

The Advancements in Non-Invasive Brain Stimulation Techniques and Their Application to Parkinson's Disease

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Abstract : Parkinson's disease (PD) is a progressive neurodegenerative disorder characterized by motor symptoms, including tremors, bradykinesia, rigidity, and freezing of gait (FOG), which arise from degeneration of the basal ganglia. While pharmacological treatments, particularly dopaminergic therapies, remain the primary approach for managing PD, their long-term effectiveness diminishes due to complications such as dyskinesia and motor fluctuations. Deep brain stimulation (DBS) has emerged as an alternative for symptom management but remains invasive, costly, and associated with significant risks. In light of these challenges, non-invasive brain stimulation (NIBS) techniques are gaining attention as promising alternatives for treating PD. These methods, including transcranial magnetic stimulation (TMS), transcranial direct current stimulation (tDCS), and microwave brain stimulation (MBS), offer advantages such as reduced risk and non-invasiveness while providing targeted modulation of brain activity. Recent innovations, such as hemispherical antenna arrays for focused stimulation and advanced signal patterns like high-frequency prime harmonics and temporal interference (TI), have further enhanced the precision and efficacy of NIBS. These techniques have shown potential in modulating neuronal excitability, improving gait, and reducing motor symptoms in PD patients, with some approaches demonstrating effectiveness in treating FOG. Despite promising results, continued research is necessary to refine these technologies, optimize treatment protocols, and evaluate their long-term impact on PD progression. This review highlights recent advances in non-invasive brain stimulation for PD and discusses their potential as adjunctive therapies for managing motor symptoms and improving quality of life in PD patients.

Keywords : Parkinson's disease, non-invasive brain stimulation, deep brain stimulation, transcranial magnetic stimulation, transcranial direct current stimulation, freezing of gait, microwave brain stimulation, neuromodulation

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