INPLASY

Application of Brain-Computer Interface-Based Functional Electrical Stimulation, Transcranial Direct Current Stimulation and Motor Rehabilitation in Upper Limb Rehabilitation of Stroke Survivors: A Systematic Review and Network Meta-Analysis

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ADMINISTRATIVE INFORMATION

Support - No.

Review Stage at time of this submission - Completed but not published.

Conflicts of interest - None declared.

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Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 22 May 2025 and was last updated on 22 May 2025.

INTRODUCTION

Review question / Objective To systematically evaluate the efficacy of brain-computer interface (BCI)-based functional electrical stimulation (FES) and transcranial direct current stimulation (tDCS) on upper limb functional recovery after stroke, and to compare the advantages of different intervention combinations through network meta-analysis, providing evidence-based medicine for clinical practice.

Condition being studied Despite growing evidence supporting BCI-based therapies, critical knowledge gaps persist regarding their comparative effectiveness. No prior synthesis has directly evaluated the efficacy hierarchy across BCI-FES, standalone FES, and tDCS-augmented protocols. This network meta-analysis represents the first comprehensive comparison of these interventions, with the dual objectives of identifying optimal treatment strategies and establishing precision rehabilitation frameworks tailored to individual patient profiles.

METHODS

Participant or population
• Adult patients with ischemic/hemorrhagic stroke (disease duration ≥1 month)
• Upper limb motor dysfunction (Brunnstrom stage ≥II)
• Age ≥18 years.

Intervention
Must include BCI-FES For combined interventions:
• BCI-FES must specify trigger thresholds
• Composite interventions (e.g., tDCS + rehab) should be categorized separately.

Comparator • Active control: Other interventions (e.g., BCI vs. tDCS) Examples:

• Passive control: Conventional rehab (PT/OT) or sham stimulation (e.g., tDCS placebo) • BCI group vs. conventional rehab group
• FES group vs. sham stimulation group.

Study designs to be included
• Included: Randomized controlled trials (RCTs)• Excluded: Non-randomized studies (cohort/case series), conference abstracts, incomplete data.

Eligibility criteria
1. Mixed interventions without separate upper limb outcome reporting
2. Duplicate publications or phased data from the same study
3. Non-English/Chinese literature with unavailable full texts
4. Substandard intervention parameters (e.g., tDCS current <1mA).

Information sources
• Initial screening excludes non-stroke/non-upper limb interventions (e.g., gait training)
• Full-text review for parameter compliance and data completeness
• Preset subgroup analysis by disease duration (≤6mo vs. >6mo).

Main outcome(s) For study selection, initial screening was performed based on titles and abstracts to exclude clearly ineligible studies, followed by full-text review for final inclusion determination. Extracted data included: basic study characteristics (e.g., authors, publication year), participant characteristics (e.g., sample size, age, stroke type), intervention details (e.g., stimulation parameters, training frequency and duration), and outcome measure data. The methodological rigor of the included studies was critically appraised using the Cochrane Collaboration's tool for assessing risk of bias.

Quality assessment / Risk of bias analysis For studies not reporting means and standard deviations, conversion was performed using formulas recommended in the Cochrane Handbook. Heterogeneity was assessed using Higgins I^2 statistics, with $I^2 \leq 25\%$ indicating low heterogeneity, 25% substantial heterogeneity. When substantial heterogeneity was present, potential sources were investigated, and random-effects models were applied; otherwise, fixed-effects models were used.

Strategy of data synthesis For network meta-analysis, a Bayesian framework was employed. The model assumed homogeneity across studies and comparability of indirect comparisons between different interventions. When both direct and indirect comparisons were available, mixed treatment effects models were used, combining results through inverse-variance weighting. Analyses were performed using the gemtc package in R. Inconsistency was evaluated by comparing direct and indirect evidence within the network meta-analysis. If results showed statistical consistency between direct and indirect evidence, consistency models were applied. The surface under the cumulative ranking curve (SUCRA) was used to rank intervention efficacy, with relative effect sizes and 95% credible intervals calculated to provide intuitive references for clinical decision-making.

Subgroup analysis For network meta-analysis, a Bayesian framework was employed. The model assumed homogeneity across studies and comparability of indirect comparisons between different interventions. When both direct and indirect comparisons were available, mixed treatment effects models were used, combining results through inverse-variance weighting. Analyses were performed using the gemtc package in R. Inconsistency was evaluated by comparing direct and indirect evidence within the network meta-analysis. If results showed statistical consistency between direct and indirect evidence, consistency models were applied. The surface under the cumulative ranking curve (SUCRA) was used to rank intervention efficacy, with relative effect sizes and 95% credible intervals calculated to provide intuitive references for clinical decision-making.

Sensitivity analysis For network meta-analysis, a Bayesian framework was employed. The model assumed homogeneity across studies and comparability of indirect comparisons between different interventions. When both direct and indirect comparisons were available, mixed treatment effects models were used, combining results through inverse-variance weighting. Analyses were performed using the gemtc package in R. Inconsistency was evaluated by comparing direct and indirect evidence within the network meta-analysis. If results showed statistical consistency between direct and indirect evidence, consistency models were applied. The surface under the cumulative ranking curve (SUCRA) was used to rank intervention efficacy, with relative effect sizes and 95% credible intervals calculated to provide intuitive references for clinical decision-making.

Country(ies) involved China.

Keywords Stroke; Upper limb function; Brain-computer interface; Functional electrical stimulation; Transcranial direct current stimulation.

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