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Mini Review

Unlocking Healing Potential: Heart Rate Variability Biofeedback Intervention in Mild Traumatic Brain Injury Rehabilitation-A Mini Review

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ABSTRACT

Mild Traumatic Brain Injury (mTBI) presents notable challenges for effective rehabilitation strategies. This mini-review investigates the potential of Heart Rate Variability Biofeedback (HRV-BF) intervention in mTBI rehabilitation. Despite a limited number of studies, existing literature suggests promising outcomes linked to HRV-BF intervention, including enhancements in physiological and neuropsychological functioning. HRV-BF training could provide a non-invasive and readily accessible means of improving vagal tone and autonomic nervous system regulation, potentially assisting in managing mTBI symptoms. Nevertheless, further research with larger sample sizes and robust study designs is necessary to confirm the effectiveness and long-term advantages of HRV-BF intervention in mTBI rehabilitation. This review emphasizes the importance of exploring an innovative and non-invasive approach, HRV-BF, to optimize outcomes and enhance the quality of life for individuals recuperating from mTBI.

Keywords: Mild Traumatic Brain Injury (mTBI); Heart rate variety biofeedback; Rehabilitation; Neuropsychological functioning; Autonomic nervous system

INTRODUCTION

Mild Traumatic Brain Injury (mTBI) represents a significant public health concern with millions of cases reported annually worldwide. mTBI is characterized by a Glasgow Coma Scale score (GCS) between 13 and 15, loss of consciousness lasting less than 30 minutes, and posttraumatic amnesia lasting less than 24 hours [1]. Despite its mild classification, mTBI can have profound effects, including cognitive impairments and emotional disturbances that adversely affect quality of life [2,3]. The potential effectiveness of non-invasive interventions in addressing the complex symptoms associated with Traumatic Brain Injury (TBI) has gained a great deal of attention in recent years [4]. Heart Rate Variability Biofeedback (HRV-BF) has been used clinically for the treatment of a variety of disorders, including neurological disorders and traumatic brain injuries [5-9]. This article aims to provide an overview of the current landscape of non-invasive interventions for mTBI, with a specific focus on HRV biofeedback. This review synthesizes existing literature and discusses potential mechanisms of action, clinical applications, and future directions to understand the role that HRV-BF can play in the comprehensive rehabilitation of mTBI.

LITERATURE REVIEW

Impact of mild traumatic brain injury

Injuries to the brain cause damage to both the central and peripheral nervous systems, resulting in traumatic changes in biochemical and neuropathological function [10,11]. An increase in sympathetic nervous system activity and an under-activation of the parasympathetic nervous system accompanies mTBI and Post-Concussion Syndrome (PCS) after injury [5].

Heart Rate Variability (HRV) is an indicator of central-peripheral

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neural feedback and also serves as an indicator of the integration of the central nervous system and the autonomic nervous system [12,13]. Patients with mTBI have been shown to have a decrease in HRV [14]. Cognitive and emotional changes can profoundly affect HRV, and are associated with efficient attentional regulation, inhibition, and frontal lobe functioning [15]. Individuals with greater emotional regulation ability exhibit greater resting HRV levels [16,17]. In summary, many previous studies have demonstrated that HRV affects brain function, while also reflecting the emotional and cognitive functions that recruit the central autonomic network.

Irrespective of the extent of the TBI, any level of severity can lead to short-term and long-term neuropsychological deficits [3,18]. Within three months of a mTBI, patients may experience problems with delayed memory, working memory, fluency, processing speed, attention, executive function, and psychiatric symptoms [3,19-24]. While most patients with mTBI recover within three months, those who take longer often experience difficulties with working memory, concentration, and verbal learning, as well as depression, anxiety, and irritability [3,25,26]. The effects of mild traumatic brain injury on neuropsychological function have been demonstrated both in acute and chronic conditions.

Intervention

Traditional treatment approaches for brain injury often involve symptom management and compensatory and restorative rehabilitation strategies, but emerging non-invasive interventions offer promising avenues for improving outcomes.

Psychoeducation is widely employed as an intervention for mTBI due to its effectiveness in providing comprehensive understanding, empowerment, and practical coping strategies, thereby enhancing the rehabilitation process and improving outcomes for individuals with brain injuries. As part of psychoeducation and supportive interventions, education on brain injury and post-concussion syndrome is provided, along with assurances of full recovery and guidance regarding coping with symptoms, resting, and gradual return to normal activity [27,28]. Studies have shown that psychoeducation has significant advantages over cognitive rehabilitation, with several systematic reviews indicating its effectiveness, such as reducing the severity and duration of somatic symptoms, long-term post-traumatic symptoms, and exacerbated mental distress following mTBI and during the chronic phase [29-34]; however, there is a lack of empirical evidence supporting its effectiveness in improving cognitive function.

In recent years, non-invasive interventions, particularly those leveraging technologies like vagus nerve stimulation and HRV-BF, have garnered attention for their potential to address the complex symptoms associated with TBI [35]. HRV-BF enriches the neurovisceral connection and refines the interplay between top-down and bottom-up processes through the activation of pathways associated with vagus nerve stimulation [36-38]. Limited studies, primarily consisting of pilot studies or case reports, have explored the effectiveness of HRV-BF in treating TBI, with only one study, conducted by Lu, et al., employing randomized control to investigate its effects on top-down and bottom-up processes in mTBI [9].

Lu, et al., aimed to replicate and build upon recent discoveries indicating that HRV-BF may enhance HRV, cardiovagal activity, mood disturbance, post-concussion symptoms, severity of headaches, depression, and sleep disturbances following traumatic brain injury [5-7,9]. In Lu, et al., study [9], participants with mTBI in the HRV-BF group underwent a 10-week HRV-BF protocol based on Lehrer, et al., methodology, with the expectation that this intervention [36], would lead to notable enhancements in HRV compared to the baseline, echoing prior research by Lagos, et al., and Kim, et al., which observed an increase in LF and LF/HF ratios among HRV-BF participants from pre to post-tests [5,6]. Lu, et al., study also revealed a significant rise in SDNN, RMSSD, and HF among participants in the HRV-BF group, as compared to a psychoeducation comparison group, indicating a direct influence of the training on vagal-cardiac activity [9,37,39].

Research in non-TBI populations suggests a positive influence of HRV-BF on cognitive functions [40]. It has been shown in Lu, et al., study that HRV-BF training results in improved executive functioning, information processing, and verbal memory among patients with mTBI [9]. This study contributes to the existing literature and is the first to demonstrate the efficacy of HRV-BF in restorative rehabilitation on cognition following mTBI. The emotional disturbances arising from a brain injury can manifest in various forms, all of which have the potential to significantly impact the individual's quality of life. Lu et al., study, in line with earlier research, confirms the efficacy of HRV-BF in enhancing emotional regulation among TBI patients, leading to reductions in depression, anger, and tension [5,7,9]. Additionally, diverging from past studies, this study reveals that HRV-BF not only alleviates depression symptoms but also mitigates anxiety and irritability in individuals with mild traumatic brain injury [9].

Post-concussion syndrome often occurs after a mTBI, with many patients seeing symptoms resolve within hours to one to two months, while some may suffer for years [3]. Healthcare providers across healthcare systems face challenges managing persistent PCS due to the chronicity of symptoms. Only one prior preliminary case study, conducted by Lagos, et al., demonstrated clinically significant improvements in post-concussion symptoms in concussed patients [5]. In Lu, et al., study HRV-BF participants showed significantly fewer total post-concussion symptoms than participants in the psychoeducation group between pre and post-tests, aligning with the findings of Lagos, et al., [5,9]. Lu, et al., research team is additionally interested in investigating the variation in how HRV-BF affects a range of neuropsychological and somatic pathological conditions after a brief intervention, with a consideration of the influence of top-down and bottom-up processes facilitated by vagus nerve stimulation. Lu and his colleagues found that the benefits of the HRV-BF intervention effect were greater for physical symptoms than for cognitive and emotional symptoms [9,41]. Lu, et al., study provides the first opportunity for psychoeducation and HRV-BF to be compared in their impact on heart rate variability and neuropsychological functioning [9].

However, given the limited sample size in Lu's study and its focus on mTBI, we cannot definitively draw conclusions or provide specific recommendations for all types of brain injury. Nevertheless, despite these limitations in Lu, et al., study, the HRV-BF group exhibited moderate to large effect sizes in terms of improving HRV and neuropsychological functioning, where as a psychoeducation comparison group did not [9].

DISCUSSION

Previous studies, despite their utilization of small sample sizes or case reports, yield pilot data for larger-scale investigations. Subsequent research should utilize larger sample sizes and extended follow-up periods to investigate the long-term effects of HRV-BF intervention, including whether individuals with better recovery demonstrate improved long-term brain injury prognoses, such as reduced post-concussion symptoms, enhanced cognitive function, or increased heart rate variability.

Traditional treatment approaches for TBI often involve symptom management and compensatory and restorative rehabilitation strategies, but emerging non-invasive interventions offer promising avenues for improving outcomes. The HRV-BF intervention targets the underlying neurophysiological mechanisms disrupted by the injury, aiming to restore functions and alleviate symptoms.

CONCLUSION

A review of the literature indicates that HRV-BF is a promising modality for the management of mTBI. HRV-BF can contribute to addressing TBI through several mechanisms, including regulating the central-peripheral neural network, boosting HRV, stimulating the vagal afferents, balancing the autonomic system, and enhancing neuropsychological functioning. HRV-BF training presents a potentially effective approach to rehabilitation, facilitating rapid physiological and neuropsychological enhancements with minimal cognitive effort. Prior research significantly enhances the mental health field by underscoring the advantages of innovative treatments for individuals with mTBI, with the aim of mitigating the adverse effects of such injuries on both public health and patient well-being.

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