

Non-invasive Brain Stimulation for Chronic Pain

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Introduction

Non-invasive brain stimulation (NIBS) techniques, including transcranial magnetic stimulation (TMS) and transcranial direct current stimulation (tDCS), are emerging as promising adjunctive therapies in pain management, offering a drug-free alternative or complement to traditional treatments by modulating neural activity in specific brain regions involved in pain processing [1]. Research indicates that NIBS can effectively reduce various types of chronic pain, such as neuropathic, musculoskeletal, and inflammatory pain, by altering pain perception and decreasing hypersensitivity, although the precise mechanisms are still being investigated [1]. The application of transcranial direct current stimulation (tDCS) for chronic low back pain (CLBP) shows potential for pain relief and functional improvement, with meta-analyses suggesting it can significantly reduce pain intensity and improve disability [2]. This meta-analysis synthesizes current evidence, highlighting that tDCS, particularly anodal stimulation over the motor cortex, can significantly reduce pain intensity and improve disability in CLBP patients [2]. Repetitive transcranial magnetic stimulation (rTMS) is another technique that has been explored for managing chronic pain conditions, with reviews detailing its ability to modulate cortical excitability, influence neurotransmitter systems, and promote neuroplasticity [3]. This comprehensive review delves into the mechanisms and clinical applications of rTMS for managing chronic pain conditions, discussing its effectiveness in various pain disorders, including fibromyalgia, neuropathic pain, and migraine [3]. The study investigates the efficacy of high-frequency repetitive transcranial magnetic stimulation (rTMS) applied to the primary motor cortex in patients with refractory neuropathic pain, indicating a significant reduction in pain intensity and an improvement in quality of life [4]. Results from this randomized controlled trial suggest rTMS can modulate pain processing pathways, offering a novel approach beyond pharmacological interventions for challenging neuropathic pain cases [4]. A systematic review and meta-analysis examines the effectiveness of transcranial direct current stimulation (tDCS) in managing migraine, finding that it can reduce the frequency and intensity of migraine attacks when applied to specific cortical regions [5]. This review highlights the need for standardized protocols and further research to solidify tDCS as a reliable treatment option for migraineurs, with findings suggesting it can reduce attack frequency and intensity [5]. The study evaluates the impact of inhibitory repetitive transcranial magnetic stimulation (rTMS) on pain perception and cognitive processing in individuals with chronic pain, suggesting it can modulate sensory and affective pain dimensions by influencing activity in pain-related brain networks [6]. This research contributes to understanding the neural mechanisms underlying NIBS effectiveness in pain relief by examining how rTMS influences pain perception and cognitive processing [6]. A randomized controlled trial investigates the effectiveness of anodal transcranial direct current stimulation (tDCS) applied to the primary motor cortex for patients with painful diabetic neuropathy, reporting significant reductions in pain intensity and improvements in nerve conduction velocity [7]. The study reports that tDCS significantly reduced

pain intensity and improved nerve conduction velocity compared to sham stimulation, indicating a potential therapeutic benefit for this debilitating condition [7]. The article provides an overview of transcranial magnetic stimulation (TMS) as a treatment for chronic pain, focusing on its neurobiological mechanisms and clinical outcomes, highlighting its efficacy in reducing pain related to conditions like fibromyalgia and neuropathic pain [8]. It highlights the efficacy of TMS in reducing pain related to conditions like fibromyalgia and neuropathic pain, discussing the importance of targeting specific brain regions and optimizing stimulation parameters for maximal therapeutic effect [8]. A systematic review and meta-analysis assesses the efficacy of transcranial direct current stimulation (tDCS) in alleviating phantom limb pain (PLP), with authors concluding that tDCS can be effective in reducing PLP intensity and improving quality of life for amputees [9]. The authors emphasize the need for further research to establish optimal stimulation protocols for this specific pain condition, noting tDCS's effectiveness in reducing PLP intensity and improving quality of life [9]. The study investigates the potential of repetitive transcranial magnetic stimulation (rTMS) to modulate pain sensitivity and improve motor function in patients with chronic stroke-related pain, suggesting that rTMS can reduce pain intensity and enhance motor recovery, offering a dual benefit for stroke survivors [10]. These findings point to rTMS as a promising intervention for improving the lives of individuals with post-stroke pain, demonstrating its potential to reduce pain intensity and enhance motor recovery [10].

Description

Non-invasive brain stimulation (NIBS) encompasses techniques such as transcranial magnetic stimulation (TMS) and transcranial direct current stimulation (tDCS), which are increasingly recognized for their potential as adjunctive therapies in pain management. These methods operate by modulating neural activity within brain regions crucial for pain processing, offering a non-pharmacological avenue or a supplementary approach to conventional treatments [1]. Evidence suggests that NIBS can effectively alleviate a variety of chronic pain conditions, including neuropathic, musculoskeletal, and inflammatory pain. This efficacy is attributed to its ability to alter pain perception and reduce hypersensitivity, with ongoing research aiming to fully elucidate the underlying neurobiological mechanisms, which are thought to involve neuroplastic changes, neurotransmitter modulation, and alterations in cortical excitability [1]. The utilization of transcranial direct current stimulation (tDCS) for chronic low back pain (CLBP) has demonstrated promising results in terms of pain reduction and functional enhancement. Meta-analyses of existing studies indicate that tDCS, particularly when employing an anodal stimulation protocol over the motor cortex, can lead to significant decreases in pain intensity and improvements in disability among CLBP patients [2]. These findings synthesize current evidence, underscoring tDCS as a viable non-pharmacological option for CLBP. However, the need for more extensive, randomized controlled trials is emphasized to establish optimal stimulation protocols and confirm long-term efficacy

[2]. Repetitive transcranial magnetic stimulation (rTMS) is another important NIBS modality that has been investigated for its role in managing chronic pain. Reviews highlight its capacity to modulate cortical excitability, influence neurotransmitter systems, and foster neuroplasticity, all of which contribute to pain alleviation [3]. This comprehensive review explores both the mechanisms and clinical applications of rTMS in the context of chronic pain management. It specifically discusses the effectiveness of rTMS across a range of pain disorders, such as fibromyalgia, neuropathic pain, and migraine, while also stressing the significance of individualized treatment parameters and the continuous development of targeted rTMS protocols [3]. Research has focused on the efficacy of high-frequency repetitive transcranial magnetic stimulation (rTMS) applied to the primary motor cortex for patients experiencing refractory neuropathic pain. The outcomes of such studies have indicated a substantial reduction in pain intensity and a notable improvement in the quality of life for these patients following rTMS treatment [4]. These results suggest that rTMS holds potential as an adjunctive therapy for challenging cases of neuropathic pain. The authors propose that rTMS may work by modulating pain processing pathways, thereby offering a novel therapeutic approach that complements or extends beyond conventional pharmacological interventions [4]. Transcranial direct current stimulation (tDCS) has also been examined for its effectiveness in managing migraine. A systematic review and meta-analysis focusing on this application found that tDCS, particularly when delivered to the supraorbital and dorsolateral prefrontal cortices, can effectively reduce both the frequency and intensity of migraine attacks [5]. This review underscores the necessity for standardized treatment protocols and further research to firmly establish tDCS as a dependable therapeutic option for individuals suffering from migraines, noting its capacity to decrease attack frequency and intensity [5]. The impact of inhibitory repetitive transcranial magnetic stimulation (rTMS) on pain perception and cognitive processing in individuals with chronic pain has been the subject of study. Findings suggest that rTMS can influence both sensory and affective dimensions of pain by modulating activity within pain-related neural networks [6]. This line of research contributes to a deeper understanding of the neural mechanisms that underpin the effectiveness of NIBS in achieving pain relief, particularly through its effects on pain perception and cognitive processing [6]. Anodal transcranial direct current stimulation (tDCS) applied to the primary motor cortex has been investigated for its effectiveness in patients with painful diabetic neuropathy. A randomized controlled trial in this area reported that tDCS led to significant reductions in pain intensity and improvements in nerve conduction velocity when compared to sham stimulation [7]. This suggests a potential therapeutic benefit of tDCS for individuals afflicted with this debilitating condition, highlighting its ability to reduce pain and improve nerve function [7]. Transcranial magnetic stimulation (TMS) is reviewed as a treatment for chronic pain, with a focus on its underlying neurobiological mechanisms and observed clinical outcomes. The review emphasizes TMS's effectiveness in alleviating pain associated with conditions like fibromyalgia and neuropathic pain [8]. Furthermore, the authors highlight the critical importance of precise targeting of specific brain regions and the optimization of stimulation parameters to achieve maximal therapeutic benefits from TMS interventions for chronic pain [8]. A systematic review and meta-analysis was conducted to evaluate the efficacy of transcranial direct current stimulation (tDCS) in the management of phantom limb pain (PLP). The authors concluded that tDCS can be effective in reducing the intensity of PLP and improving the quality of life for individuals experiencing this type of pain [9]. They also emphasize the need for continued research to define and validate optimal stimulation protocols specifically for phantom limb pain, noting the potential for tDCS to reduce pain and enhance life quality [9]. Finally, the potential of repetitive transcranial magnetic stimulation (rTMS) to modulate pain sensitivity and improve motor function in patients suffering from chronic stroke-related pain has been explored. Pilot studies suggest that rTMS can effectively reduce pain intensity and also contribute to enhanced motor recovery, providing a dual benefit for stroke survivors [10]. These findings propose

rTMS as a promising intervention that could significantly improve the quality of life for individuals dealing with post-stroke pain by addressing both pain and motor deficits [10].

Conclusion

Non-invasive brain stimulation (NIBS) techniques, including TMS and tDCS, are emerging as effective adjunctive therapies for chronic pain management. These methods modulate neural activity in pain-processing regions, offering drug-free alternatives. Studies demonstrate NIBS's efficacy in reducing various chronic pain types like neuropathic, musculoskeletal, and inflammatory pain by altering pain perception and hypersensitivity. Specific applications show tDCS is beneficial for chronic low back pain and migraine, while rTMS shows promise for refractory neuropathic pain, fibromyalgia, and stroke-related pain. Mechanisms involve neuroplasticity and neurotransmitter modulation. Personalized approaches and optimized stimulation parameters are crucial for maximizing outcomes and minimizing side effects.

Acknowledgement

None.

Conflict of Interest

None.

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How to cite this article: Muthoni, Grace A.. "Non-invasive Brain Stimulation for Chronic Pain." *J Anesthesiol Pain Res* 08 (2025):323.

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Received: 01-Dec-2025, Manuscript No. japre-26-182016; **Editor assigned:** 03-Dec-2025, PreQC No. P-182016; **Reviewed:** 17-Dec-2025, QC No. Q-182016; **Revised:** 22-Dec-2025, Manuscript No. R-182016; **Published:** 29-Dec-2025, DOI: 10.37421/2684-5997.2025.8.323
