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EFFECT OF FUNCTIONAL CIRCUIT TRAINING ON EXERCISE-INDUCED SLEEP IMPROVEMENT IN INDIVIDUALS WITH OBSTRUCTIVE SLEEP APNEA: A RANDOMIZED CONTROLLED TRIAL

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ABSTRACT

Background: Obstructive Sleep Apnea (OSA) is a common sleep-related breathing disorder characterized by recurrent episodes of upper-airway obstruction, sleep disturbance, and excessive daytime sleepiness. Exercise-based interventions have increasingly been investigated as an adjunctive approach for improving sleep-related outcomes in individuals with OSA. Functional Circuit Training combines aerobic, resistance, functional, and core exercises within a progressive training program and may provide a greater physiological stimulus than conventional physiotherapy. The aim of this study was to determine the effectiveness of Functional Circuit Training on exercise-induced sleep improvement and daytime sleepiness in individuals with mild to moderate OSA.

Methods: This randomized controlled trial included 60 adults aged 30–60 years diagnosed with mild to moderate OSA. Participants were randomly allocated into Group A (n=30), which received Functional Circuit Training, and Group B (n=30), which received conventional physiotherapy. Both interventions were administered three times per week for 8 weeks, with each session lasting 45–60 minutes. The primary outcome was the Exercise-Induced Sleep Improvement Scale for Obstructive Sleep Apnea (EISIS-OSA), and the secondary outcome was the Epworth Sleepiness Scale (ESS). Pre- and post-intervention assessments were performed and analyzed using paired and independent t-tests.

Results: Both groups demonstrated statistically significant improvements in EISIS-OSA and ESS scores ($p < 0.0001$). EISIS-OSA improved from 41.830 ± 3.927 to 72.780 ± 3.901 in Group A and from 43.123 ± 3.861 to 57.717 ± 3.672 in Group B. ESS decreased from 15.337 ± 1.964 to 8.283 ± 2.536 in Group A and from 15.650 ± 1.603 to 10.540 ± 2.162 in Group B. Between-group analysis demonstrated significantly greater improvement in Group A for both outcomes ($p < 0.001$).

CONCLUSION: Functional Circuit Training was more effective than conventional physiotherapy in improving exercise-induced sleep outcomes and reducing excessive daytime sleepiness in individuals with mild to moderate OSA.

KEYWORDS: Obstructive Sleep Apnea; Exercise Therapy; Circuit Training; Sleep Quality; Daytime Sleepiness.

INTRODUCTION

Obstructive sleep apnea (OSA) is one of the most common sleep-related breathing disorders and represents a growing public health challenge worldwide. It is characterized by repeated episodes of partial or complete collapse of the upper airway during sleep, leading to intermittent hypoxia, frequent arousals, and disruption of normal sleep architecture. These recurring respiratory events not only impair the quality of sleep but also contribute to excessive daytime sleepiness, cognitive impairment, mood disturbances, reduced work productivity, and a diminished quality of life. Over time, untreated OSA has been associated with several serious health consequences, including hypertension, cardiovascular disease, type 2 diabetes mellitus, stroke, and increased mortality [1].

Recent epidemiological studies estimate that nearly one billion adults between 30 and 69 years of age are affected by OSA globally, with approximately 425 million experiencing moderate-to-severe disease that requires clinical management [2]. The impact of OSA extends far beyond breathing disturbances during sleep. Individuals with OSA frequently experience fragmented sleep characterized by reduced sleep efficiency, prolonged sleep latency, frequent nocturnal awakenings, decreased slow-wave sleep, and alterations in rapid eye movement (REM) sleep [3]. Such disturbances compromise the restorative functions of sleep and often result in persistent fatigue, impaired attention and memory, reduced physical performance, emotional instability, and poorer health-related quality of life [4].

Continuous positive airway pressure (CPAP) therapy remains the first-line treatment for patients with moderate-to-severe OSA. By maintaining upper airway patency throughout the night, CPAP effectively reduces the apnea–hypopnea index (AHI), improves nocturnal oxygenation, and relieves excessive daytime sleepiness. Despite its proven clinical effectiveness, long-term adherence to CPAP remains a major challenge. Many individuals discontinue or inconsistently use the device because of discomfort, mask-related problems, claustrophobia, dryness of the airway, or inconvenience during sleep. Consequently, there is increasing interest in identifying complementary and non-pharmacological treatment strategies that can improve sleep quality and overall health while enhancing long-term patient adherence [5].

Among these strategies, regular physical exercise has emerged as an important component of OSA management. Exercise is increasingly recognized not only for its role in weight management but also for its independent effects on reducing the severity of sleep apnea. Research has demonstrated that structured exercise programs can improve cardiorespiratory fitness, enhance upper airway muscle function, reduce systemic inflammation, improve autonomic nervous system regulation, and decrease the frequency of apnea and hypopnea events, even in the absence of substantial weight loss [6]. These findings highlight exercise as a promising adjunctive therapy for improving both respiratory function and overall health in individuals with OSA.

Exercise is also well known for its positive influence on sleep. Both acute and long-term exercise interventions have been shown to improve sleep onset, increase total sleep duration, enhance sleep efficiency, and promote deeper stages of restorative sleep. Several physiological mechanisms have been proposed to explain these effects, including regulation of body temperature, synchronization of circadian rhythms, increased secretion of melatonin, modulation of cortisol levels, improved autonomic balance, and reductions in anxiety and depressive symptoms [7]. For individuals with OSA, who often experience chronic sleep fragmentation, these exercise-induced adaptations may help restore healthier sleep patterns and improve daytime functioning [8].

Functional circuit training (FCT) has recently gained attention as an innovative and practical exercise approach that combines aerobic exercise, resistance training, balance activities, flexibility exercises, and core stabilization within a single structured training session [9]. Unlike traditional exercise programs that focus on one fitness component at a time, FCT incorporates multi-joint, functional movements that closely resemble everyday activities. This integrated training approach improves muscular strength, endurance, cardiovascular fitness, coordination, balance, and movement efficiency simultaneously while maintaining high participant engagement through varied and time-efficient exercise sessions [10].

Most randomized controlled trials evaluating exercise interventions in OSA have focused on aerobic exercise, resistance training, or combined exercise programs. Although these studies have reported improvements in sleep quality, apnea severity, daytime sleepiness, cardiorespiratory fitness, and quality of life, there is limited evidence regarding the effectiveness of functional circuit training as a distinct exercise modality. Moreover, few studies have comprehensively examined its impact on both subjective and objective measures of sleep in individuals with OSA [11]. This lack of evidence highlights an important gap in the current literature and emphasizes the need for well-designed randomized controlled trials to evaluate the effectiveness of functional circuit training in this population.

Considering the increasing global burden of OSA, the limitations associated with long-term CPAP adherence, and the growing evidence supporting exercise as a therapeutic intervention, investigating the effects of functional circuit training on exercise-induced sleep improvement is both timely and clinically relevant. The findings of such research may provide valuable evidence for developing effective, non-invasive and accessible exercise-based rehabilitation strategies that can complement conventional treatment, improve sleep quality, enhance physical function, and ultimately contribute to better long-term health outcomes and quality of life in individuals living with obstructive sleep apnea.

MATERIALS AND METHODS

This randomized controlled trial was conducted on 60 adults aged 30–60 years diagnosed with mild to moderate Obstructive Sleep Apnea (OSA) at Outpatient Department (OPD) of ACS Medical College and Hospital, Chennai. The study was carried out in the Department of Physiotherapy in collaboration with the affiliated sleep clinic. Prior to participation, all eligible subjects were provided with a participant information sheet and written informed consent was obtained. The purpose of the study, intervention procedures, potential benefits, and possible risks were explained to all participants before enrolment in accordance with the ethical principles of the Declaration of Helsinki. Ethical approval was obtained from the Institutional Ethics Committee before commencement of the study.

Inclusion and Exclusion Criteria
Adults aged 30–60 years, both males and females, diagnosed with mild to moderate Obstructive Sleep Apnea (Apnea–Hypopnea Index [AHI] 5–30 events/hour) confirmed by overnight polysomnography, medically stable, cleared by their physician to participate in exercise, and willing to provide informed consent were included in the study.
Individuals with severe obstructive sleep apnea (AHI >30 events/hour), unstable cardiovascular disease, uncontrolled hypertension, neurological disorders, musculoskeletal conditions limiting exercise participation, recent surgery, pregnancy, cognitive impairment, psychiatric illness, or any contraindication to moderate-intensity exercise were excluded from the study.

Study Procedure
A total of eligible individuals attending the sleep clinic were screened for participation. Sixty participants who fulfilled the inclusion criteria were recruited into the study. Demographic information including age, gender, body mass index (BMI), and Apnea–Hypopnea Index (AHI) was recorded before the intervention.
Baseline assessments were performed using the Exercise-Induced Sleep Improvement Scale for Obstructive Sleep Apnea (EISIS-OSA) and the Epworth Sleepiness Scale (ESS). Participants were then randomly allocated into two equal groups (n = 30 each) using a simple randomization technique with concealed allocation.
Participants in Group A received Functional Circuit Training, while those in Group B received Conventional Physiotherapy. Both groups underwent supervised intervention sessions three times per week for 8 weeks, with each session lasting approximately 45–60 minutes. At the end of the intervention period, all outcome measures were reassessed using the same assessment tools to determine the effectiveness of the interventions.

Intervention
Group A – Functional Circuit Training (Experimental Group)
Participants allocated to Group A underwent a supervised Functional Circuit Training (FCT) program for 8 weeks, with three sessions per week, each lasting 45–60 minutes. Each session consisted of a warm-up, functional circuit training, and cool-down with stretching exercises. The training program was designed according to the principles of overload, progression, recovery, and individualization. Exercise intensity was maintained at moderate intensity (Borg RPE 12–15) and monitored at the end of each session using the Borg 6–20 Rating of Perceived Exertion Scale. Participants performed each exercise station for 60 seconds followed by 30 seconds of rest, with the number of stations progressively increased throughout the intervention period. The Functional Circuit Training protocol is presented in Tables 1 and 2.

Table 1. Functional Circuit Training Exercise Categories

Exercise Category	Examples of Exercises
Upper-body push	Resistance band chest press, wall push-up, knee push-up, dumbbell chest press, triceps dip, standard push-up
Upper-body pull	Renegade row, seated resistance band row, standing resistance band row, bent-over row, upright row
Knee-dominant	Resistance band squat walk, step-up, Bosu squat, forward lunge, Bulgarian split squat
Hip-dominant	Resistance band deadlift, banded sumo deadlift, glute bridge, single-leg Romanian deadlift, standing hip extension, Bosu hamstring bridge
Core stabilization	Side crunch, side plank with crunch, mountain climber, Bosu plank, medicine ball woodchopper, stability ball plank
Medicine ball	Rotational throw, overhead throw, forward throw, scoop toss
Aerobic conditioning	Basic step-up, jumping jacks, high knees, step jump, resisted running

Table 2. Functional Circuit Training Progression

Parameter	Weeks 1–2	Weeks 3–4	Weeks 5–8
Number of stations	10	12	14
Work duration	60 s	60 s	60 s
Rest duration	30 s	30 s	30 s
Frequency	3 sessions/week	3 sessions/week	3 sessions/week
Session duration	45–60 min	45–60 min	45–60 min

Exercise intensity	Borg RPE 12–15	Borg RPE 12–15	Borg RPE 12–15
Progression	Gradual increase in the number of stations while individualizing exercise selection according to participant tolerance.		

Group B – Conventional Physiotherapy (Control Group)
Participants allocated to Group B received conventional physiotherapy for 8 weeks, with three supervised sessions per week, each lasting 45–60 minutes. The intervention focused on improving aerobic capacity, breathing efficiency, flexibility, and healthy lifestyle habits. Walking intensity was maintained at moderate intensity (Borg RPE 11–13) and progressed according to the participant's tolerance. The Conventional Physiotherapy protocol is summarized in Table 3.

Table 3. Conventional Physiotherapy Protocol

Parameter	Description
Warm-up	5 minutes of active range of motion and mobility exercises
Aerobic exercise	Brisk walking (20–25 minutes) at moderate intensity (Borg RPE 11–13)
Breathing exercises	Diaphragmatic breathing, pursed-lip breathing, and thoracic expansion exercises
Stretching	Static stretching of major upper- and lower-limb muscle groups
Lifestyle modification	Education on sleep hygiene, weight management, and regular physical activity
Cool-down	5 minutes of slow walking and stretching
Frequency	3 sessions per week
Session duration	45–60 minutes
Total duration	8 weeks

Outcome Measures
Primary Outcome Measure
The Exercise-Induced Sleep Improvement Scale for Obstructive Sleep Apnea (EISIS-OSA) was used to assess exercise-related improvements in sleep quality among individuals with obstructive sleep apnea. The questionnaire evaluates perceived changes in sleep quality, nocturnal symptoms, sleep duration, and restorative sleep following exercise intervention. Assessments were performed at baseline and after the 8-week intervention (12).

Secondary Outcome Measure
The Epworth Sleepiness Scale (ESS) was used to assess excessive daytime sleepiness. The ESS consists of eight items that measure the likelihood of falling asleep during common daily situations, with scores ranging from 0 to 24. Higher scores indicate greater daytime sleepiness. The ESS was administered before and after the intervention (13).

Statistical Analysis
The collected data were analyzed using **SPSS Statistics Version 29.0**. Descriptive statistics were used to summarize demographic characteristics and outcome variables. Continuous data were expressed as **mean ± standard deviation**, while categorical data were presented as frequencies and percentages. Data normality was assessed using the **Shapiro–Wilk test**. Within-group comparisons were performed using the **Paired t-test** for normally distributed data and Between-group comparisons were analyzed using the **Independent t-test**. Statistical significance was established at **$p < 0.05$**.

RESULT
Within-group comparisons of Exercise-Induced Sleep Improvement Scale for Obstructive Sleep Apnea (EISIS-OSA) and Epworth Sleepiness Scale (ESS) scores were performed using the Paired t-test, while between-group comparisons of post-test scores were analyzed using the Independent t-test. Statistical significance was established at $p < 0.05$. The obtained p-values demonstrated statistically highly significant improvements in both outcome measures following the interventions.

Table 1: Within-Group Comparison of Pre-test and Post-test EISIS-OSA in Group A and Group B Using Paired t-test

GROUP		MEAN (SD)	t VALUE	Df	standard error of difference	p-value

GROUP A	PRE TEST	41.830 (3.927)	26.792	29	1.155	< 0.0001
	POST TEST	72.780 (3.901)	26.792			
Group B	PRE TEST	43.123 (3.861)	16.126	29	0.905	< 0.0001
	POST TEST	57.717 (3.672)	16.126			

Graph 1

Table 1 represents the within-group comparison of pre-test and post-test Exercise-Induced Sleep Improvement Scale for Obstructive Sleep Apnea (EISIS-OSA) scores for Group A and Group B using the Paired t-test. The analysis demonstrated a statistically highly significant improvement in EISIS-OSA scores following the intervention in both groups ($p < 0.0001$). These findings indicate that both Functional Circuit Training and Conventional Physiotherapy were effective in improving exercise-induced sleep outcomes among individuals with obstructive sleep apnea. However, Group A demonstrated a greater increase in EISIS-OSA scores compared to Group B, indicating that Functional Circuit Training was more effective in enhancing sleep quality and exercise-induced sleep improvement

Table 2: Between-Group Comparison of Post-test EISIS-OSA Between Group A and Group B Using Independent t-test

GROUP		MEAN (SD)	t VALUE	Df	Standard error of difference	p-value
GROUP A	POST TEST	72.780 (3.901)	15.40	58	0.978	<0.0011
GROUP B	POST TEST	57.717 (3.672)	15.40			

Graph

Table 2 represents the between-group comparison of post-test Exercise-Induced Sleep Improvement Scale for Obstructive Sleep Apnea (EISIS-OSA) scores between Group A and Group B using the Independent t-test. The analysis revealed a statistically highly significant difference between the groups ($p < 0.0011$). The significantly higher post-test EISIS-OSA score observed in Group A (72.78 ± 3.90) compared to Group B (57.72 ± 3.67) indicates greater improvement in exercise-induced sleep quality following Functional Circuit Training. These findings suggest that Functional Circuit Training was more effective than Conventional Physiotherapy in improving sleep-related outcomes among individuals with obstructive sleep apnea.

Table 3: Within-Group Comparison of Pre-test and Post-test ESS Scale in Group A and Group B Using Paired t-test

GROUP		MEAN (SD)	t VALUE		Df	p-value
GROUP A	PRE TEST	15.337 (1.964)	0.560	12.586	29	< 0.0001
	POST TEST	8.283 (2.536)	0.560			
Group B	PRE TEST	15.650 (1.603)	10.005	0.511	29	< 0.0001
	POST TEST	10.540 (2.162)	10.005			

Graph 3

Table 3 presents the within-group comparison of pre-test and post-test Epworth Sleepiness Scale (ESS) scores for Group A and Group B using the Paired t-test. The analysis demonstrated a statistically highly significant reduction in ESS scores following the intervention in both groups ($p < 0.0001$). Since lower ESS scores indicate reduced excessive daytime sleepiness, the findings suggest that both interventions were effective in reducing daytime sleepiness among individuals with obstructive sleep apnea. Group A exhibited a greater reduction in ESS scores than Group B, indicating the superior effectiveness of Functional Circuit Training in improving daytime alertness and reducing excessive daytime somnolence.

Table 4: Between-Group Comparison of Post-test ESS Scale Between Group A and Group B Using Independent t-test

GROUP		MEAN (SD)	t VALUE	Df	Standard error of difference	p-value
GROUP A	POST TEST	8.283 (2.536)	3.708	58	0.608	< 0.0001
GROUP B	POST TEST	10.540 (2.162)	3.708			

Graph 4

Table 4 represents the between-group comparison of post-test Epworth Sleepiness Scale (ESS) scores between Group A and Group B using the Independent t-test. The analysis revealed a statistically highly significant difference between the groups ($p < 0.0001$). The significantly lower post-test ESS score observed in Group A (8.28 ± 2.54) compared to Group B (10.54 ± 2.16) indicates greater improvement in excessive daytime sleepiness following Functional Circuit Training. These findings suggest that Functional Circuit Training was more effective than Conventional Physiotherapy in reducing daytime sleepiness among individuals with obstructive sleep apnea.

Although both Functional Circuit Training and Conventional Physiotherapy produced significant improvements in sleep quality and daytime sleepiness, participants who underwent Functional Circuit Training (Group A) exhibited significantly greater improvements than those receiving Conventional Physiotherapy (Group B). These findings indicate that Functional Circuit Training is a more effective intervention for enhancing exercise-induced sleep quality and reducing excessive daytime sleepiness in individuals with obstructive sleep apnea.

DISCUSSION

The present study demonstrated that both Functional Circuit Training (FCT) and conventional physiotherapy improved sleep-related outcomes and daytime sleepiness in individuals with mild to moderate obstructive sleep apnea (OSA). However, the greater improvement observed in the FCT group suggests that a progressive, multicomponent exercise program may be more effective than conventional physiotherapy.

These findings are supported by **Lin et al.**, who reported through a systematic review and meta-analysis that exercise significantly improved Epworth Sleepiness Scale (ESS), cardiorespiratory fitness, and OSA severity. Their subgroup analysis also suggested that combining **aerobic and resistance training** may provide greater benefits than aerobic exercise alone. This supports the present FCT protocol, which combined aerobic conditioning with resistance, functional, core, and medicine-ball exercises (14).Similarly, **Peng et al.** found that exercise significantly improved ESS, sleep quality, and cardiorespiratory fitness, with combined aerobic and resistance exercise producing greater reductions in OSA severity than aerobic exercise alone. The superior response observed with FCT in the present study may therefore be related to its combination of different exercise modalities rather than a single form of exercise (15). **Kline et al.**, who demonstrated that a structured program combining aerobic and resistance training improved OSA severity and sleep quality compared with stretching. Their findings suggested that exercise-related benefits may occur independently of weight reduction, indicating that improvements in physical fitness may contribute to better OSA-related outcomes (16). Furthermore, **Bughin et al.** reported that an individualized exercise program improved selected markers of OSA and daytime sleepiness. This is relevant to the present study because exercise selection within the FCT program was individualized according to participants' functional capacity. Such individualization may have enabled participants to exercise at an appropriate intensity while progressively increasing their training load (17).

The greater effectiveness of FCT may therefore be attributed to its **multicomponent structure, progressive overload, moderate exercise intensity, and individualized exercise selection**. The combination of aerobic and resistance exercises may improve cardiorespiratory fitness, muscular strength, functional capacity, and overall physiological regulation, which may subsequently contribute to improved sleep and reduced daytime sleepiness (18). The circuit format may have further contributed to the effectiveness of the intervention. Repeated bouts of moderate-intensity exercise with short recovery periods created a sustained physiological demand during each session (19). The progressive increase in exercise stations throughout the program provided a gradual increase in training volume and allowed participants to adapt to increasing exercise demands. This progression was consistent with the principles of overload and individualization and may have promoted greater physiological adaptation than a relatively consistent conventional exercise program (20,21).

Exercise may influence OSA through several physiological pathways. Regular physical activity can improve cardiorespiratory fitness, metabolic health, body composition, and autonomic regulation. These adaptations may contribute to improved sleep regulation and reduced fatigue. Increased physical fitness may also reduce the physiological effort required during daily activities, potentially improving daytime alertness (22). Although the present study did not directly evaluate mechanisms such as sleep architecture or autonomic function, these physiological adaptations may partly explain the observed improvements.

However, Functional Circuit Training provided a more varied and progressive exercise stimulus. Individualization allowed exercises to be modified according to each participant's functional capacity while maintaining the intended movement pattern. This approach may have improved exercise tolerance and allowed participants to progressively achieve an appropriate training stimulus without excessive fatigue. The variety of exercises may also have increased participant engagement compared with repetitive aerobic exercise (23,24).

Future research should include larger sample sizes, longer follow-up periods, and objective sleep parameters such as the Apnea–Hypopnea Index, oxygen saturation, sleep architecture and polysomnographic measures. Such studies would help determine whether the improvements associated with Functional Circuit Training are accompanied by measurable changes in OSA severity. Overall, the present findings suggest that both interventions were beneficial; however, the greater improvement following Functional Circuit Training supports the use of a **progressive, individualized, multicomponent exercise approach** for improving sleep-related outcomes and reducing daytime sleepiness in individuals with mild to moderate OSA.

CONCLUSION

The study concludes that Functional Circuit Training provides a promising exercise-based approach for individuals with mild to moderate Obstructive Sleep Apnea. The findings indicate meaningful benefits in sleep-related functioning and daytime alertness following the intervention. Compared with conventional physiotherapy, Functional Circuit Training demonstrated a stronger overall therapeutic response, supporting its potential role within physiotherapy management of OSA. Its supervised and progressive format may also make it suitable for incorporation into rehabilitation programs for medically stable individuals. Therefore, Functional Circuit Training may be recommended as an adjunctive strategy alongside appropriate medical management, particularly for individuals seeking a structured exercise approach to address sleep-related symptoms and daytime consequences of OSA.

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Conflict of Interest

The authors declare that they have no conflicts of interest related to this study or its publication.

Author Contributions

Jayabharathi.R: Conceptualization, Methodology, Investigation, Data Curation, Formal Analysis, Writing – Original Draft Preparation, and Writing – Review & Editing.
Ramachandran.S: Methodology, Investigation, Supervision, and Writing – Review & Editing.
Senthilkumar.N, Mohankumar.G,: Data Curation, Formal Analysis, and Writing – Review & Editing.
All authors read and approved the final version of the manuscript and agreed to be accountable for all aspects of the work.

Institutional Review Board Statement

The study was conducted in accordance with the ethical principles of the Declaration of Helsinki and was approved by the Institutional Review Board/Ethics Committee of ([Dr.M.G.R Educational and Research Institute],[26/PHYSIO/IRB/2025-2026], [24.4.2026]).

Informed Consent Statement

Written informed consent was obtained from all participants before enrollment in the study. Participants were informed about the purpose and procedures of the study, their voluntary participation, and their right to withdraw from the study at any time without penalty.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request, subject to applicable ethical and confidentiality restrictions.

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