

Neuromodulation For Sleep And Cognition In Mild Cognitive Impairment And Early Alzheimer’S Disease: A Systematic Review



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INTRODUCTION

Sleep disturbances are associated with accelerated β -amyloid accumulation and cognitive decline in early stages of Alzheimer’s disease (AD). Non-invasive brain stimulation techniques, such as transcranial direct current stimulation (tDCS) and gamma-band transcranial alternating current stimulation (tACS), have emerged as potential strategies to improve sleep quality and cognitive function. This review compares the efficacy of tDCS and tACS on subjective sleep quality and cognitive outcomes in patients with mild cognitive impairment (MCI) or mild neurocognitive disorder due to AD (NCD-AD).

METHODS

A systematic search of PubMed and Cochrane Library was conducted for studies published between 2010 and 2025, using the keywords "Alzheimer Disease","tDCS", "tACS ", "Sleep Disorders", "Cognitive function" and related terms. Randomized controlled trials (RCTs) enrolling participants ≥ 60 years with MCI/NCD-AD were eligible. Duplicates and non-English publications were excluded. All titles/abstracts were screened, followed by a full-text assessment.

RESULTS

The screening identified 17 records, of which 5 studies met the inclusion criteria. Repeated anodal tDCS (1-2 mA) improved the Pittsburgh Sleep Quality Index (PSQI) (mean $\Delta = -1.9$, $p < 0.001$) and ADAS-Cog ($\Delta = -1.2$, $*p^* = 0.031$), with greater effects in participants who entered the trial with sleep impairment (PSQI > 5). Emerging data suggests that 40 Hz high-definition tACS (HD-tACS) yields greater benefits than HD-tDCS, with a larger PSQI reduction (6.01 points versus 3.72, $p < 0.001$) and greater MoCA improvement scores (+2.5 points versus +1.5, $p < 0.01$) at 2-month follow-up. Also, a 4-week protocol combining 40 Hz rTMS and tDCS over the bilateral angular gyrus in 84 moderate-AD patients reduced Neuropsychiatric Inventory scores and improved PSQI more than single-modal or sham stimulation ($p = 0.017$). Immediate (online) memory gains were observed in MCI, while long-term effects were variable, with sustained benefits reported for 8-12 weeks in several trials.

CONCLUSION

Both tDCS and 40 Hz HD-tACS are safe, non-pharmacological interventions that significantly enhance sleep quality and cognition in early AD, with gamma-band tACS showing superior efficacy. Baseline sleep quality emerges as a predictive biomarker of treatment response. Larger, multicenter RCTs with standardized protocols and integrated biomarkers are needed to confirm these findings and refine patient-selection criteria.

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