

EFFECT OF REPETITIVE TRANSCRANIAL MAGNETIC STIMULATION ALONG WITH OROPHARYNGEAL EXERCISES IN THE INDIVIDUALS WITH SLEEP APNEA

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ABSTRACT

Objective: To evaluate combined rTMS and oropharyngeal exercises (OPEs) in improving sleep quality and reducing respiratory events during sleep in obstructive sleep apnea (OSA).

Methods: This Pre-post study of 10 adults (age 30–60 y; NoSAS > 7) was conducted between December 2023 and March 2025. Participants completed 15 sessions of rTMS (10 Hz, 20 minutes per session) over 5 weeks, in conjunction with regular oropharyngeal exercises. Outcomes included PSQI, ESS, and polysomnographic indices (AHI, central/obstructive apneas). Paired t-tests were used; significance at $p < 0.05$.

Results: PSQI improved from 11 ± 3.27 to 4.9 ± 1.52 ($p = 0.0008$); ESS from 10.9 ± 4.34 to 3.7 ± 1.95 ($p = 0.0012$). Central apneas decreased from 58.7 ± 5.66 to 5.4 ± 2.75 ($p < 0.000001$); obstructive events (246.3 ± 62.3 to 205.4 ± 61.6) and AHI (74.9 ± 3.2 to 74.1 ± 4.5) did not change significantly ($p = 0.19$; $p = 0.63$, respectively).

Interpretation: This combined rTMS + OPE protocol significantly enhances subjective sleep quality and reduces central apneas in OSA, suggesting a novel adjunctive therapeutic option.

Keywords: obstructive sleep apnea, repetitive transcranial magnetic stimulation, oropharyngeal exercises, sleep quality, Pittsburgh Sleep Quality Index, Epworth Sleepiness Scale.

INTRODUCTION

Obstructive Sleep Apnea (OSA) is a highly prevalent sleep disorder, yet frequently underdiagnosed, and significantly impacts an individual's health and quality of life. It is characterized by repeated episodes of upper airway obstruction during sleep, resulting in intermittent hypoxia, arousals from sleep, and poor sleep architecture. These disturbances lead to symptoms such as excessive daytime sleepiness, impaired concentration, mood disturbances, and an increased risk of cardiovascular, metabolic, and neurocognitive complications (Gottlieb & Punjabi, 2020; Pinto et al., 2016; Vanek et al., 2020). The global prevalence of OSA among adults ranges from 9% to 38%, with even higher rates reported among men, older adults, and individuals with obesity (Benjafield et al., 2019; Goyal et al., 2025).

The pathophysiology of OSA is multifactorial, involving anatomical narrowing of the upper airway, impaired neuromuscular control, and instability in ventilatory control systems (Suzuki, 2022; Pham & Schwartz, 2015). Risk factors such as obesity, retrognathia, enlarged soft tissues, and neuromuscular dysfunction contribute to upper airway collapsibility during sleep, especially during rapid eye movement (REM) stages when muscle tone is naturally reduced. In addition to mechanical obstruction, central neural mechanisms also play a critical role. Deficits in neural

drive to the pharyngeal dilator muscles and alterations in the brainstem respiratory centers have been associated with both obstructive and central apneic events (Kryger et al., 2017; Dempsey et al., 2010).

Polysomnography (PSG) is the gold standard for the diagnosis of OSA, evaluating indices such as the apnea-hypopnea index (AHI), oxygen desaturation index (ODI), and arousal index (Iber et al., 2007; Kapur et al., 2017). These parameters help guide treatment and monitor disease progression. Treatment options for OSA range from lifestyle interventions to medical and surgical therapies. The most widely used treatment is Continuous Positive Airway Pressure (CPAP), which provides pneumatic splinting of the airway during sleep and effectively reduces AHI (Sullivan et al., 1981). However, despite its clinical efficacy, CPAP adherence remains suboptimal, with studies reporting poor long-term compliance due to discomfort, mask-related issues, and perceived inconvenience (Weaver, 2019).

Given these limitations, alternative and adjunctive interventions are increasingly being explored. One such approach is oropharyngeal exercises (OPEs), which aim to strengthen the muscles of the tongue, soft palate, and lateral pharyngeal walls. These exercises enhance upper airway stability, thereby reducing collapsibility during sleep. Multiple studies have shown that OPEs significantly reduce

snoring, AHI, and excessive daytime sleepiness (Guimarães et al., 2009; Atilgan et al., 2019; Kaur et al., 2020). These exercises are simple, non-invasive, cost-effective, and can be integrated into physiotherapy protocols for mild to moderate OSA.

Another emerging therapy is repetitive transcranial magnetic stimulation (rTMS), a non-invasive brain stimulation method that uses magnetic pulses to modulate neural activity. rTMS has been studied extensively in neuropsychiatric disorders and is now gaining traction in sleep medicine. It is believed to enhance cortical plasticity, improve neural regulation of respiratory function, and influence autonomic control (Lanza et al., 2023; Rousseau et al., 2015; Das et al., 2013). Preliminary studies suggest that rTMS may improve sleep quality, reduce daytime sleepiness, and positively influence respiratory patterns in individuals with sleep apnea (Li et al., 2022; Liu et al., 2025).

Given the multifaceted etiology of OSA involving both mechanical and neuromuscular components, a combination of interventions targeting both domains may yield better therapeutic outcomes. Integrating rTMS with oropharyngeal exercises could potentially offer a dual benefit: strengthening the upper airway muscles mechanically and enhancing neural regulation centrally. However, research on such combined approaches remains limited. This study was therefore designed to investigate the combined effect of repetitive transcranial magnetic stimulation along with oropharyngeal exercises in individuals diagnosed with obstructive sleep apnea. The results may provide insight into novel, integrative strategies for managing OSA in clinical practice.

MATERIALS AND METHODS

Study Design and Setting

This study was conducted as a pre-post interventional trial at the Department of Physiotherapy, Desh Bhagat University, in collaboration with Neuroroots Clinic and Osteocare Clinic, Patiala. The primary objective was to assess the effectiveness of combining repetitive transcranial magnetic stimulation (rTMS) with oropharyngeal exercises (OPEs) in individuals diagnosed with obstructive sleep apnea (OSA). The study duration was five weeks.

Participants

A total of 10 participants aged between 30 and 60 years were

recruited. All had been clinically diagnosed with OSA and had a NoSAS score greater than 7, indicating moderate to high risk. Inclusion criteria included both male and female participants within the specified age range who were willing to give informed consent. Exclusion criteria encompassed individuals with craniofacial malformations, a history of alcohol or drug abuse, the presence of metallic implants near the cranial area (such as pacemakers or cochlear implants), or any neurological or psychiatric conditions that could contraindicate rTMS. Additionally, individuals who had previously undergone CPAP therapy or surgical interventions for OSA were excluded. Institutional ethical approval was obtained, and all participants provided written informed consent before the initiation of the intervention.

Intervention Protocol

The intervention consisted of two components: rTMS and oropharyngeal exercises. rTMS was administered using a frequency of 10 Hz and an amplitude of 55% of the maximum stimulator output. Each session lasted for 20 minutes and was delivered three times per week for five consecutive weeks, with a total of 15 sessions. The stimulation was targeted over the prefrontal cortex using standard EEG positioning methods.

In addition to rTMS, participants performed a set of oropharyngeal exercises designed to strengthen the muscles of the tongue, soft palate, and lateral pharyngeal walls. The exercises included tongue brushing, suction, vowel pronunciation, soft palate elevation, cheek puffing, and gargling. Participants were instructed to perform these exercises twice daily, each session lasting 15 to 20 minutes, for the entire five-week duration. Adherence was monitored through weekly therapist interactions and self-maintained exercise logs.

Outcome Measures

Subjective assessment was done using the **Pittsburgh Sleep Quality Index (PSQI)** and the **Epworth Sleepiness Scale (ESS)**, whereas Objective assessment using **overnight polysomnography (PSG)** was conducted before and after the intervention period.

Pittsburgh Sleep Quality Index

The Pittsburgh Sleep Quality Index (PSQI) will be used to assess subjective sleep quality over the past month. This 19-item self-report questionnaire yields seven component

scores, which are summed to create a global score (0-21), with higher scores indicating worse sleep quality (Buysse et al., 1989). A global PSQI score greater than 5 has demonstrated a sensitivity of approximately 85-90% and a specificity of around 87% in distinguishing between good and poor sleepers (Kang et al., 2017; Solecka et al., 2022). This makes it a valuable tool for identifying individuals with significant sleep difficulties.

Epworth Sleepiness Scale

The Epworth Sleepiness Scale (ESS) will assess daytime sleepiness using an eight-item questionnaire. Participants rate their likelihood of dozing in various situations (0-3). Total scores range from 0 to 24, with higher scores indicating greater sleepiness. A score of ≥ 10 often suggests excessive daytime sleepiness, a key symptom in sleep disorders (Feltner et al., 2022; Bastien et al., 2021). The ESS offers a brief, self-administered measure of an individual's propensity to fall asleep during the day.

Polysomnography

Polysomnography (PSG), the gold standard for diagnosing obstructive sleep apnea (OSA), will serve as the primary outcome measure. This comprehensive overnight in laboratory study will continuously record electroencephalogram (EEG), electrooculogram (EOG), electromyogram (EMG), electrocardiogram (ECG), respiratory effort, airflow, oxygen saturation, body position, and snoring. The Apnea Hypopnea Index (AHI), calculated as the average number of apneas and hypopneas per hour of sleep, will determine OSA severity, aligning with established criteria (Sateia et al., 2017).

PSG provides detailed physiological data crucial for accurate OSA diagnosis and characterization, allowing for the analysis of sleep architecture and respiratory events (Chazal et al., 2019). Secondary outcomes, including the Oxygen Desaturation Index (ODI) and arousal index, will also be assessed to provide a comprehensive understanding of the impact of sleep-disordered breathing.

Statistical Analysis

Statistical analysis was carried out using SPSS version 16.0. Pre- and post-intervention comparisons were made using the paired t-test to evaluate the significance of differences in outcome measures. Results were reported as mean $\pm$ standard deviation (SD), and a p-value of less than 0.05 was considered statistically significant.

RESULTS

Participant Characteristics

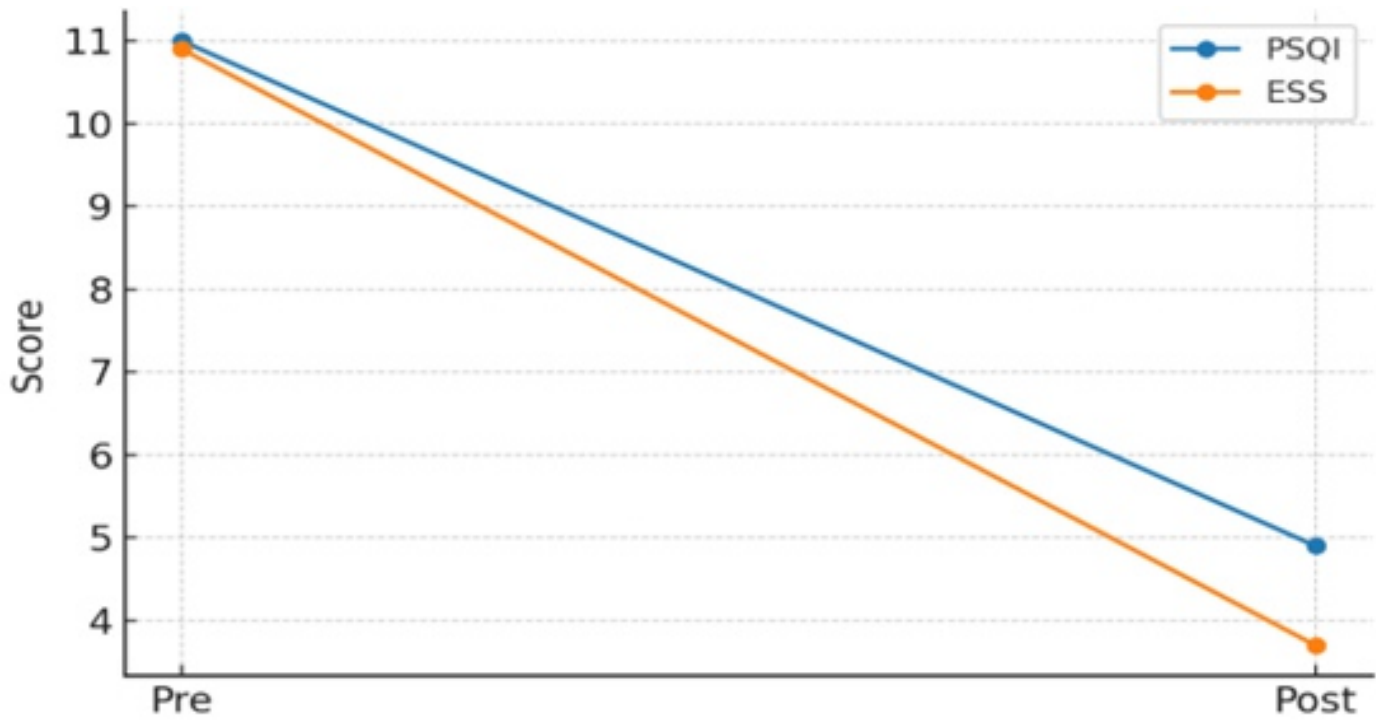
Ten participants (7 males, 3 females) completed the study. The mean age was 43.1 ± 9.1 years and the mean BMI was 30.76 ± 3.11 kg/m². All participants had a NoSAS score greater than 7 and were diagnosed with moderate to severe OSA on baseline polysomnography.

Subjective Outcomes

Following the intervention, the Pittsburgh Sleep Quality Index (PSQI) improved significantly from 11 ± 3.27 to 4.9 ± 1.52 ($p = 0.00076$). The Epworth Sleepiness Scale (ESS) score decreased from 10.9 ± 4.34 to 3.7 ± 1.95 ($p = 0.0012$), indicating reduced daytime sleepiness.

Outcome	Pre-intervention (Mean $\pm$ SD)	Post-intervention (Mean $\pm$ SD)	p-value
PSQI	11 ± 3.27	4.9 ± 1.52	0.00076
ESS	10.9 ± 4.34	3.7 ± 1.95	0.0012

Table 1: Changes in subjective sleep measures pre- and post-intervention



Polysomnographic Outcomes

The **apnea-hypopnea index (AHI)** remained statistically unchanged (74.92 ± 3.19 pre-intervention vs 74.05 ± 4.51 post-intervention; $p = 0.63$).

Central apnea events showed a marked reduction from 58.7 ± 5.66 to 5.4 ± 2.75 ($p < 0.000001$).

Obstructive apnea events decreased from 246.3 ± 62.27 to 205.4 ± 61.64 , but this difference did not reach statistical significance ($p = 0.19$).

Parameter	Pre-intervention (Mean $\pm$ SD)	Post-intervention (Mean $\pm$ SD)	p-value
AHI (events/h)	74.92 ± 3.19	74.05 ± 4.51	0.63
Central apneas (n)	58.7 ± 5.66	5.4 ± 2.75	<0.000001
Obstructive apneas (n)	246.3 ± 62.27	205.4 ± 61.64	0.19

Table 2: Polysomnographic parameters before and after intervention

Percentage Change in Key Outcomes

The greatest percentage improvement was observed in central apnea events (-90.8%), followed by ESS (-66.1%) and PSQI (-55.5%). Obstructive apnea events decreased by 16.6% (Table 3).

Outcome	Pre	Post	% Change
PSQI	11	4.9	55.5%
ESS	10.9	3.7	66.1%
Central apneas	58.7	5.4	90.8%
Obstructive apneas	246.3	205.4	16.6%

Table 3: Percentage change in key outcomes

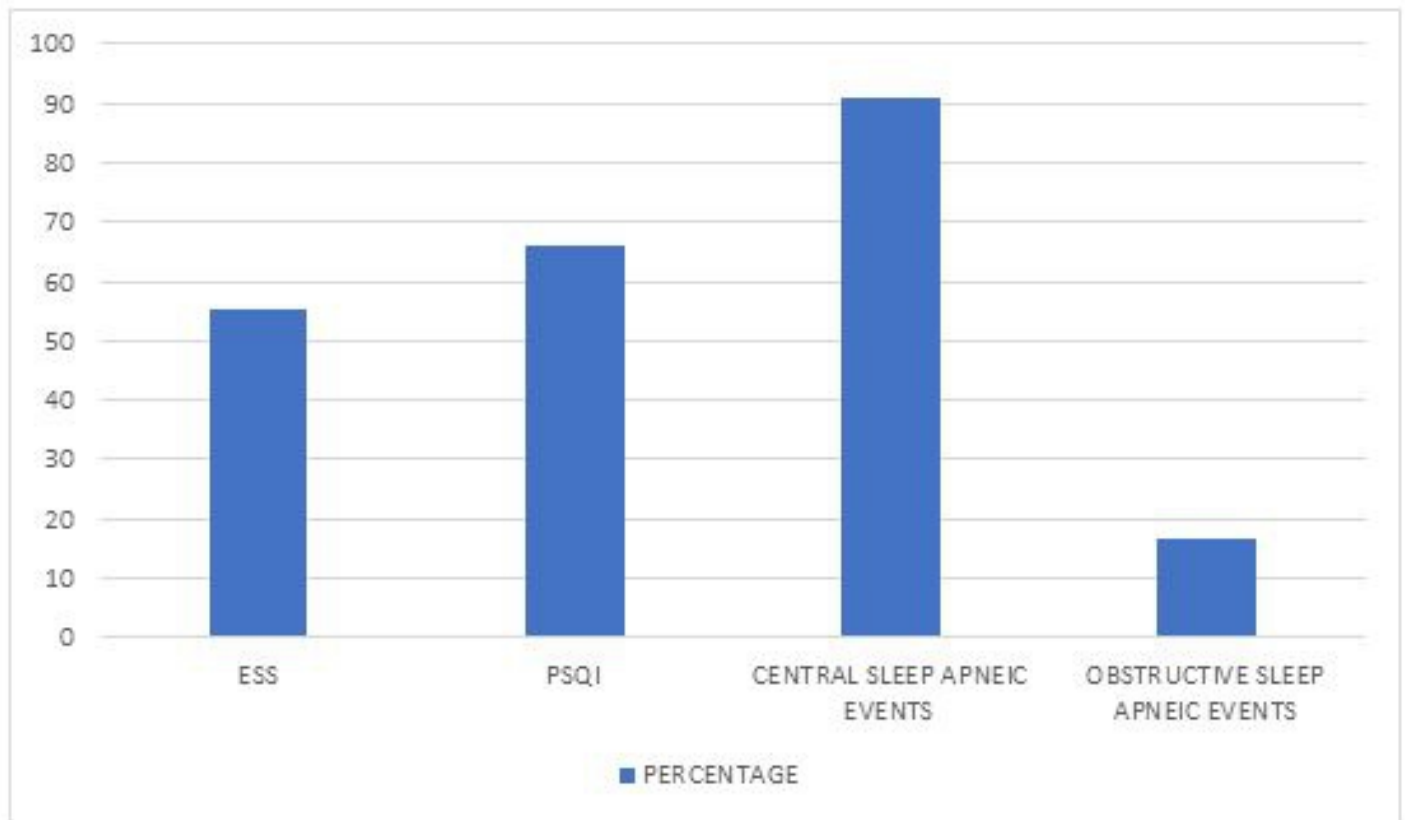


Figure 2: Percentage change in key outcomes

DISCUSSION

Principal Findings

This study demonstrates that combining repetitive transcranial magnetic stimulation (rTMS) with oropharyngeal exercises (OPEs) significantly improved subjective sleep quality and reduced daytime sleepiness in individuals with OSA. A particularly noteworthy finding was the substantial reduction in central apnea events, whereas obstructive events and overall AHI remained largely unchanged.

Comparison with Previous Studies

Previous studies have established that OPEs can enhance upper airway muscle tone, reduce airway collapsibility, and lead to modest reductions in AHI and snoring intensity (Guimarães et al., 2009; Kaur et al., 2020). Similarly, rTMS has been reported to modulate cortical excitability and autonomic control, potentially influencing respiratory rhythm generation (Rousseau et al., 2015; Lanza et al., 2023). Our findings align with these observations, as the intervention yielded improvements in sleep-related symptomatology and central apnea indices. Unlike some OPE studies that reported significant reductions in obstructive events, our cohort—characterized by high baseline AHI and severe OSA—showed no significant change

in this parameter. This difference may reflect the mechanical limitations of airway patency in severe disease, where structural factors dominate.

Possible Mechanisms

The reduction in central apneas may be attributed to rTMS-induced neuromodulation of cortical and subcortical respiratory centers, enhancing ventilatory drive stability. High-frequency rTMS over motor and prefrontal regions could improve the neural output to upper airway dilator muscles and respiratory pattern generators, thereby reducing central pauses in breathing. Meanwhile, OPEs likely contributed to peripheral muscle strengthening, potentially improving airway patency during sleep. The combination of central neuromodulation and peripheral muscle training may thus exert complementary effects.

Strengths and Limitations

A major strength of this study is its novel combination of two non-invasive, patient-friendly interventions targeting both neural and muscular contributors to OSA. The pre-post design with objective PSG measurements provides a robust assessment of physiological outcomes. However, the small sample size and absence of a control group limit the generalizability of findings and prevent definitive causal inferences. Self-reported adherence to OPEs may have

introduced bias, and the short follow-up precludes assessment of long-term efficacy.

CLINICAL IMPLICATIONS

The findings suggest that combined rTMS and OPE therapy could serve as an adjunct for OSA patients, particularly those with central apnea components or poor CPAP tolerance. The significant reduction in central apneas indicates potential utility in mixed sleep apnea cases, where conventional therapies may be insufficient.

FUTURE DIRECTIONS

Future studies should employ randomized controlled designs with larger sample sizes, include sham stimulation arms, and assess long-term adherence and durability of effects. Exploration of optimal rTMS parameters and integration with other rehabilitative approaches may further enhance outcomes.

CONCLUSION

The combination of repetitive transcranial magnetic stimulation and oropharyngeal exercises significantly improved subjective sleep quality and reduced daytime sleepiness in individuals with obstructive sleep apnea. The most striking finding was a substantial reduction in central apnea events, suggesting that this integrative approach may positively influence central respiratory control mechanisms. While obstructive events and overall AHI did not change significantly, the observed benefits highlight the potential of targeting both neural and muscular pathways in OSA management. Given the small sample size and short intervention period, these results should be interpreted as preliminary; however, they provide a strong rationale for further large-scale, randomized controlled trials to establish the efficacy, optimal parameters, and long-term effects of this novel therapeutic combination.

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