LETTER

Non-drug therapy for sleep disorders in the elderly: a focus on neurofeedback technology

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Abstract

Sleep disorders are a significant clinical problem for older patients, increasing in prevalence and significantly impacting their overall health. Due to limitations in the safety and availability of traditional treatments, EEG-based neurofeedback technology (NF) has emerged as a promising non-pharmacological intervention. Evidence supports the efficacy of NF protocols, particularly those targeting the sensorimotor rhythm and individual alpha peak frequency, for the treatment of sleep disorders. Clinical studies demonstrate that NF leads to significant improvements in both subjective sleep quality and objective sleep parameters, including sleep onset latency and total sleep duration. This technology offers several advantages for use in geriatrics, including non-invasiveness, the absence of pharmacological side effects, the ability to be personalized, and potential for home-based implementation. Additional benefits include a reduction in concomitant symptoms of anxiety and depression, enhancing its clinical utility in older patients with complex presentations. While existing data support the therapeutic potential of NF, future research should prioritize larger randomized controlled trials, particularly in older adults, assessing long-term outcomes, and standardizing protocols. These findings position EEG-based neurofeedback as a valuable component of comprehensive geriatric care for sleep disorders, offering a safe and effective approach to improving sleep quality and overall well-being in aging populations.

Keywords: Insomnia, sleep, aging, neurofeedback, EEG, elderly

Clinical efficacy, advantages and prospects for the elderly

Sleep disorders, particularly insomnia, represent a significant and growing challenge in geriatric medicine, with prevalence notably increasing with age, affecting a substantial portion of the elderly population. In older adults, insomnia often manifests as fragmented sleep, early morning awakenings, and reduced sleep efficiency. This condition is not merely a nocturnal inconvenience but a serious health concern that exacerbates age-associated decline, contributing to cognitive impairment, metabolic and cardiovascular diseases, and compromised immune function [1-3]. The therapeutic landscape for insomnia in this demographic is fraught with challenges. While pharmacotherapy offers short-term relief, it carries significant

risks of side effects, dependence, and dangerous interactions in the context of polypharmacy, which is common among older adults [4]. Although cognitive-behavioral therapy for insomnia is considered the gold standard, its widespread adoption is hindered by significant time and financial costs, creating substantial accessibility barriers for many elderly individuals [5, 6].

In this context, EEG neurofeedback (NF) has emerged as a compelling non-pharmacological alternative, with a growing evidence base substantiated by numerous clinical studies, systematic reviews, and meta-analyses. This technology is grounded in the principles of operant conditioning, enabling patients to learn self-regulation of their brain activity through real-time feedback. The relevance of this approach for the aging brain is particularly pronounced. Key NF protocols that have been rigorously investigated target the sensorimotor rhythm (SMR, 12-15 Hz) and, most notably, the individual alpha peak frequency (iAPF) [7-10]. The iAPF serves as a key biomarker of the dynamic balance between cortical activation and relaxation. A robust body of research indicates that in patients with insomnia, the iAPF is often shifted towards lower frequencies, reflecting a persistent state of heightened cortical activation that disrupts the natural process of falling asleep. This specific neurophysiological dysregulation

is frequently observed and can be exacerbated in aging, thereby positioning iAPF-based NF as a mechanistically targeted intervention for geriatric chronic insomnia.

The efficacy of NF is not merely theoretical but is confirmed by a synthesis of empirical data from multiple clinical trials. Analysis of contemporary studies demonstrates consistent and significant improvements in sleep parameters relevant to older adults. Subjective measures, most commonly the Pittsburgh Sleep Quality Index (PSQI), show substantial score reductions of 25-45%, indicating a markedly improved perception of sleep quality. These subjective reports are robustly supported by objective measurements obtained through polysomnography and actigraphy, which demonstrate a 20-40% decrease in sleep onset latency and a clinically meaningful increase of 15-40 minutes in total sleep time. For elderly patients, who typically suffer from prolonged sleep initiation and fragmented sleep architecture, these gains represent a substantial enhancement in quality of life [10-13]. The underlying mechanism is intrinsically linked to the core objective of NF training: training in self-regulation, control of biological rhythms of brain activity, the stabilization of the iAPF and a concomitant reduction in pathological theta and high-beta oscillatory power, which indicates a successful down-regulation of pre-sleep hyperarousal at a neurophysiological level [14-16].

The advantages of NF, as highlighted across various reviews and original studies, make it exceptionally suitable for the nuances of geriatric care. Its fundamental non-invasiveness and absence of drug-related side effects are paramount for older adults who are highly susceptible to adverse drug reactions. The personalized approach, guided by the individual's unique iAPF biomarker, allows for precise tailoring of therapy to address the heterogeneous nature of age-related sleep changes and comorbidities [16-19]. Furthermore, the potential for application in outpatient or even home settings significantly enhances feasibility and accessibility for patients with mobility limitations or those residing in remote areas. For example, a systematic review by Recio-Rodriguez *et al*. consolidates findings from multiple randomized trials, reinforcing the conclusion that NF is a validated intervention for enhancing sleep quality [16]. Beyond its primary effect on sleep, NF demonstrates a valuable potential for alleviating comorbid symptoms of anxiety and depression, which are highly prevalent in the elderly and further degrade overall quality of life and functional independence.

Despite the promising and consolidating evidence, the field acknowledges certain limitations in the current research landscape, including small sample sizes in some pioneering studies and a relative lack of long-term follow-up data specifically for aging cohorts. The heterogeneity in NF protocols across studies, while reflecting a dynamic field of inquiry, complicates direct comparison and underscores the need for standardization. Future research directions, as outlined in consensus statements and review articles, must involve large-scale, multicenter studies specifically powered to include and analyze older adult subgroups. This will be crucial for establishing optimized,

age-adapted protocols. Parallel technological development should focus on creating intuitive and senior-friendly systems to ensure high adoption rates among the geriatric demographic. A critical and promising avenue for future investigation involves a deeper exploration of how NF modulates age-specific physiological pathways, particularly those linking sleep disruption, impaired glymphatic clearance, and the progression of neurodegeneration and inflammaging [20-24].

In conclusion, EEG-neurofeedback represents a safe, effective, and personalized tool for managing insomnia in the elderly, with its efficacy supported by a converging body of evidence from clinical trials and systematic reviews. By directly targeting the core neurophysiological disturbances of sleep in the aging brain, it offers a viable and compelling strategy to improve sleep quality and, consequently, overall health and well-being in the growing elderly population. With continued technological refinement, standardized research, and dedicated clinical validation, NF technology is poised to become an integral component of geriatric sleep medicine and a cornerstone of age-adapted personalized healthcare.

Declarations

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