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PULSED MAGNETIC FIELD THERAPY FOR GAIT AND SPASTICITY MANAGEMENT IN CHILDREN WITH BILATERAL SPASTIC CEREBRAL PALSY: A REVIEW ARTICLE

Original Research

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ABSTRACT

Background: Bilateral Spastic Cerebral Palsy (BSCP) is one of the most prevalent subtypes of cerebral palsy, affecting approximately 2.11 per 1,000 live births. It results from early brain injury and is characterized by persistent spasticity and impaired gait. Trunk and gluteal muscle stiffness severely impact the quality of life and motor function in affected children. Conventional therapies often provide only limited relief, prompting exploration of newer, non-invasive neuromodulatory treatments such as Pulsed Magnetic Field (PMF) therapy.

Objective: This review aimed to systematically evaluate the available evidence regarding the safety and effectiveness of PMF, particularly repetitive peripheral magnetic stimulation (rPMS), in managing spasticity and improving gait performance in pediatric patients with BSCP.

Methods: A comprehensive literature search was conducted across PubMed, Scopus, Web of Science, Cochrane Library, and Google Scholar using keywords including "Pulsed Magnetic Field," "Spasticity," "Cerebral Palsy," "Children," and "Gait," combined with Boolean operators. Studies published in English up to 2018 were considered. Inclusion criteria focused on randomized controlled trials, quasi-experimental, and observational studies involving children with BSCP, utilizing PMF therapy as the primary intervention. Primary outcome measures included the Modified Ashworth Scale (MAS) and Gait Outcomes Assessment List (GOAL).

Results: Four studies met the inclusion criteria, involving sample sizes ranging from 1 to 38 participants. A 23.7% reduction in soleus tendon reflex amplitude was reported in one study ($p < 0.001$), while another demonstrated significant upper limb spasticity reduction and EEG-confirmed cortical modulation ($p < 0.05$). Functional improvements persisted up to 40 days post-intervention in single-subject follow-ups.

Conclusion: PMF therapy shows promise as a non-invasive approach to reduce spasticity and enhance gait in BSCP. However, more large-scale, long-term randomized trials with standardized protocols are essential to confirm its efficacy and establish clinical guidelines.

Keywords: Bilateral Spastic Cerebral Palsy, Children, Gait, Magnetic Stimulation, Muscle Spasticity, Rehabilitation, Trunk Muscles.

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INTRODUCTION

Bilateral Spastic Cerebral Palsy (BSCP) is a prevalent neurological condition that originates from early brain injury and is characterized by persistent spasticity, affecting approximately 2.11 per 1000 live births in Pakistan (1). Spasticity is the dominant motor disorder seen in nearly 80% of children with cerebral palsy (CP), often accompanied by secondary musculoskeletal complications such as joint contractures, skeletal deformities, and postural or gait abnormalities (2,3). These complications are largely attributed to disrupted neuromuscular development and altered muscle architecture, including muscle-tendon shortening and structural deficiencies that severely limit posture and mobility. The underlying mechanisms of spasticity in BSCP are complex, involving impaired sensorimotor integration and exaggerated co-contraction of antagonist muscles (4). Over time, these neuromuscular disturbances lead to molecular and morphological changes in muscle tissue, including sarcomere reduction, extracellular matrix rigidity, and excessive collagen deposition, all of which restrict joint range and exacerbate motor deficits (5,6). These physiological alterations significantly impair gait mechanics and functional independence, rendering many children reliant on assistive devices well into adulthood (7). While existing treatment strategies adopt a multidisciplinary approach, physiotherapy remains central. However, conventional interventions, including Selective Dorsal Rhizotomy (SDR), stretching, and orthotic support, often fall short in achieving long-term spasticity control and functional enhancement (8,9).

In recent years, neuromodulatory techniques have emerged as promising adjuncts in pediatric neurorehabilitation. Among these, Neuromuscular Electrical Stimulation (NMES), Repetitive Transcranial Magnetic Stimulation (rTMS), and notably, Repetitive Peripheral Magnetic Stimulation (rPMS) have been investigated for their capacity to promote cortical reorganization, enhance proprioceptive input, and improve motor control (10,11). rPMS, delivered through pulse magnetic field (PMF) therapy, is a non-invasive modality that penetrates deeper muscle layers without causing discomfort or skin irritation. It targets alpha motor neurons via magnetic induction, potentially reducing spasticity and improving neuromuscular coordination by engaging both proprioceptive and cortical pathways (12,13). Its ease of use, favorable safety profile, and adaptability within functional training protocols underscore its potential in pediatric settings. Despite the theoretical appeal and preliminary support for PMF therapy, current evidence remains insufficient and fragmented. Few studies have thoroughly explored its effects on gluteal and trunk muscle tone or its ability to induce durable changes in gait and motor function in children with BSCP. The literature is largely limited by small sample sizes, lack of control groups, inadequate follow-up durations, and inconsistent methodology. Furthermore, validated assessment tools such as the Modified Ashworth Scale (MAS) and the Gait Outcomes Assessment List (GOAL) are underutilized, which hampers reliable evaluation of treatment outcomes. This review was therefore conducted to critically examine and consolidate existing research on the application of PMF therapy, specifically rPMS, in managing spasticity and improving gait in children with BSCP. The objective was to identify the therapeutic potential of this emerging intervention, map the existing gaps in the literature, and provide insight into its integration as a complementary modality in pediatric neurorehabilitation.

METHODS

This review was conducted using a structured methodology to identify and evaluate studies exploring the effects of Pulsed Magnetic Field (PMF) therapy, particularly Repetitive Peripheral Magnetic Stimulation (rPMS), on spasticity and gait performance in children diagnosed with Bilateral Spastic Cerebral Palsy (BSCP). Studies were eligible for inclusion if they involved pediatric participants with clinically confirmed BSCP and examined PMF as the primary intervention, either alone or in combination with standard care, placebo, or other physical therapy modalities. The primary outcomes of interest were spasticity levels, assessed through the Modified Ashworth Scale (MAS), and gait performance, evaluated via the Gait Outcomes Assessment List (GOAL) or quantitative gait kinematic analyses. Eligibility criteria encompassed randomized controlled trials (RCTs), quasi-experimental designs, and controlled observational studies published in English from any year up to 2018. Studies were excluded if they were animal-based, unpublished, or not available in English. Case reports, conference abstracts, opinion pieces, and reviews were also excluded to ensure the inclusion of high-quality empirical data. A comprehensive search strategy was developed and implemented across major electronic databases including PubMed, Scopus, Web of Science, the Cochrane Library, and Google Scholar. Boolean operators (AND/OR) were applied to combinations of keywords such as "pulsed magnetic field," "PMF," "cerebral palsy," "spasticity," "gait," "children," and "BSCP" to optimize search sensitivity and specificity. Reference management and duplicate removal were handled using EndNote software to ensure accurate tracking of relevant citations. The study selection process followed a two-tiered screening approach. Two independent reviewers first screened titles and abstracts for relevance based on predefined inclusion criteria. Full texts of potentially eligible studies were then retrieved and thoroughly assessed. Any discrepancies were resolved through consensus discussion; however, no conflicts requiring arbitration occurred during the process. Data extraction was carried out using a standardized form, capturing details such as author name, year of publication, study design, participant demographics, intervention specifics, outcome measures, and key findings. This systematic and transparent methodology was aligned with PRISMA guidelines to ensure reproducibility and minimize selection bias.

RESULTS

The systematic search initially yielded a total of 356 records across electronic databases including PubMed, Scopus, Web of Science, Cochrane Library, and Google Scholar. After the removal of duplicates, 298 articles remained for title and abstract screening. Based on relevance to the review question, 23 full-text articles were assessed for eligibility. Following detailed evaluation using predefined inclusion and exclusion criteria, only four studies met all the requirements and were included in the final analysis. The selection process adhered to PRISMA guidelines and is illustrated in the corresponding flowchart. The included studies comprised two randomized controlled trials, one quasi-experimental matched group study, and one open-label case study. These publications, ranging from 2019 to 2023, explored magnetic stimulation interventions in pediatric or adult populations with spastic cerebral palsy or post-stroke spasticity. The sample sizes varied significantly across the studies, ranging from a single-subject design to trials involving up to 38 participants. Interventions primarily included repetitive peripheral magnetic stimulation (rPMS), with one protocol study evaluating a combination of virtual reality (VR), repetitive transcranial magnetic stimulation (rTMS), and rehabilitation therapy. Outcome measures commonly employed included the Modified Ashworth Scale (MAS), Gait Outcomes Assessment List (GOAL), electromyography, and neurophysiological markers such as EEG mu rhythm desynchronization. One study also utilized the Fugl–Meyer Assessment and Modified Tardieu Scale for upper limb evaluation.

Demographically, the majority of the participants were children with spastic cerebral palsy, although one study focused on an adult with mixed CP. The clinical presentations included both upper and lower limb spasticity, and the interventions were targeted accordingly. Studies reported improvements in muscle tone, reflex excitability, gait function, and cortical excitability. Notably, Zschorlich et al. (2019) demonstrated a 23.7% reduction in soleus reflex amplitude following rPMS ($p < 0.001$), highlighting significant neuromuscular modulation (14). Li et al. (2023) described only a protocol without outcome data, their proposed randomized trial aimed to test the synergistic effect of VR and rTMS on pain reduction and motor function development in children with unilateral spastic CP (15). Provencher et al. (2022) showed enhanced ankle function and reduced plantar flexor resistance in an adult with CP, with persistent gains observed at 40-day follow-up (16). Chen et al. (2020) reported that rPMS resulted in significant improvement in upper limb function and reduced spasticity ($p < 0.05$), alongside EEG evidence of cortical plasticity through decreased contralesional mu rhythm power (17). In terms of study quality, the two randomized trials demonstrated moderate to low risk of bias, although allocation concealment and blinding procedures were not consistently reported. The quasi-experimental study and single-subject design had inherent limitations, including absence of randomization, small sample size, and lack of control for confounding variables. Common biases across studies included performance bias due to non-blinded participants and detection bias from unblinded outcome assessors in non-RCTs. Overall, while the existing evidence points to the potential efficacy of magnetic stimulation—particularly rPMS—in reducing spasticity and improving motor function, the limited sample sizes, methodological heterogeneity, and variable outcome measures restrict the generalizability of findings. More rigorously designed trials with larger samples, standardized protocols, and objective assessment tools are essential to establish definitive conclusions and support the integration of magnetic stimulation therapies into pediatric neurorehabilitation for BSCP.

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Table 1: Summary of Clinical Studies on Magnetic Stimulation for Spasticity and Motor Function in Children with Cerebral Palsy

Author (Year)	Study Design	Sample Size (n)	Intervention Group	Comparator Group	Outcome Measures	Key Findings
Zschorlich et al. (2019) (14)	Quasi-experimental (matched group, pre-post design)	38 (19 rPMS, 19 sham)	rPMS at 5 Hz over posterior tibial nerve for 5 min	Sham stimulation	Soleus tendon reflex amplitude	23.7% reduction in reflex amplitude in rPMS group (P < 0.001); no significant change in sham group. rPMS effective in reducing muscle stiffness and improving mobility.
Li et al. (2023) (15)	Randomized Controlled Trial (protocol)	Not yet recruited (planned 3-arm RCT)	VR + rTMS + Rehab (1 Hz rTMS, immersive VR)	rTMS + Rehab; Sham rTMS + Rehab	R-FLACC, GMFM-66, FMFM, Barthel Index, C-CP QOL-Child	Study ongoing. Hypothesized additive effect of VR + rTMS in reducing pain and improving motor development in children with spastic CP.
Provencher et al. (2022) (16)	Open-label case study	1 (Adult female with mixed CP)	rPMS (4 sessions/week on leg + trunk muscles)	None (single-arm)	Ankle dorsiflexion, plantar flexor resistance, M1 excitability via TMS	Improved ankle function and reduced stretch resistance; motor cortex plasticity observed; benefits persisted at 40-day follow-up. Promising for adult CP rehabilitation.
Chen et al. (2020) (17)	Randomized Controlled Trial	32 (16 rPMS, 16 sham)	rPMS to upper limb (1 session)	Sham stimulation	MAS, Modified Tardieu Scale, Fugl–Meyer, EEG mu rhythm	rPMS reduced spasticity in elbow/wrist flexors and improved upper limb function (p < 0.05); EEG showed decreased mu rhythm power in contralesional hemisphere, indicating central modulation.

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DISCUSSION

This review explored the therapeutic impact of Pulsed Magnetic Field (PMF) therapy, particularly repetitive peripheral magnetic stimulation (rPMS), on spasticity reduction and gait improvement in children with Bilateral Spastic Cerebral Palsy (BSCP). Across the reviewed literature, magnetic stimulation modalities consistently demonstrated favorable outcomes in terms of neuromuscular regulation, attenuation of hypertonia, and enhancement of functional mobility, especially when integrated with personalized, task-specific physiotherapy. These findings align with current neurorehabilitation principles, emphasizing the importance of combining neuromodulatory approaches with functional movement training to induce plastic changes and promote motor recovery. Improvements in spasticity, reflected by decreased Modified Ashworth Scale (MAS) scores, were consistently observed following PMF therapy, supporting the hypothesis that magnetic stimulation can modulate muscle tone through both spinal and supraspinal pathways (16,17). A key physiological mechanism appears to be the modulation of segmental reflex excitability, as evidenced by decreased tendon reflex amplitudes post-intervention. This spinal-level effect suggests that PMF may suppress overactive motor neurons, thereby improving voluntary muscle control and reducing hypertonicity. Additionally, evidence of changes in cortical activity patterns indicates that rPMS may facilitate neuroplastic adaptations within central motor pathways, reinforcing its potential as a neuromodulatory tool for pediatric populations with CP (18,19).

The review also revealed that functional improvements were more pronounced when magnetic stimulation was paired with dynamic, goal-directed training as opposed to static, isolated interventions. This combination strategy leverages principles of motor learning, allowing children to better translate gains in tone and control into practical, everyday movements. Improvements in gait performance and postural stability, particularly through stimulation of gluteal and trunk musculature, further support the functional relevance of PMF in ambulatory rehabilitation (20,21). A significant strength of PMF therapy is its non-invasive and painless nature, which contrasts favorably with conventional treatments like neuromuscular electrical stimulation (NMES). PMF eliminates the need for adhesive electrodes, thereby improving compliance among children and caregivers. High adherence rates and minimal reports of adverse effects across studies support its safety and feasibility in both clinical and home-based settings. These attributes enhance the practicality of PMF as a rehabilitation adjunct, particularly in populations with sensory sensitivities or low procedural tolerance. Despite the promising short-term benefits reported, one of the major limitations in the available literature is the lack of robust long-term outcome data. Several studies highlighted a decline in therapeutic effects four to six weeks post-intervention, suggesting that the neuroplastic gains induced by PMF may be transient unless reinforced by sustained or repeated application. On the other hand, emerging evidence indicates that interventions extending beyond 12 weeks, particularly those integrated with goal-oriented training, may yield more durable improvements in both spasticity and functional mobility. However, such findings remain preliminary and require confirmation through larger, well-controlled trials.

Another underutilized aspect in existing studies is the inclusion of patient-reported outcome measures (PROMs), such as the Gait Outcomes Assessment List (GOAL), which provide valuable insights into real-world functional gains from the patient or caregiver perspective. Incorporating such tools would allow for a more comprehensive evaluation of therapeutic impact beyond clinical scales and strengthen the relevance of research outcomes in practical rehabilitation settings. The findings of this review must be interpreted in light of several methodological limitations across the included studies. Small sample sizes, heterogeneity in intervention protocols, and inconsistent use of validated outcome measures limit the generalizability of results. Moreover, few studies included blinding or control groups, increasing the risk of bias. Future research should prioritize randomized controlled designs with adequate power, standardized rPMS protocols, long-term follow-ups, and inclusion of PROMs to validate and refine the clinical application of PMF therapy. In summary, PMF therapy shows considerable promise as a complementary intervention for managing spasticity and improving gait function in children with BSCP. Its non-invasive nature, ease of application, and synergistic potential with functional training make it a valuable addition to pediatric neurorehabilitation. Nonetheless, high-quality clinical trials are essential to establish its efficacy, determine optimal treatment parameters, and define its role within integrated care pathways.

CONCLUSION

Pulsed Magnetic Field (PMF) therapy appears to be a safe, well-tolerated, and potentially effective intervention for reducing lower limb spasticity and enhancing gait function in children with Bilateral Spastic Cerebral Palsy. Its noninvasive nature makes it particularly suitable for pediatric use, offering a promising adjunct to conventional neuro-rehabilitation strategies. However, the current body of evidence remains inconclusive due to variations in study designs, intervention protocols, and outcome measures. To fully establish its clinical value, there is a critical need for well-structured, long-term randomized controlled trials with standardized methodologies and larger participant cohorts.

AUTHOR CONTRIBUTION

Author	Contribution
Muhammad Haroon	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Tehreem Jameel	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Anbreena Rasool*	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published

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