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The Effects of Transcranial Direct Current Stimulation on Heart Rate Variability and Cardiac Autonomic Function: A Systematic Review

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ABSTRACT

Introduction: Transcranial Direct Current Stimulation (tCDS) is a non-invasive neuromodulation technique that alters neuronal activity through weak electrical currents. While tDCS has been widely studied for its effects on cognition, mood, and pain, emerging research suggests that it may also influence the autonomic nervous system function, particularly Heart Rate Variability (HRV). HRV is an important indicator of autonomic regulation, reflecting the balance between sympathetic and parasympathetic activity.

Aim: This systematic review aims to evaluate the effects of tDCS on HRV and autonomic function by synthesising existing literature. It seeks to identify optimal stimulation parameters and assess the potential clinical applications of tDCS in autonomic regulation. Additionally, it aims to address inconsistencies in prior findings and provide recommendations for future research.

Materials and Methods: The review follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. A systematic search was conducted in NCBI, PubMed, and Google Scholar using the terms “Heart rate variability,” “Autonomic function,” and “Non-invasive stimulation” in combination with “Transcranial direct current stimulation.” Only peer-reviewed studies published in English between 2015 and 2025 were included. Studies involving animals or using transcranial alternating current stimulation or repetitive transcranial magnetic stimulation as interventions were excluded.

Results: This systematic review analysed 13 studies involving 245 participants, including healthy individuals, patients suffering from Hemiplegia due to stroke, fibromyalgia, cerebral palsy, spinal cord injury, and refractory epilepsy. The findings indicate that tDCS significantly modulates HRV and autonomic function in most cases, with the left Dorsolateral Prefrontal Cortex (DLPFC) being the most effective stimulation site. Nine studies reported positive effects {positive outcomes included increases in Standard Deviation of Normal-to-Normal Intervals (SDNN), Root Mean Square of Successive Differences (RMSSD) and High Frequency (HF) power suggesting enhanced parasympathetic activity. Some studies also reported improvements in Low Frequency to High Frequency (LF/HF) and stress reduction}, while 4 studies reported no significant effects (minimal changes in SD2-RR intervals), particularly when stimulation was applied to M1 or T3/Fp2 regions. Additionally, dose-dependent responses were observed, with higher intensities (3 mA) yielding superior autonomic benefits compared to lower intensities (1-1.5 mA).

Conclusion: The tDCS is a promising non-invasive intervention for enhancing autonomic regulation by modulating HRV, particularly when applied to the left DLPFC at 2-3 mA. The findings suggest that tDCS can be a valuable non-invasive approach for modulating autonomic function and enhancing HRV. Future research should focus on standardising protocols, assessing long-term efficacy, and exploring its broader applications in clinical and rehabilitation settings.

Keywords: Autonomic function, Dorsolateral prefrontal cortex, Non-invasive neuromodulation

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