard Deviations, and Significance



Note. Posttraumatic stress disorder symptoms as measured with the PCL-5 questionnaire decreased significantly with HBOT treatment. The *p* values were determined using the Wilcoxon signed-rank test and adjusted using the Bonferroni correction. PCL-5 = Posttraumatic Stress Disorder Checklist for the *Diagnostic and Statistical Manual of Mental Disorders*, fifth edition; HBOT = hyperbaric oxygen therapy.
*** $p < .001$. **** $p < .0001$.

this period, PCL-5 scores did not change further from the level observed after 40 treatments (1 month, 20.7 ± 14.4; 3 months, 20.7 ± 12.6; 6 months, 22.3 ± 14.4).

In addition to the global PTSD severity score on the PCL-5, we analyzed the four subscales associated with the four symptom clusters that define PTSD. When we examined scores on these subsections, percent decrease in symptoms was similar across subscales and similar to the overall percent change in the global score (intrusion: −59%, avoidance: −60%, negative: −60%, arousal: −58%, and global: −60%; Supplemental Table 3).

HBOT Effects on PTSD-Associated Symptoms

PTSD is often associated with other mental health issues, which were measured with secondary psychometric tests. There were reductions in the global score on the BSI-18 (self-report measure of depression, anxiety, and somatization) from 35.0 ± 15.2 prior to HBOT to 12.4 ± 12.3 after HBOT ($p < .001$; Table 3). This was a 65% reduction in score with an effect size of −1.64, CI [−1.1, −2.2]. When subsection scores of the BSI-18 were examined, results were similar across subsections (depression: −64%, anxiety: −70%, and somatization: −61%; Supplemental Table 3).

Veterans' scores on the SLEEP, Perceived Stress Scale–10, and Short Urgency, Premeditation (lack of), Perseverance (lack of), Sensation Seeking, Positive Urgency, Impulsive Behavior Scale all decreased significantly from baseline to posttreatment ($p < .001$; Table 3). Mean score on SLEEP was 27.1 ± 8.5 at baseline and 12.8 ± 9.9 at post, which is a 53% reduction with an effect size of −1.5, CI [−1, −2.1]. Stress, as measured with the Perceived Stress Scale–10, went from 24.2 ± 3.5 to 19.7 ± 2.8, changing by 19% with an effect size of −1.42, CI [−0.9, −1.9]. The Short Urgency, Premeditation (lack of), Perseverance (lack of), Sensation Seeking, Positive Urgency, Impulsive Behavior Scale self-report measure of impulsive behavior went from 10.5 ± 3.8 at baseline to 6.3 ± 4.4 at post, decreasing by 40% with an effect size of −1.03, CI [−0.6, −1.5] (Table 3). Scores on the Positive and Negative Suicide Ideation–Positive Index and Connor-Davidson Resilience Scale–10 significantly increased ($p < .001$; Table 3). Positive and Negative Suicide Ideation–Positive Index, measuring positive outlook, went from 17.9 ± 4.5 at baseline to 24.1 ± 5.3 posttreatment, changing by 35% with an effect size of 1.26, CI [0.8, 1.7]. Resilience, as measured by the Connor-Davidson Resilience Scale–10, started at 23.1 ± 6.8 and were to 30.8 ± 7.4 after treatment, changing by 34% with an effect size of 1.09, CI [0.6, 1.5] (Table 3). TBI status had no significant effect on baseline levels of PTSD symptoms (Supplemental Table 5).

Discussion

The goal of this program evaluation was to examine whether veterans with chronic PTSD symptoms could benefit from a 40-session treatment regimen of HBOT delivered by community providers. Veterans who underwent the standard HBOT treatment reported lower scores on the PCL-5, and these scores remained at this lower level up to 6 months posttreatment. Symptoms of other comorbid mental health issues such as depression, anxiety, somatization, sleep disturbances, impulsiveness, and stress exhibited a similar trajectory. Performance on self-report measures of positive

Table 3

Psychometric Scores of Veterans Who Underwent Hyperbaric Oxygen Therapy Treatment

	Baseline	Post				
Survey	*M* ± *SD*	*M* ± *SD*	*p*	% Δ	*d*	95% CI
PCL-5	51.0 ± 15.4	20.6 ± 16.4	3.4E−09	−60%	−1.91	[−1.4, −2.5]
BSI-18	35.0 ± 15.2	12.4 ± 12.3	3.8E−09	−65%	−1.64	[−1.1, −2.2]
SLEEP	27.1 ± 8.5	12.8 ± 9.9	9.9E−09	−53%	−1.55	[−1, −2.1]
PSS-10	24.2 ± 3.5	19.7 ± 2.8	9.4E−08	−19%	−1.42	[−0.9, −1.9]
SUPPS-P-8	10.5 ± 3.8	6.3 ± 4.4	6.4E−07	−40%	−1.03	[−0.6, −1.5]
PANSI-PI	17.9 ± 4.5	24.1 ± 5.3	9.1E−08	35%	1.26	[0.8, 1.7]
CD-RISC-10	23.1 ± 6.8	30.8 ± 7.4	2.9E−07	34%	1.09	[0.6, 1.5]

Note. $n = 50$. % Δ = percent change; *d* = Cohen's *d* (effect size); CI = confidence interval associated with Cohen's *d*; PCL-5 = Posttraumatic Stress Disorder Checklist for the *Diagnostic and Statistical Manual of Mental Disorders*, fifth edition; BSI-18 = Brief Symptom Inventory; PSS-10 = Perceived Stress Scale–10; SUPPS-P-8 = Short Urgency, Premeditation (lack of), Perseverance (lack of), Sensation Seeking, Positive Urgency, Impulsive Behavior Scale; PANSI-PI = Positive and Negative Suicide Ideation–Positive Index; CD-RISC-10 = Connor-Davidson Resilience Scale–10.

outlook and resilience had higher reported levels following the treatment period. Together, these results are consistent with the possibility that HBOT may be associated with changes in PTSD and other psychiatric symptom measures in U.S. veterans.

HBOT's Significant Effect on the PCL-5 Implies Merit for PTSD Treatment

For the veterans who completed the HBOT treatment regimen with the community providers involved in this program evaluation, there were clinically significant reductions in their PTSD symptoms with post-treatment scores falling below diagnostic thresholds (National Center for PTSD, 2016b). The observed changes in PCL-5 scores from pre to post (mean difference of 30 and Cohen's d of −1.91, CI [−1.4, −2.5]) were larger than commonly reported effect sizes and mean differences for cognitive processing therapy (CPT) and prolonged exposure therapy (PE), two of the most effective talk therapy interventions for PTSD treatment (Kitchiner et al., 2019). Further, these reductions remained stable out to 6 months posttreatment. These data are consistent with results reported in the literature in which PTSD symptoms remained at reduced levels up to almost 2 years after treatment with HBOT (Doenyas-Barak, Kutz, Lang, et al., 2023; Harch et al., 2017). Given the magnitude of these associations, more rigorous controlled studies are needed to determine whether HBOT contributes to these changes.

The evidence that HBOT is associated with changes for veterans experiencing symptoms of PTSD is complicated. Some studies suggest that HBOT is associated with PTSD symptom reductions (Doenyas-Barak et al., 2022, 2024), but most studies examine PTSD symptoms on a background of TBI. As a result, Veterans Administration/Department of Defense Clinical Practice Guidelines conclude that there is insufficient data to recommend for or against HBOT (Lang et al., 2024). However, the Department of Veterans Affairs has authorized treatment with HBOT for persistent PTSD in veterans who had previously undergone two rounds of evidence-based treatments, CPT or PE, at select Veterans Administration Medical Centers (U.S. Department of Veterans Affairs, 2017). While these psychotherapies reduce PTSD symptoms, for many veterans, there are residual symptoms. At their core, these treatments are based on different modalities of learning and memory and target neurocircuitry that involves the amygdala, hippocampus, ventromedial and dorsomedial prefrontal cortex, insula, dorsal anterior cingulate cortex, and striatum (Fani et al., 2016; Lucassen et al., 2014; Nisar et al., 2020; Xu et al., 2025). When there are residual symptoms after psychotherapy, they often involve hyperarousal symptoms (Schnurr & Lunney, 2019); while there is some overlap in the neurocircuitry mediating hyperarousal and the neurocircuitry mediating intrusion and avoidance (amygdala, prefrontal cortex; Zotev et al., 2018), other brain regions are involved in hyperarousal (hypothalamus, locus coeruleus, periaqueductal gray, hypothalamic–pituitary–adrenal axis; Brzozowska & Grabowski, 2025; Naegeli et al., 2018). Unlike CPT and PE that target specific regions/neural circuits of the brain, the benefit of HBOT may be that it is nonspecific, increasing oxygen availability throughout the brain which could be compatible with multiple mechanistic explanations, though this program evaluation as performed does not address mechanism.

Symptoms of Comorbid Psychiatric or Medical Conditions Improved After HBOT

In an epidemiologic study on prevalence of PTSD as defined by the *Diagnostic and Statistical Manual of Mental Disorders*, fifth edition, criteria in the U.S. population, lifetime prevalence of PTSD was 6.1% (Goldstein et al., 2016). Within this population, there were significant comorbidities between PTSD and substance and alcohol use disorders, mood disorders (major depression, dysthymia, and Bipolar I), anxiety disorders (generalized anxiety, agoraphobia, social phobia, panic disorder), and personality disorders. Therefore, it was important to assess whether symptoms of these comorbidities were also modified after HBOT treatment to determine whether there was a generalized improvement in mental health domains. In this regard, there were statistically significant reductions in scores on self-report measures of depression, anxiety, somatization, sleep disturbances, impulsivity, and stress, as well as higher reported levels in measures of positive outlook and resilience.

TBI Did Not Affect Retention or Efficacy of Treatment

TBI, particularly blast injury, is the signature injury of the military operations of the last 2 decades (Lindberg et al., 2022). While the focus of this evaluation was PTSD symptoms, the reality is that in armed services and veteran populations TBI is common and there is an association between TBI and PTSD (Hoffman & Taylor, 2019). In two recent systematic reviews and meta-analyses examining the association of TBI with PTSD, those veterans with TBI had an increased risk of PTSD (Greer et al., 2020; Loignon et al., 2020). Further, when the two conditions were present together, there was increased PTSD symptom severity. Therefore, we investigated whether TBI influenced the effect of HBOT treatment on PTSD symptoms among veterans who sought treatment at community providers. Of the 50 participants who completed the surveys, the majority (70%) reported a history of TBI. The subgroup comparison between participants who reported a history of TBI and those who did not revealed no significant differences between average scores on the PCL-5 ($p > .4$ at all time points), similarity of changes in PCL-5 score ($p > .45$), or retention within the study ($\chi^2 < 0.1$, critical value of 3.84; Supplemental Table 5). These results indicate that TBI history was not associated with differences in reported symptom change in this sample.

Limitations

Since this was designed as a program evaluation as opposed to a rigorous clinical study, the results presented here cannot be considered a definitive test of whether HBOT contributed to observed symptom changes. Our team relied on the HBOT providers to choose which veterans participated in the program evaluation and to distribute the surveys, which led to inconsistencies in the distribution of surveys and gaps in survey completion. Although only 57% of participants completed surveys at pre, mid, and final time points, importantly, we did not observe bias in completers and noncompleters, even though reasons for dropping out were not collected. With the large dropout rate and the lack of controls, we cannot definitively attribute symptom change to HBOT; symptom changes may reflect expectancy effects, nonspecific therapeutic engagement, regression to the mean, or other unmeasured factors.

Another limitation of this program evaluation was variability in treatment delivery. All three providers offered a total of 40 sessions, one session per day, 5 days per week, with 1 hr spent at 1.5 ATA. However, one provider began all treatment sessions with a 10-min

gradual increase to 2–2.5 ATA, before decreasing pressure to 1.5 ATA for the 1-hr treatment. Based on the anonymity of the experimental design, we could not determine which veterans came from which provider. The effects of the differences in provider operating procedures, therefore, cannot be assessed using this data. It should be noted, however, that even with these differences, HBOT was consistently associated with fewer PTSD symptoms.

In retrospect, it would have been valuable to collect additional information in the surveys. No data were collected on potential confounding variables such as concurrent talk therapy, pharmaceutical therapy, or changes in medication. It was also possible to submit the surveys without completing all questions in the battery; this led to the exclusion of valuable but incomplete data. The design of the demographic questions also led to limitations. For example, the racial categories did not leave room for multiracial identification, the age and education categories were not uniform in their sizes and were categorical instead of requiring specific values, and measures of economic status were not collected. The demographic measures for this evaluation did not reveal any significant differences in baseline measures nor response to treatment.

Recommendations

HBOT protocols reported in the literature vary considerably. The protocol used by the community providers (1.5 ATA, 100% oxygen for 40 sessions) was at the lower range of effective doses. A recent systematic review that examined seven randomized controlled trials and one prospective case series found pressures ranging from 1.2 to 2.4 ATA administered over 40–60 sessions, with reliable changes in PTSD symptoms reported at both 1.5 ATA and 2.0 ATA in two trials each and clinically meaningful changes in two trials that used the 1.5 ATA protocol (Andrews & Harch, 2024). These two doses have been consistently used in the literature since the mid-20th century (Holbach et al., 1977); in the Holbach study, the lower dosage stabilized cerebral metabolism and neurologic function improved, while at the higher dosage, cerebral blood flow decreased and cerebral metabolism shifted toward anaerobic metabolism leading the investigators to suggest that this dose induced oxygen toxicity through inhibition of key enzymes in metabolic pathways. In a more recent clinical trial, higher pressures and longer treatment durations were associated with more durable symptom patterns, with reported symptom levels remaining stable for up to 2 years following 60 sessions at 2.0 ATA (Doenyas-Barak, Kutz, Levi, et al., 2023). Reanalysis of this randomized trial data further suggests that sustained benefit has been associated with achieving a 35% reduction in symptoms, which may reflect stabilization of neural repair mechanisms (Danan et al., 2025). These findings suggest that higher dose, longer duration protocols may accelerate attainment of a sustainable therapeutic threshold.

Central nervous system oxygen toxicity studies reported both 1.5 ATA and 2.0 ATA are safe (Lambertsen et al., 1987). However, the dose range is limited, with doses less than 1.4 ATA not considered hyperbaric and doses above 3.0 ATA considered toxic. In their systematic review, Andrews and Harch (2024) reanalyzed the data from the eight studies they examined. When percent change in PTSD symptoms was plotted against barometric pressure, 1.5 ATA appeared better; this is consistent with the observed changes in PCL-5 scores in this program evaluation. However, when symptoms were plotted against total oxygen delivered, the 2.0 ATA dose was better, suggesting that total tissue oxygenation may be the more crucial factor. If this is the case, then increasing the number of sessions using 100% oxygen at 1.5 ATA to a number that results in a similar degree of oxygenation as observed with 2.0 ATA for 60 sessions, there should be similar stable changes in PTSD symptomology at both pressures. This study has not been done.

The optimal dosing regimen has not yet been established, and this should be the priority of future randomized controlled trials in the field. Further, if we want to advance rigor and reproducibility, consensus guidelines on optimal HBOT dosing protocols are urgently needed. This process should include all stakeholders with a vested interest in optimizing the physical and mental health of our veterans, including the Veterans Administration, Department of Defense, granting agencies, researchers, regulatory oversight, medical doctors, psychiatrists and psychologists, HBOT providers, and veterans. With such guidelines, treatment could be standardized.

There is great disparity between HBOT providers and the services they offer. Those associated with larger medical centers or research enterprises have a larger, multidisciplinary team that can offer widespread services, addressing more of the veterans' physical and psychological needs. Smaller storefront providers may not have the same resources. It can only benefit the industry if these multidisciplinary services are standardized or regulated. The Undersea and Hyperbaric Medical Society is in a position to spearhead such an initiative.

The mechanisms underlying HBOT's apparent effects on PTSD symptoms remain unclear, which is likely a key factor behind the inconsistent results found in the literature. Future studies should incorporate biometric measures to elucidate potential pathways of action. Many veterans present with both TBI and PTSD, conditions that share overlapping symptom profiles and frequently co-occur. Differentiating whether HBOT exerts therapeutic effects on both PTSD and TBI, or just one of them, is critical (Vasterling et al., 2018). The inclusion of biomarkers such as neuroimaging, neurofilament light chain, and adrenal hormone levels may help distinguish treatment effects across these pathologies and provide greater insight into the biological mechanisms underlying HBOT's impact on psychological symptoms (Hier et al., 2021; Naegeli et al., 2018).

The lessons learned from this program evaluation indicate that future research on HBOT as a potential therapy for PTSD should use a randomized clinical trial design, collecting data on concurrent treatment and streamlining the validated psychometric measures so they can be completed in a shorter amount of time and maximizing the completion of all questions. Beyond these considerations, in addition to randomized controlled trials to establish the optimal dosing regimen and standardization of care delivered by HBOT providers, it is unclear if HBOT is a complementary therapy that can only treat residual symptoms still present after evidence-based therapies (CPT or PE) have been administered or whether it is a standalone, alternative therapy that can replace CPT and PE. In this regard, potential randomized controlled trial designs might consist of the following: (a) HBOT + established evidence-based therapy (CPT or PE) versus an evidence-based therapy alone, (b) HBOT compared directly to an evidence-based therapy, and (c) HBOT versus sham HBOT (i.e., simulated HBOT at low or minimum ATA).

Conclusion

This evaluation showed that HBOT had statistically significant positive effects on all psychometric measures, with durable and

clinically significant decreases in symptoms of PTSD. While these results appear promising for the future of HBOT as a treatment for PTSD for U.S. veterans, more rigorous study is required for validation. A randomized clinical trial design with experimental and control groups would provide more rigorous evaluation of HBOT treatment effects and could also ensure that optimal dosing (session pressure, time in the treatment, and time between treatments) is consistent between participants. Further, for community providers, consensus guidelines are needed to deliver high-quality, standardized treatment, including availability of psychological trauma-trained clinicians. It is recommended that future researchers use biometric data to better understand the mechanisms underpinning the HBOT effect and that widely used measures of PTSD comorbidities also be collected. Further study is needed to gain a deeper understanding of the effects of HBOT on symptoms of PTSD, including direct comparison to the current evidence-based, gold-standard treatments for PTSD.

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