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Repetitive transcranial magnetic stimulation in post-traumatic headache after mild traumatic brain injury: a systematic review and meta-analysis

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Introduction
Patients with mild traumatic brain injury (mTBI) who develop persistent headaches often exhibit impaired supraspinal pain modulatory pathways, particularly involving prefrontal cortical connectivity. Repetitive transcranial magnetic stimulation (rTMS) has emerged as a promising non-pharmacological therapeutic option for this condition.

Objective
To evaluate the efficacy of rTMS in patients with post-traumatic headache following mTBI.

Methods
This systematic review and meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and the Cochrane Handbook for Systematic Reviews of Interventions. Randomized controlled trials (RCTs) were systematically searched in PubMed, Embase, and the Cochrane Library databases up to April 2026. Eligible studies included adult patients diagnosed with persistent headache attributed to traumatic brain injury according to the International Classification of Headache Disorders, 3rd edition (ICHD-3), as well as persistent post-concussion symptoms (PPCS) lasting at least three months. Participants were required to be on stable preventive pharmacological treatment prior to study inclusion. Exclusion criteria included prior exposure to TMS therapy, contraindications to TMS, history of migraine prior to the most recent trauma, and structural brain disease. The primary outcome was the reduction in debilitating headache frequency at 4 weeks post-treatment. Secondary outcomes included daily headache intensity. Statistical analyses were performed using ReviewManager. A random-effects model was applied to account for between-study heterogeneity. Effect sizes were expressed as mean differences (MD) or standardized mean differences (SMD) with 95% confidence intervals (CI), as appropriate. Statistical heterogeneity was assessed using the I^2 statistic.

Results
Four RCTs were included, comprising a total sample of 140 patients. Of these, 100 (71.4%) were male. At 4 weeks post-treatment, debilitating headache frequency showed a statistically significant reduction, with a mean difference of −0.83 (95% CI: −1.62 to −0.05; p=0.04), although substantial heterogeneity was observed (I^2=84%). For daily headache intensity at 4 weeks, the mean difference was −0.72 (95% CI: −1.55 to 0.11; p=0.09), indicating no statistically significant difference between groups. Heterogeneity was absent (I^2=0%).

Conclusion
rTMS was associated with a modest reduction in headache frequency but not in daily intensity. The substantial heterogeneity across studies and the limited number of RCTs highlight the need for larger, high-quality randomized trials to confirm these findings.

Keywords:
Neuromodulation
Headache
Meta-analysis
rTMS

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