



Case Report

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Evaluating the Impact of Hyperbaric Oxygen, Photobiomodulation, and Molecular Hydrogen Therapy in a 26-Year-Old Retired Soccer Player with Persistent Post-Concussion Symptoms: A Case Study

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Abstract

This case study examines the therapeutic efficacy of Hyperbaric Oxygen Therapy (HBOT), Photobiomodulation Therapy (PBM), and Molecular Hydrogen Therapy (H₂) in a 26-year-old retired soccer athlete with a history of six untreated concussions. The patient presented with cognitive impairments, emotional instability, and physical symptoms. The uniqueness of this case lies in the use of an integrative approach to address long-term post-concussion symptoms, supported by comprehensive assessments. The primary diagnoses included cognitive dysfunction and emotional instability related to post-concussion syndrome. Interventions comprised HBOT, PBM, and H₂ therapy, with pre- and post-treatment evaluations conducted using EEG, ANS testing, and GAD-7 and PHQ-9 questionnaires. The results revealed significant improvements in cognitive function, as evidenced by increased P300 voltage and enhanced performance on cognitive tests, as well as in emotional stability and autonomic regulation. These findings suggest that an integrative therapeutic approach may be effective in managing chronic post-concussion symptoms, highlighting the potential benefits of combining these therapies in the treatment of complex, long-term post-concussion issues.

Keywords: Concussions; Neurorehabilitation; Integrative therapies; Cognitive function; Sports rehabilitation

List of Abbreviations

HBOT: Hyperbaric Oxygen Therapy; PBM: Photo Bio Modulation; H₂: Molecular Hydrogen Therapy; P300: A component of the event-related potential (ERP) measured in EEG; EEG: Electroencephalogram; ANS: Autonomic Nervous System; GAD-7: Generalized Anxiety Disorder 7-item scale; PHQ-9: Patient Health Questionnaire 9-item scale

Background

Concussions, a subset of mild traumatic brain injuries (TBIs), are prevalent in high-contact sports and present significant health challenges, particularly for athletes. They have the potential to cause lasting neurological, cognitive, and emotional impairments, leading to persistent post-concussion symptoms (PPCS). Symptoms such as cognitive deficits, emotional instability, chronic headaches, and fatigue can severely impact an individual's quality of life. Despite the debilitating effects of PPCS, current treatment

strategies often focus on rest and symptom management, creating a gap in effective, long-term therapeutic solutions.

Recent advancements in neurorehabilitation and integrative medicine have introduced therapies like Hyperbaric Oxygen Therapy (HBOT), Photobiomodulation (PBM), and Molecular Hydrogen Therapy (H₂). These modalities target various physiological disruptions caused by brain injuries and have shown promise in improving outcomes for individuals with neurological impairments [1]. However, there is a notable lack of research evaluating the combined therapeutic effects of these modalities in a structured, programmatic manner. This case report aims to address this gap by examining the longitudinal impact of an integrative therapeutic approach in treating a retired athlete with chronic post-concussion symptoms.

HBOT promotes oxygen delivery to damaged tissues, facilitating cellular repair, reducing inflammation, and stimulating neuro-

genesis, which can lead to improved cognitive function. PBM uses specific wavelengths of light to enhance mitochondrial function, ATP production, and modulate inflammatory responses, thereby promoting healing and reducing pain in affected brain regions [1]. Molecular Hydrogen Therapy, with its antioxidant properties, helps reduce oxidative stress and inflammation, which are often elevated following brain injuries. By neutralizing harmful free radicals, molecular hydrogen may protect neural cells from damage and promote the recovery of cognitive and motor functions. This case report evaluates the combined impact of HBOT, PBM, and H₂ therapy on cognitive function, emotional stability, and autonomic regulation in a single patient, contributing to a broader understanding of how integrative therapeutic approaches can address the complex nature of post-concussion symptoms.

Case Presentation

The patient is a 26-year-old retired soccer athlete with a history of six concussions sustained over a nine-year period. None of these concussions involved a loss of consciousness, and the patient did not receive extensive neurological evaluation or treatment following these injuries. Primary concerns included persistent cognitive impairments, emotional instability, chronic headaches, and fatigue, all of which significantly affected daily functioning and quality of life. The patient had not engaged in any specialized treatments or rehabilitative interventions for concussion symptoms prior to this case. The patient's medical history includes a series of concussions but no significant neurological or psychiatric disorders. There were no major surgeries or chronic illnesses reported. The family medical history is unremarkable, with no known genetic disorders affecting neurological or psychological health. Psychosocially, the patient has experienced increased stress and anxiety related to the ongoing symptoms, which have impacted both personal and professional life. There is no history of substance abuse or severe mental health issues. Clinical findings were gathered through detailed verbal history and diagnostic assessments. The patient reported persistent cognitive impairments, including memory, attention, and executive function difficulties. Emotional instability was also a significant concern, characterized by mood swings, heightened anxiety, and chronic fatigue. Chronic headaches were frequent, described primarily as tension-type with occasional migraine-like features, contributing to considerable discomfort and disruption in daily activities. Physical examination and cognitive evaluations revealed marked deficits in cognitive function, corroborated by the reduced P300 voltage observed in EEG findings.

The patient also demonstrated signs of autonomic dysregulation, including altered heart rate variability, indicating an imbalance with increased sympathetic activity. These findings aligned with the patient's complaints of chronic stress and anxiety, as well as autonomic dysregulation. Psychoassessments further supported the clinical picture, with the GAD-7 and PHQ-9 questionnaires indicating moderate to severe levels of anxiety and moderate depressive symptoms. In summary, the clinical findings from both

verbal history and assessments provided a comprehensive view of the patient's ongoing cognitive, emotional, and autonomic disturbances, highlighting the complex nature of their post-concussion syndrome.

Methods

Pre- and post-treatment evaluations were conducted to assess cognitive function, autonomic regulation, and emotional well-being in a 26-year-old retired soccer athlete with a history of multiple concussions. The EEG system measured electrical activity in the brain to evaluate cognitive function and neural processing efficiency [2]. Autonomic regulation was assessed through Heart Rate Variability (HRV) and other metrics, providing insights into parasympathetic activity and endothelial function. Psychometric assessments included the PHQ-9 and GAD-7 questionnaires, which are validated tools for evaluating depressive and anxiety symptoms.

The treatment protocol consisted of three sessions per week for five weeks, incorporating Hyperbaric Oxygen Therapy (HBOT), Photobiomodulation, and Molecular Hydrogen Therapy. The patient underwent 15 sessions of HBOT at 1.5 ATA for 40 minutes each, aimed at improving oxygen delivery, reducing neuroinflammation, and promoting neurogenesis. Photobiomodulation involved 20-minute sessions of near-infrared light therapy, delivering a dose of 329Hz, which stimulates cellular metabolism and enhances neural repair mechanisms [1]. Molecular Hydrogen Therapy was administered via nasal absorption for 20 minutes, three times a week, to mitigate oxidative stress and support mitochondrial function. Outcomes were measured at baseline and following the treatment protocol.

Results

Wavi EEG Outcomes

Table 2 presents a comprehensive overview of the EEG metrics before and after the intervention. The most significant finding is the marked increase in P300 voltage, which rose from 10.6 μ V at baseline to 13.8 μ V post-treatment (Table 1). This increase in P300 voltage is particularly noteworthy, as the P300 component reflects the brain's response to cognitive stimuli. The enhanced amplitude of the P300 indicates improved neural processing efficiency and cognitive resource allocation, suggesting that the intervention may facilitate better cognitive performance and engagement with stimuli.

The theta/beta power ratio at the CZ electrode is a well-established metric that reflects changes in neural oscillatory activity associated with cognitive functions [2]. Increases in this ratio are indicative of enhanced neural connectivity and activity within cognitive networks, contributing to more efficient neural network functioning and cognitive processing. It is important to note that all reference ranges for the metrics reported in this study are derived from age- and gender-adjusted normative data, ensuring a more accurate interpretation of the results. Specifically, a signif-

icant increase in the theta/beta power ratio was observed, rising from 1.2 to 1.7 (target range, < 2.5) from baseline to post-treatment, indicating improvements in cognitive control and reduced cognitive interference, which are essential for tasks involving sustained attention and executive function (Table 1).

As shown in Figure 1, the topographical map of the P300 test depth amplitude highlights a notable increase in post-treatment in the Central-Parietal region, reinforcing the observed improvements in cognitive processing efficiency. Cognitive performance improvements were also evident in standardized tests. The Flanker Test showed reduced reaction times, indicating decreased cognitive interference and enhanced executive functioning [3]. Similarly, the Trail Making Test (B) revealed a reduction in completion time by 6 seconds, reflecting improved cognitive processing speed and task-switching ability. Post-treatment evaluations of the autonomic nervous system (ANS) demonstrated substantial improvements across several key metrics (Table 2). Heart Rate Variability

(HRV) showed a notable increase, suggesting enhanced parasympathetic activity and reduced sympathetic dominance. This improvement in HRV is associated with better stress management and overall autonomic regulation [4]. Endothelial function, crucial for vascular health and effective blood flow, also normalized from previously impaired levels, indicating improved vascular function [5]. Additionally, the patient’s parasympathetic response showed significant enhancement, reflecting improved physiological resilience and reduced stress. Improvements in sweat and micro-circulatory responses suggest enhanced physiological resilience and better microcirculation [5]. The PHQ-9 and GAD-7 scores additionally exhibited significant improvements, with depressive symptoms reducing from moderate to mild severity and anxiety symptoms decreasing from severe to moderate levels (Table 3). These changes underscore enhanced emotional stability and reduced psychological distress following the integrative therapeutic regimen [6].

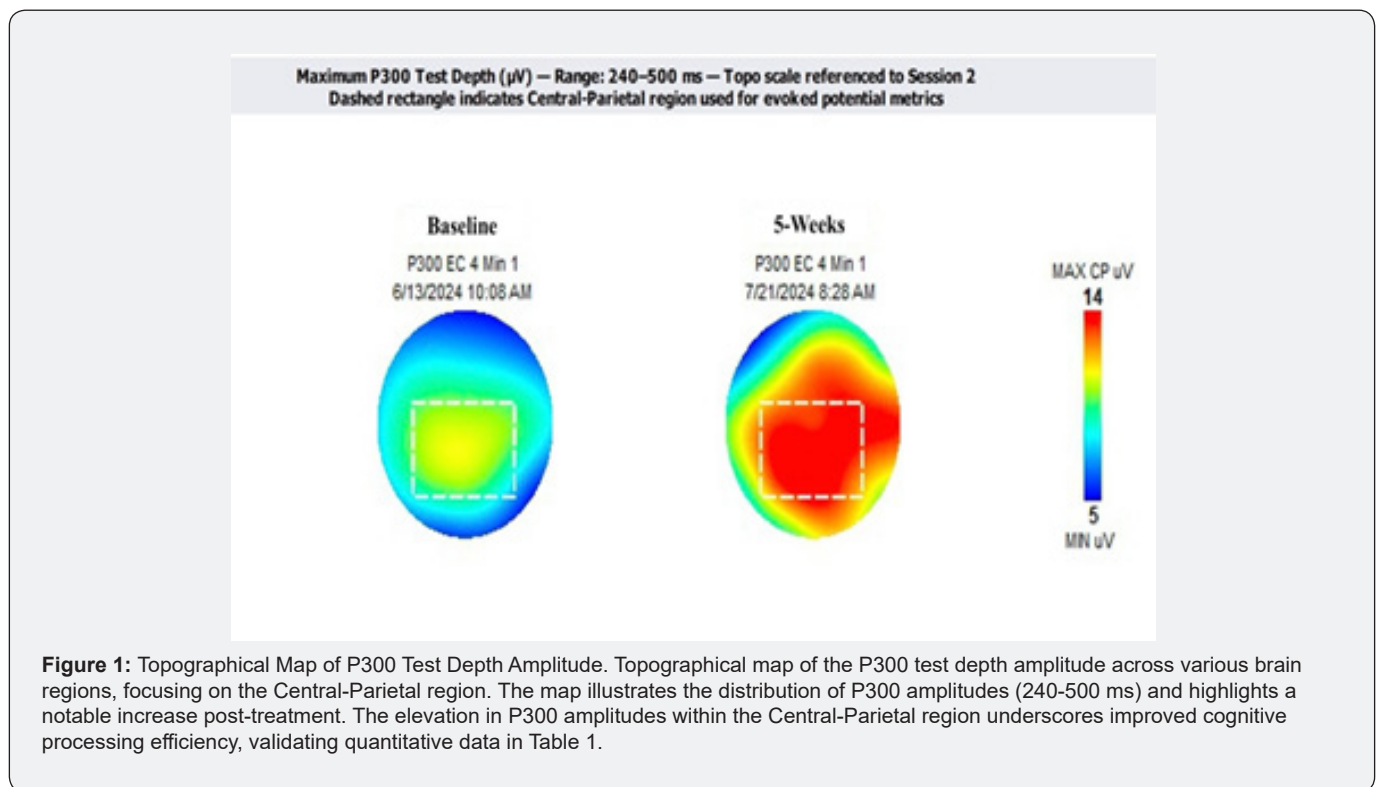


Table 1: Overview of EEG based assessment of cognitive function.

Metric	Baseline Value	Follow-up Value	Target Range
P300 Voltage (μV)	10.6	13.8	9-22 (μV)
Theta/Beta Power (CZ Electrode)	1.2	1.7	1.1-2.5
Reaction Time (Congruent Stimuli, ms)	385	360	N/A
Reaction Time (Incongruent Stimuli, ms)	425	405	N/A
Trail Making Test (B) Completion Time (s)	150	120	47-92 (sec)

Table 2: Autonomic Nervous System (ANS) Outcomes.

ANS Metric	Baseline Value	Post-Treatment Value
Cardiometabolic Risk	Mild	Low
Endothelial Function	Impaired	Normal
Parasympathetic Response	Low	Acceptable
Sweat Response	Low	Normal
Microcirculatory Response	Low	Normal

Table 3: Psychometric Assessments.

Metric	Baseline Score	Post-Treatment Score
PHQ-9	6	3
GAD-7	7	4

Discussion and Conclusions

This case study underscores the potential benefits of an integrative therapeutic approach in managing post-concussion symptoms, demonstrating notable improvements in cognitive function, emotional stability, and autonomic regulation. The strength of this approach lies in its multi-modal therapeutic protocol, which addresses various aspects of post-concussion pathology, including neuroinflammation, oxidative stress, and impaired neural processing. This holistic strategy provides a comprehensive means of promoting recovery. However, limitations such as single-patient design, lack of a control group, and the subjective nature of some assessments suggest the need for more objective measurements and a larger sample size in future research.

The observed improvements are consistent with existing literature supporting the use of Hyperbaric Oxygen Therapy (HBOT), Photobiomodulation (PBM), and Molecular Hydrogen Therapy (H₂) in neurological rehabilitation. HBOT has been shown to reduce neuroinflammation and enhance cerebral oxygenation, which fosters neurogenesis and aids cognitive recovery [7,8]. Similarly, PBM is known to stimulate cellular repair and reduce oxidative stress, contributing to improved neural processing efficiency [9]. Molecular Hydrogen Therapy’s antioxidant properties are well-documented, with evidence suggesting its role in mitigating oxidative damage and enhancing mitochondrial function, both crucial for cognitive processing. By integrating these modalities, the approach addresses the multifactorial nature of persistent post-concussion symptoms, offering a more comprehensive treatment strategy than traditional methods.

The positive outcomes observed in this patient highlight the potential efficacy of targeting inflammation, oxidative stress, and cellular repair processes in improving cognitive and emotional health. While the case demonstrates a favorable response to the combined therapies, it also emphasizes the need for more extensive research to substantiate these benefits. Future studies

should involve larger sample sizes and controlled designs, incorporating robust biodata such as blood biomarkers and physiological markers. Expanding research to include a diverse patient population with varying concussion severities and age groups could further optimize treatment protocols, ensuring broader applicability. In conclusion, this case report suggests that an integrative therapeutic approach combining HBOT, PBM, and Molecular Hydrogen Therapy may offer a promising strategy for managing persistent post-concussion symptoms. The multi-faceted protocol appears to effectively address key pathological processes associated with concussion, leading to improvements in cognitive function and emotional stability. This approach could fill a significant gap in current concussion management, providing a more holistic and effective means of addressing the complex aftermath of traumatic brain injury.

Declarations

Ethics Approval and Consent to Participate

Not applicable. The study involved a single patient who provided informed consent to participate in the wellness intervention and to the use of anonymized data for research and publication purposes.

Consent for Publication

Informed consent for publication was obtained from the patient. The patient was fully briefed on the treatments, including potential benefits, risks, and alternatives. They were also informed about the study’s purpose and consented to the use of their anonymized data for research and publication. The patient retains the right to withdraw consent at any time without affecting their care.

Availability of Data and Materials

Due to the confidentiality of the patient’s medical information, the data supporting the findings of this study are not publicly available. Anonymized data may be provided upon reasonable

request, subject to ethical and privacy considerations.

Competing Interests

The authors declare that there are no financial or non-financial competing interests related to this study. The intervention was conducted as part of the routine wellness services provided by the clinic. Contributions from colleagues involved in review and editorial processes were independent of any financial interests.

Funding

This research was conducted as part of the routine wellness interventions provided by the clinic and did not receive external funding. All treatments and assessments were included as part of the clinic's standard care practices.

Authors' Contributions

The study was conceptualized and designed collaboratively, with all authors contributing to the implementation of the intervention protocol. Responsibilities included patient assessment, data collection, analysis, and interpretation of results. The team also managed the patient's progress throughout the study and facilitated all pre- and post-intervention testing, including WAVI EEG and ANS assessments. Contributions to the manuscript preparation, review, and editorial work were also shared among the authors.

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