

Systematic Review

The Effects of High-Intensity Interval Training (HIIT) on Sleep Quality in Obese Patients: A Systematic Review and Meta-Analysis of Randomized Controlled Trials

Kittibhum Kawinchotpaisan ^{1,*} , Charnsiri Segsarnviriya ²  and Phawit Norchai ¹¹ Department of Anti-Aging and Regenerative Medicine, College of Integrative Medicine, Dhurakij Pundit University, Bangkok 10210, Thailand² Department of Otorhinolaryngology Head and Neck Surgery, Samitivej Thonburi Hospital, Bangkok 10600, Thailand

* Correspondence: kawinchotpaisan@gmail.com

Abstract: Background: Obesity adversely affects sleep quality through mechanisms such as obstructive sleep apnea (OSA) and hormonal imbalances that disrupt the circadian rhythm. High-intensity interval training (HIIT) helps reduce fat, inflammation, and stress, which in turn leads to improvements in deep and restful sleep. Method: This study aimed to examine the effects of HIIT on sleep quality in obese patients through a systematic review and meta-analysis of studies published in five databases: PubMed, Scopus, Ovid, The Cochrane Library, and Google Scholar. Randomized controlled trials (RCTs) comparing obese patients undergoing HIIT with control groups and assessing sleep quality via subjective measures such as the Pittsburgh Sleep Quality Index (PSQI) and objective assessments were included. Result: Eight eligible studies were identified, with six included in the meta-analysis, comprising a total of 191 participants. The analysis revealed that HIIT significantly improved overall sleep quality, as evidenced by a reduction in PSQI scores (mean difference, -3.51 ; 95% CI $(-4.78, -2.25)$; $p < 0.001$). Significant improvements were also observed in PSQI subscales, including sleep duration (mean difference, -0.42 ; 95% CI $(-0.58, -0.26)$; $p < 0.001$), habitual sleep efficiency (mean difference, -0.32 ; 95% CI $(-0.59, -0.05)$; $p = 0.02$), and daytime dysfunction (mean difference, -0.66 ; 95% CI $(-1.27, -0.05)$; $p = 0.03$). Moreover, HIIT led to a notable reduction in OSA severity, as reflected by lower Apnea–Hypopnea Index (AHI) scores (mean difference, -28.31 , 95% CI $(-34.39, -22.22)$; $p < 0.001$). Conclusion: HIIT significantly improves sleep quality in obese patients and reduces the severity of obstructive sleep apnea. Further long-term studies with improved control of confounding factors are recommended to validate and strengthen these findings.

Keywords: high-intensity interval training (HIIT); obesity; obese; sleep quality

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1. Introduction

Obesity is a major global health crisis, with prevalence rising sharply, particularly among sedentary individuals. Contributing factors include prolonged screen time, excessive calorie intake, and insufficient physical activity [1,2]. According to the World Health Organization (WHO), in 2021, an estimated 1.9 billion people were overweight, with over 650 million classified as obese. This condition increases the risk of noncommunicable diseases (NCDs) such as cardiovascular diseases, type II diabetes, dyslipidemia, and hypertension [3]. Additionally, obesity is linked to mental health disorders, including depression and anxiety, worsening overall health deterioration.

Obesity significantly impairs sleep quality through multiple interconnected physiological and psychological mechanisms. One of the most prominent contributors is obstructive sleep apnea (OSA), which is highly prevalent among individuals with excess body weight. Fat accumulation in the upper airway, particularly around the pharyngeal region and neck, narrows the airway and increases its collapsibility during sleep. This anatomical alteration leads to repeated episodes of partial or complete airway obstruction, resulting in intermittent hypoxia, sympathetic nervous system activation, sleep fragmentation, and excessive daytime sleepiness [4,5].

Additionally, obesity is characterized by a state of chronic low-grade systemic inflammation. Elevated levels of proinflammatory cytokines such as tumor necrosis factor- α (TNF- α) and interleukin-6 (IL-6) have been shown to disrupt hypothalamic regulation of sleep–wake cycles and impair insulin sensitivity, further influencing sleep homeostasis [6,7]. Hormonal dysregulation also plays a critical role. Decreased leptin and elevated ghrelin levels, common in obesity, stimulate appetite and contribute to frequent nocturnal arousals due to hunger or metabolic dysregulation [8].

Circadian rhythm disturbances are common in obesity and often worsened by behavioral patterns such as irregular sleep schedules, late-night eating, and limited light exposure. These factors disrupt melatonin release and raise evening cortisol, leading to delayed sleep onset and poor sleep efficiency [9,10]. Additionally, psychological comorbidities like depression, anxiety, and stress, which are more prevalent in individuals with obesity, are linked to insomnia and poor sleep quality [11]. Together, these factors form a self-reinforcing cycle where obesity impairs sleep, and poor sleep further promotes weight gain and metabolic dysfunction.

High-intensity interval training (HIIT) is a time-efficient exercise strategy involving short bursts of vigorous activity alternated with lower-intensity recovery. It is well regarded for improving cardiovascular health, metabolic regulation, and body composition, particularly in overweight and obese populations [12]. Standard HIIT protocols typically include aerobic or resistance exercises performed at 80 to 95% of maximum heart rate (HR_{max}), followed by recovery at 50 to 70% HR_{max}. Intervals usually last 2 to 4 min and vary by modality, such as cycling, treadmill use, or circuit training [13]. Most programs emphasize integrated movement patterns that recruit multiple muscle groups, thereby promoting greater functional capacity and overall energy expenditure.

Beyond its metabolic benefits, HIIT may positively influence sleep physiology in obesity by addressing underlying pathophysiological mechanisms. It reduces total and upper airway fat, alleviating OSA and improving sleep continuity [14,15]. HIIT also modulates systemic inflammation by decreasing TNF- α and IL-6 and increasing IL-10, contributing to sleep homeostasis [16]. Improvements in hormonal regulation such as increased leptin sensitivity and decreased ghrelin and cortisol may reduce nocturnal arousals and support deeper, more restorative sleep [17].

HIIT has been shown to promote circadian rhythm alignment by enhancing morning light sensitivity and regulating melatonin secretion, which improves sleep onset and efficiency [18]. Circadian disruptions, common in obesity, are linked to sleep disorders and metabolic issues. By influencing body temperature rhythms and clock gene expression, HIIT may support better synchronization of the sleep–wake cycle [19]. Additionally, its psychological benefits, including increased endorphins and serotonin, and reduced anxiety and depression, further enhance sleep quality [20]. These effects support HIIT as a promising nonpharmacological strategy to improve sleep in individuals with obesity.

Recent studies, such as Jiménez-García et al.'s (2021) [21], highlight HIIT's positive impact on sleep quality, demonstrating improved sleep continuity, deeper sleep phases, and fewer nocturnal awakenings compared to moderate-intensity exercise. While meta-

analyses like Min et al.'s (2021) [22] have confirmed HIIT's effectiveness in enhancing sleep quality, none has specifically examined obese patients. Given new studies emerging post-2021, an updated systematic review and meta-analysis are needed to strengthen clinical evidence and optimize evidence-based recommendations for improving sleep quality in obesity-related sleep disturbances.

Compared to moderate-intensity continuous training (MICT), which typically involves steady-state aerobic activity such as walking or cycling at 60–70% of HRmax for 30–60 min, HIIT offers greater time efficiency and yields more pronounced improvements in cardiorespiratory fitness and metabolic health in both general and obese populations. While MICT is often seen as easier to maintain and joint-friendly, emerging evidence suggests that structured, supervised HIIT programs may lead to higher engagement and comparable or superior adherence among obese individuals, particularly when adapted to individual fitness levels, comorbidities, and motivational barriers [23].

In this context, HIIT was selected as the focus of this review due to both its physiological benefits and practical feasibility as a high-impact, time-efficient intervention. Its suitability is especially relevant for individuals with obesity who commonly face limitations in time, physical tolerance, and mental readiness. However, optimal implementation strategies across diverse age groups and comorbidity profiles remain unclear, and comparative evidence between HIIT and other modalities, like MICT, on sleep outcomes in this population is still limited.

This study aims to investigate the effects of HIIT on sleep quality in obese patients using both subjective and objective measures.

2. Materials and Methods

2.1. Protocol and Registration

The research methodology involves conducting a systematic review and meta-analysis in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [24]. The study protocol was registered in PROSPERO under the registration number CRD42024611322.

2.2. Search Strategy

We conducted a comprehensive literature search according to PRISMA guidelines. Studies published before October 2024 were searched by two reviewers (K.K. and C.S.) in PubMed, Scopus, Ovid, The Cochrane Library, and Google Scholar using the keywords, MeSH terms, and phrases of the combinations of the following: "HIIT" OR "high intensity interval training" OR "high intensity interval exercise" OR "high intensity intermittent training" OR "high-intensity training" AND "Sleep Quality" OR "Sleep" AND "Obesity" OR "Obese" OR "Overweight".

2.3. Eligibility Criteria and Study Selection

The study included only randomized controlled trials (RCTs) published in English that met the following eligibility criteria:

1. Population/participants: Obese patients aged 18–75 years with a body mass index (BMI) ≥ 30 kg/m², without restrictions on comorbidities.
2. Intervention: HIIT with no restrictions on type, frequency, intensity, or duration of training.
3. Comparison/control group: Participants who did not engage in high-intensity interval training. They may have performed stretching exercises or received general recommendations.

4. Outcomes: Sleep quality was assessed through both subjective and objective methods. Subjective assessments included tools such as the Pittsburgh Sleep Quality Index (PSQI) [25] and Epworth Sleepiness Scale (ESS) [26]. Objective assessments involved the use of sleep monitoring devices, such as polysomnography (PSG) [27].

2.4. Data Extraction

Two independent reviewers (K.K. and C.S.) systematically screened titles and abstracts to identify eligible studies. Full-text articles were retrieved for in-depth evaluation. Data extraction encompassed study metadata (title, principal investigator, publication year, and country) and key characteristics (sample size, mean age, BMI, and sleep-related outcomes). HIIT protocol parameters (type, volume, duration, and frequency) were meticulously documented for accurate inter-study comparisons.

Outcome assessments included subjective measures (PSQI and ESS) and objective evaluations (PSG). For studies with missing data (e.g., means and standard deviations), corresponding authors were contacted to obtain additional information, ensuring data completeness for meta-analysis.

2.5. Quality Assessment

Two reviewers (K.K. and C.S.) independently assessed the methodological quality of the included studies using the Cochrane risk-of-bias tool for randomized trials (RoB 2), following the guidelines outlined in version 6.5 of the Cochrane Handbook for Systematic Reviews of Interventions [28]. The evaluation focused on five key domains: bias arising from the randomization process, bias due to deviations from intended interventions, bias resulting from missing outcome data, bias in the measurement of outcomes, and bias in the selection of reported results. Each domain was categorized as having a “low risk of bias”, “some concerns”, or a “high risk of bias”.

2.6. Data Analysis

The pooled effects of the included studies, comprising continuous data, were analyzed using mean differences (MDs) with a 95% confidence interval (CI) and p -value to determine statistical significance, set at $p < 0.05$. A random-effects model, calculated using the DerSimonian and Laird method, was applied to account for variability among studies. Data entry and analysis were performed using Review Manager (REVMAN) version 5.4.1, and the results were presented visually through Forest plots.

Statistical heterogeneity was assessed using the I^2 statistic, with significance defined at $p < 0.1$. The degree of heterogeneity was categorized into three levels: low ($I^2 < 25\%$), moderate ($I^2 = 25\text{--}75\%$), and high ($I^2 > 75\%$). If sufficient studies were available, subgroup analyses were conducted to explore potential sources of heterogeneity, such as variations in the type or duration of high-intensity interval training (HIIT). Publication bias was evaluated through visual inspection of Funnel plots.

3. Results

3.1. Search Results

A search across five databases, namely PubMed, Scopus, Ovid, the Cochrane Library, and Google Scholar, yielded 1987 articles on HIIT, sleep quality, and obesity. These included 41 articles from PubMed, 907 from Scopus, 10 from Ovid, 62 from the Cochrane Library, and 967 from Google Scholar, providing a wide range of research on physiological mechanisms, health impacts, and outcome evaluations. After an initial screening, numerous duplicate articles were identified and removed due to overlapping indexing across multiple databases. Articles unrelated to the research focus, such as those not involving HIIT or conducted

on non-obese populations, as well as non-English studies, were also excluded, leaving 60 articles for further evaluation.

The remaining articles were assessed for quality and relevance. Exclusions were made for studies with inaccessible full-text versions; those lacking appropriate designs, such as RCTs; and those that did not include sleep quality as a key outcome. Additionally, studies on populations outside the target group, such as children, animal models, or individuals with a BMI below the required threshold, were removed. After this selection process, eight articles were finalized for inclusion, with six meeting the criteria for meta-analysis (Figure 1).

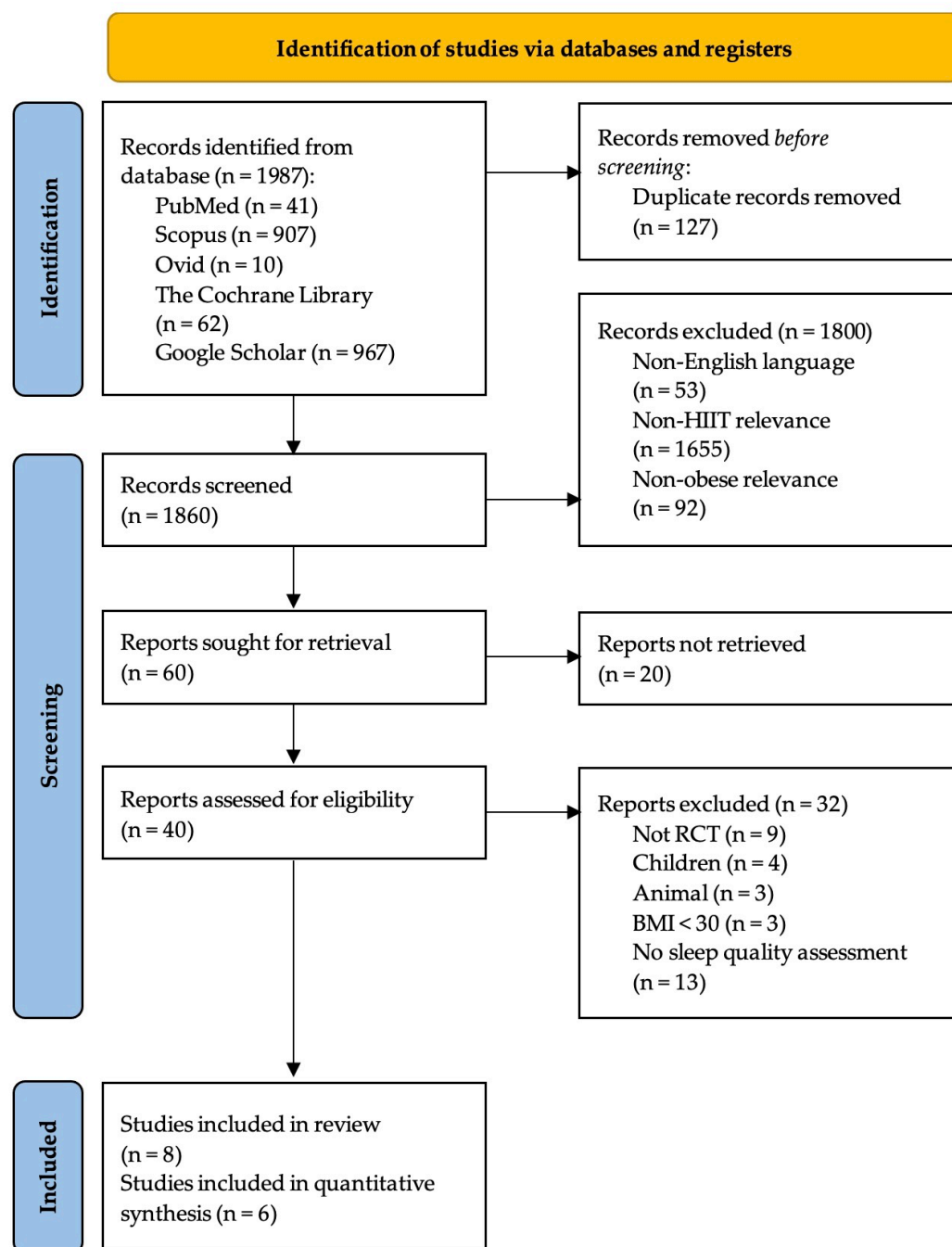


Figure 1. PRISMA flow diagram of literature search and study selection.

3.2. Study Characteristics

The eight included studies, conducted as RCTs between 2016 and 2024, took place in countries such as Norway, Iran, Chile, Spain, South Africa, and Brazil. Participants, primarily middle-aged to older adults aged 28 to over 60 years, were selected based on criteria such as obesity with sleep disorders, OSA, and poor sleep quality. Some studies focused on populations experiencing fatigue-related issues, including chronic tiredness and reduced productivity (Table 1).

Sleep quality was the primary outcome, assessed through various methods. Six studies used PSQI to report total scores, while three of these studies provided detailed data on its seven subscales. ESS assessed daytime sleepiness in two studies, and four studies used PSG to evaluate the Apnea–Hypopnea Index (AHI) for respiratory disturbances during sleep (Table 1).

Table 1. Characteristics of included studies.

Author, Year	Main Characteristic of Participants	Sample Size	Sleep Outcomes Measurement		Outcomes
			Subjective	Objective	
Karlsen et al., 2016 [29]	Obese patients with moderate-to-severe OSA - Age: 51.9 years (mean) - BMI: 37.6 kg/m² - AHI: 41.5 events/hour	HIIT = 13 Control = 15 Total = 28	ESS	AHI ODI Oxygen saturation Self-reported sleep patterns	HIIT vs. control (post-intervention comparison) - AHI NS - ESS improved ($p < 0.05$) - ODI NS - Oxygen saturation NS
Irandoost and Taheri, 2019 [30]	Obese middle-aged women with sleep disorders - Age: 47.1 years (mean) - BMI: 33.4 kg/m² - Body fat: 35.8%	HIIT = 15 Control = 14 Total = 29	PSQI		HIIT vs. Control (post-intervention comparison) PSQI improved ($p = 0.001$)
Delgado-Floody et al., 2020 [31]	Morbidly obese patients - Age: 38.0–40.7 years (mean) - BMI: 40.1–46.1 kg/m² - Poor and good sleep quality	GSQ = 15 PSQ = 14 Total = 29	PSQI		Pre-post comparisons within-group - PSQ improved ($p = 0.004$) - GSQ NS
Jiménez-García et al., 2021 [21]	Older adults with sleep disturbances and fatigue - Age: Over 65 years - BMI: 30.59 kg/m²	HIIT = 26 MIIT = 24 Control = 23 Total = 73	PSQI		HIIT vs. Control (post-intervention comparison) - Subjective sleep quality improved ($p < 0.05$) - Sleep latency improved ($p < 0.05$) - Sleep duration NS - Habitual sleep efficiency NS - Sleep disturbances improved ($p = 0.01$) - Use of sleep medication NS - Daytime dysfunction NS - Total PSQI improved ($p = 0.006$)
Smit, 2021 [32]	Overweight and healthy-weight women - Age: 19–40 years - Overweight group BMI: 33.0 kg/m² - Healthy-weight groups BMI: 22.1 kg/m²	O-HIIT = 5 O-nonHIIT = 8 H-HIIT = 8 H-nonHIIT = 6 Total = 27	PSQI		O-HIIT vs. O-nonHIIT (post-intervention comparison) - Subjective Sleep Quality improved ($p < 0.05$) - Sleep latency NS - Sleep duration NS - Habitual sleep efficiency NS - Sleep disturbances NS - Use of sleep medication NS - Daytime dysfunction NS - Total PSQI NS

Table 1. Cont.

Author, Year	Main Characteristic of Participants	Sample Size	Sleep Outcomes Measurement		Outcomes
			Subjective	Objective	
Lins-Filho et al., 2023 [33]	Adults with moderate-to-severe OSA • Age: 52.2 years (mean) • BMI: 34.2 kg/m² • AHI: 42.0 events/hour	HIIT = 17 Control = 19 Total = 36	PSQI	PSG Pulse oximetry AHI	HIIT vs. control (post-intervention comparison) • PSQI improved (<i>p</i> = 0.015) • AHI improved (<i>p</i> = 0.005) • Minimal SaO₂ improved (<i>p</i> = 0.04) • Time with SaO₂ < 90% NS • Arousals NS • Total sleep time improved (<i>p</i> = 0.049) • Sleep efficiency improved (<i>p</i> = 0.026) • Sleep onset latency improved (<i>p</i> = 0.025) • REM NS • N1 NS • N2 NS • N3 improved (<i>p</i> = 0.001)
Lins-Filho et al., 2024 [34]	Adults with moderate-to-severe OSA • Age: 52.2 years (mean) • BMI: 34.2 kg/m² • AHI: 42.0 events/hour	HIIT = 17 Control = 19 Total = 36	PSQI ESS	AHI	HIIT vs. control (post-intervention comparison) • Subjective sleep quality improved (<i>p</i> = 0.001) • Sleep latency improved (<i>p</i> = 0.029) • Sleep duration NS • Habitual sleep efficiency NS • Sleep disturbances NS • Use of sleep medication NS • Daytime dysfunction improved (<i>p</i> = 0.012) • Total PSQI improved (<i>p</i> = 0.022) • ESS improved (<i>p</i> = 0.023) • AHI improved (<i>p</i> = 0.005)
Lins-Filho et al., 2024 [35]	Adults with moderate-to-severe OSA • Age: 51.2 years (mean) • BMI: 33.9 kg/m² • AHI: 55 events/hour	HIIT = 13 Control = 13 Total = 26		AHI	HIIT vs. control (post-intervention comparison) • AHI improved (<i>p</i> < 0.01)

(AHI: Apnea–Hypopnea Index; ESS, Epworth Sleepiness Scale; PSQI, Pittsburgh Sleep Quality Index; ODI, Oxygen Desaturation Index; PSG, polysomnography; HIIT, high-intensity interval training; MIIT, moderate-intensity interval training; O-HIIT, overweight high-intensity interval training; H-HIIT, healthy high-intensity interval training; O-nonHIIT: overweight non-high-intensity interval training; H-nonHIIT, healthy non-high-intensity interval training; GSQ, good sleep quality; PSQ, poor sleep quality; NS, not significant.

HIIT protocols varied across studies. The most common approach involved treadmill running at 90–95% of maximum heart rate during intervals and 50–70% during recovery. These sessions alternated between 4-minute exercise and 3-minute rest intervals, conducted twice weekly over a 12-week period (Table 2).

Table 2. Characteristics of HIIT in included studies.

Author (Year)	HIIT				Frequency (Sessions per Week)	Length (Weeks)
	Type	Intensity	Duration			
Karlsen et al., 2016 [29]	Treadmill walk- ing/running	90–95% HRmax (exercise), 70% HRmax (rest)	~45 min (10 min warm-up at ~70% HRmax, 4 intervals × 4 min at 90–95% HRmax, separated by 3 min at ~70% HRmax)		2	12

Table 2. Cont.

Author (Year)	HIIT				
	Type	Intensity	Duration	Frequency (Sessions per Week)	Length (Weeks)
Irandoost and Taheri, 2019 [30]	35 m sprints (RAST protocol)	High intensity (near maximum effort)	~30 min (RAST protocol: 3 sets × 6 sprints of 35 m with 10 s of rest between sprints, and 4 min rest between sets)	3	1
Delgado-Floody et al., 2020 [31]	Concurrent training (HIIT + RT)	HIIT: 6–9 Borg Scale (perceived exertion) RT: 40–60% 1RM (progressive load)	45 min (HIIT: 60 s cycling at max effort + 60–120 s rest) (RT: 3 sets, 60 s per exercise with 60–120 s rest)	2	20
Jiménez-García et al., 2021 [21]	Suspension training (TRX) focusing on squat exercises	90–95% HRmax (exercise), 50–70% HRmax (rest)	45 min (TRX suspension training: 4 intervals × 4 min at 90–95% HRmax for HIIT group, or 70% HRmax for MIIT group, with recovery in between intervals)	2 (Tuesdays and Thursdays)	12
Smit, 2021 [32]	Home-based, dynamic resistance exercises	Perceived exertion level at ~16–18 (Borg scale)	~20–30 min (home-based dynamic resistance exercises: combinations of 4 exercises, each performed for 30 s, repeated multiple times for ~20–30 min)	6 (Participants allowed flexibility in scheduling sessions, up to twice a day)	14
Lins-Filho et al., 2023 [33]	Treadmill walking/running	90–95% HRmax (exercise), 50–55% HRmax (rest)	~45 min (5 intervals × 4 min of walking/running at 90–95% HRmax, interspersed with 3 min of walking at 50–55% HRmax, plus warm-up and cool-down periods)	3	12
Lins-Filho et al., 2024 [34]	Treadmill walking/running	90–95% HRmax (exercise), 50–55% HRmax (rest)	~45 min (5 intervals × 4 min of walking/running at 90–95% HRmax, interspersed with 3 min of recovery walking at 50–55% HRmax)	3	12
Lins-Filho et al., 2024 [35]	Treadmill walking/running	90–95% HRmax (exercise), 50–55% HRmax (rest)	~45 min (5 intervals × 4 min of walking/running at 90–95% HRmax, interspersed with 3 min of recovery walking at 50–55% HRmax)	3	12

HRmax, maximum heart rate; RAST, Running-Based Anaerobic Sprint Test; RT, resistance training; RM, repetition maximum; TRX, total resistance exercises.

3.3. Quality Assessment of Included Studies

The quality assessment indicated that several studies exhibited high risk of bias or some concerns across multiple bias domains. Bias arising from the randomization process often resulted from a lack of detail regarding the method of sequence generation and the absence of information about allocation concealment. In some cases, differences in baseline characteristics between intervention and control groups, such as BMI, age, or disease severity, introduced uncertainty about group equivalence. Regarding deviations from intended interventions, some studies did not clearly describe the control of confounding variables such as participants' sleep behaviors, dietary habits, or medication use during the intervention period, which may have affected the outcomes. However, other studies implemented well-defined HIIT protocols with adequate monitoring, which helped mitigate this source of bias.

Bias due to missing outcome data was present in studies that failed to report reasons for participant dropout or did not account for the potential influence of missing data on the results. In contrast, studies with complete reporting on participant flow and appropriate data handling demonstrated greater methodological rigor. Measurement bias was frequently associated with reliance on self-reporting tools such as PSQI and ESS, which are inherently subjective and less precise than objective methods like PSG. Finally, selective reporting bias was identified in studies that lacked clear presentation of secondary outcomes or omitted findings that may not have aligned with the study hypothesis. These methodological limitations, as illustrated in Figures 2 and 3, reflect a moderate-to-high level of concern and should be carefully considered when interpreting the pooled findings.

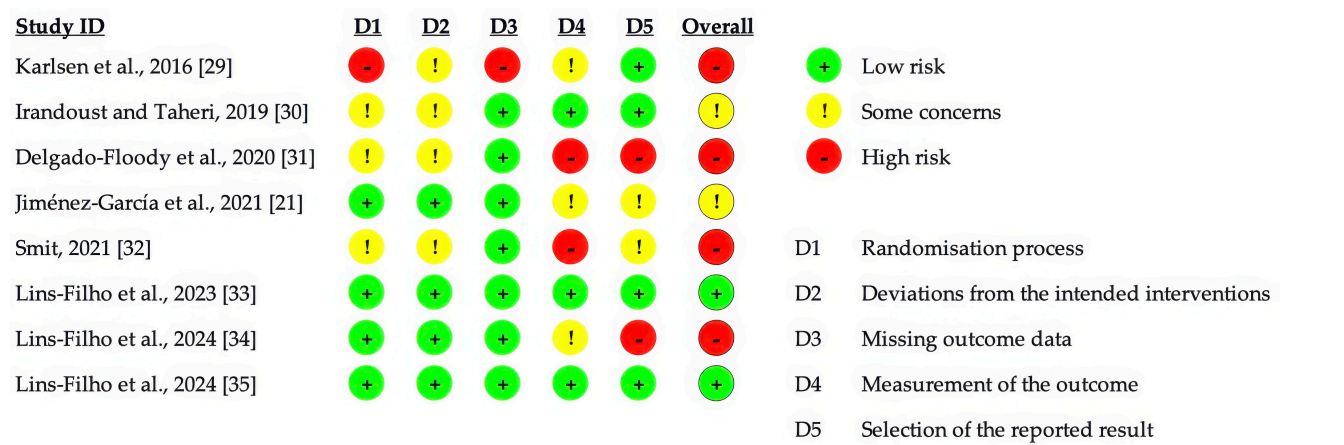


Figure 2. Quality assessment showing risk of bias in each included study.

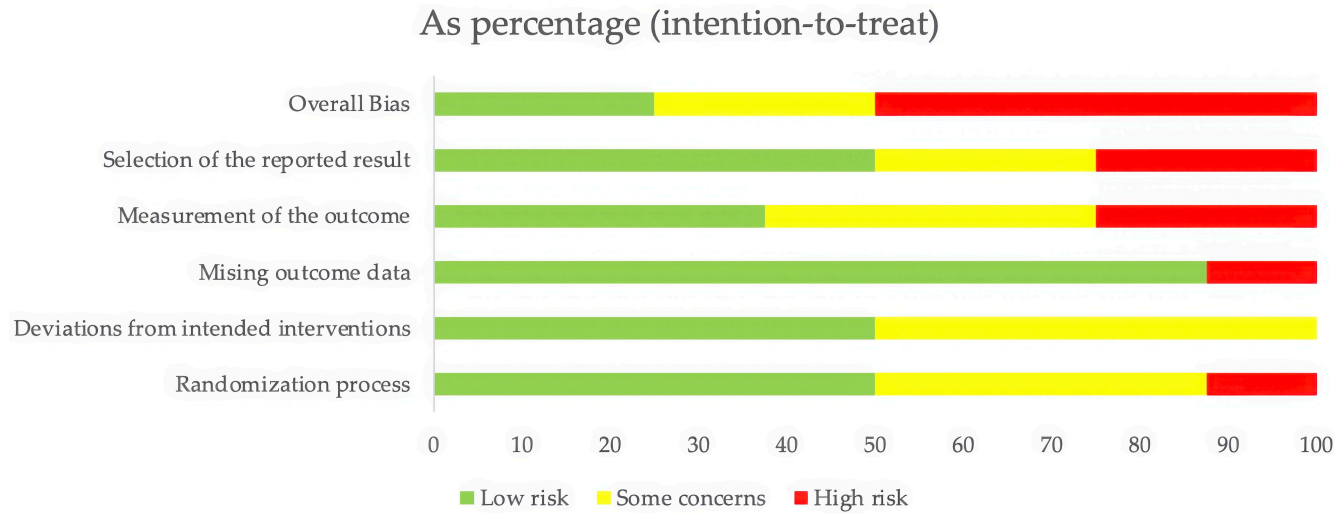


Figure 3. Quality assessment summary showing risk of bias in all included studies.

3.4. Meta-Analysis

Following a thorough selection process, eight studies were identified as suitable for inclusion, with six meeting the standards for meta-analysis to ensure robust findings. Two studies were excluded from the meta-analysis based on methodological considerations. The study by Delgado-Floody et al. (2020) [31] was excluded because it employed a single-group pre–post design without a control group, precluding the calculation of between-group effect sizes required for meta-analytic pooling. The study by Lins-Filho et al. (2024) [35], although methodologically sound, was excluded due to participant overlap with another eligible publication from the same randomized controlled trial [34]. Both studies were conducted at the same institution, during the same time period, using identical intervention protocols

and sample characteristics. To prevent data duplication and ensure statistical independence, only the publication reporting the more comprehensive and relevant outcomes was retained for inclusion.

The final six studies included 191 participants [21,29,30,32–34]. Five studies used the PSQI questionnaire to assess sleep quality [21,30,32–34], with three providing detailed results across all seven PSQI subscales [21,32,34]. Additionally, two studies employed the ESS to measure daytime sleepiness [29,34], while three studies used the Apnea–Hypopnea Index (AHI) to evaluate sleep apnea severity [29,33,34].

The PSQI and ESS are subjective tools based on participants' self-reported data to assess sleep quality and daytime sleepiness, respectively. In contrast, the AHI, derived from PSG, offers an objective assessment of sleep disorders by quantifying apnea and hypopnea episodes. Among the objective metrics, AHI was the only consistently reported parameter and thus the only one eligible for meta-analysis. Other objective measures, such as oxygen saturation and sleep stage distribution, were either not reported or lacked sufficient data for inclusion.

3.4.1. Sleep Quality

PSQI is a tool designed to evaluate sleep quality. It provides a total PSQI score and evaluates seven subscales: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction. These components allow for a detailed meta-analysis of the effects of HIIT on sleep quality across each subscale.

- Total PSQI Score

The analysis of five selected studies involving 160 participants examined the effects of HIIT on sleep quality using PSQI. The results demonstrated a statistically significant improvement in the total PSQI score for the HIIT group compared to the control group (mean difference, -3.51 ; 95% CI $(-4.78$ to $-2.25)$; $p < 0.00001$) (Figure 4). This finding highlights the positive impact of HIIT on overall sleep quality. Despite this significant difference, the analysis reported moderate heterogeneity ($I^2 = 58\%$), suggesting variability in study designs or participant characteristics, which may have influenced the results. These findings emphasize the potential of HIIT as an effective intervention to improve sleep quality.

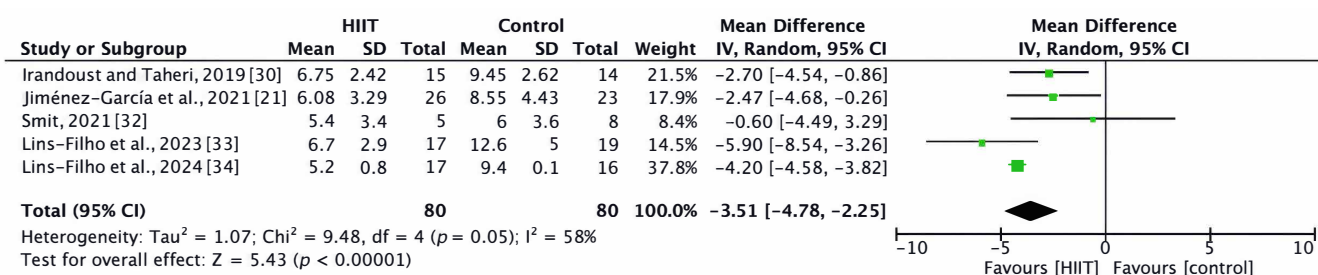


Figure 4. Forest plot showing a meta-analysis of the mean difference in total PSQI scores between the experimental group (HIIT) and the control group. Green squares represent individual studies (size reflects weight); horizontal lines show 95% CI; black diamond indicates overall effect.

- PSQI Subscales

From the selected studies that reported PSQI subscale scores, three studies with a total of 95 participants were analyzed. Significant improvements were observed in three subscales. The sleep duration subscale showed a meaningful difference favoring the HIIT group (mean difference, -0.42 ; 95% CI $(-0.58$ to $-0.26)$; $p < 0.00001$), with low

heterogeneity ($I^2 = 0\%$). The habitual sleep efficiency subscale also displayed a significant improvement in the HIIT group (mean difference -0.32 , 95% CI $(-0.59$ to $-0.05)$; $p = 0.02$), with moderate heterogeneity ($I^2 = 54\%$). Additionally, the daytime dysfunction subscale indicated a significant reduction in dysfunction (mean difference, -0.66 ; 95% CI $(-1.27$ to $-0.05)$; $p = 0.03$), despite high heterogeneity ($I^2 = 87\%$) (Figure 5).

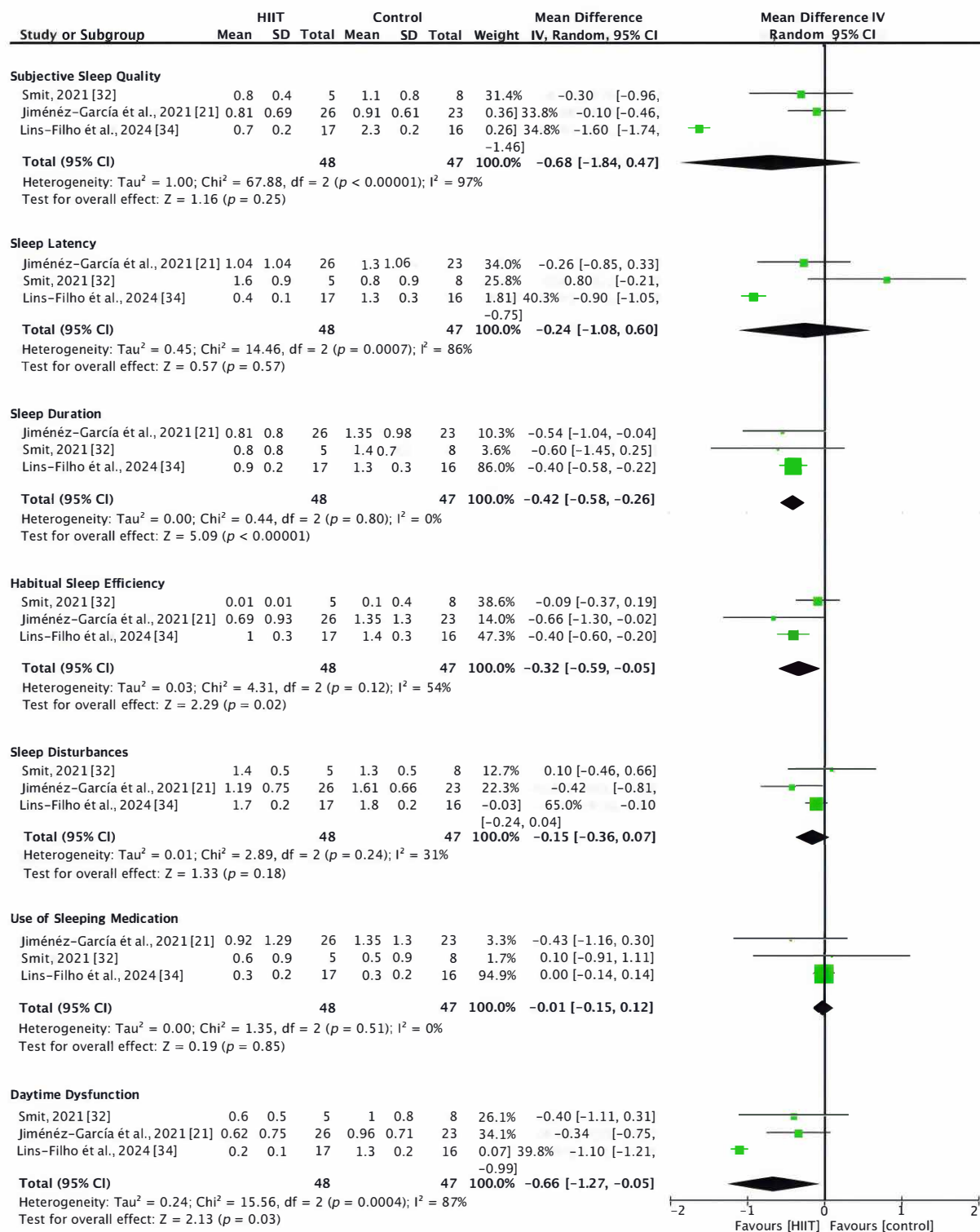


Figure 5. Forest plot showing a meta-analysis of the mean difference in PSQI subscales between the experimental group (HIIT) and the control group. Green squares represent individual studies (size reflects weight); horizontal lines show 95% CI; black diamond indicates overall effect.

Conversely, no statistically significant differences were observed in four subscales. The subjective sleep quality subscale showed no meaningful change between the HIIT and control groups (mean difference, -0.68 ; 95% CI $(-1.84$ to $0.47)$; $p = 0.25$), with high heterogeneity ($I^2 = 97\%$). Similarly, the sleep latency subscale exhibited no significant difference (mean difference, -0.24 ; 95% CI $(-1.08$ to $0.60)$; $p = 0.57$), with high heterogeneity ($I^2 = 86\%$). For the sleep disturbances subscale, no significant improvement was noted (mean difference, -0.15 ; 95% CI $(-0.36$ to $0.07)$; $p = 0.18$), with moderate heterogeneity ($I^2 = 31\%$). Finally, the subscale for the use of sleeping medication showed no significant effect (mean difference, -0.01 ; 95% CI $(-0.15$ to $0.12)$; $p = 0.85$), with low heterogeneity ($I^2 = 0\%$) (Figure 5).

• Subgroup Analysis

A subgroup analysis based on the duration of HIIT was conducted. Two studies with a total of 42 participants involved training sessions lasting 30 min or less. The meta-analysis revealed a statistically significant difference in total PSQI scores between the HIIT and control groups (mean difference, -2.32 ; 95% CI $(-3.98$ to $-0.65)$; $p = 0.006$), with low heterogeneity ($I^2 = 0\%$).

In contrast, three studies with a total of 118 participants included training sessions longer than 30 min. The meta-analysis showed a statistically significant improvement in total PSQI scores in the HIIT group compared to the control group (mean difference, -4.11 ; 95% CI $(-5.45$ to $-2.77)$; $p < 0.00001$), with moderate heterogeneity ($I^2 = 49\%$) (Figure 6).

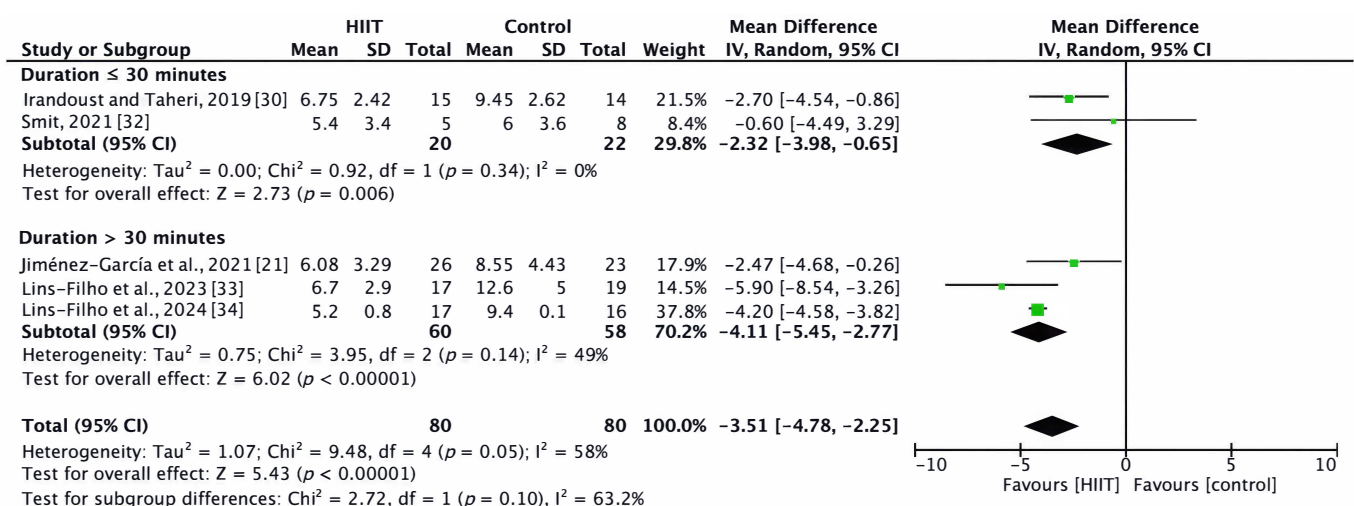


Figure 6. Forest plot of the subgroup meta-analysis showing the mean difference in total PSQI scores between the experimental group (HIIT) and the control group, categorized by studies with exercise durations of 30 min or less and more than 30 min. Green squares represent individual studies (size reflects weight); horizontal lines show 95% CI; black diamond indicates overall effect.

3.4.2. Daytime Sleepiness

From the selected studies included in the analysis, a total of two studies with 64 participants utilized ESS, a tool to evaluate daytime sleepiness following HIIT. The analysis (Figure 7) revealed no significant difference in total ESS scores between the HIIT and control groups (mean difference, -1.09 ; 95% CI $(-6.43$ to $4.25)$; $p = 0.69$). High heterogeneity was observed ($I^2 = 83\%$), suggesting differences in baseline sleepiness and HIIT protocols across the included studies.

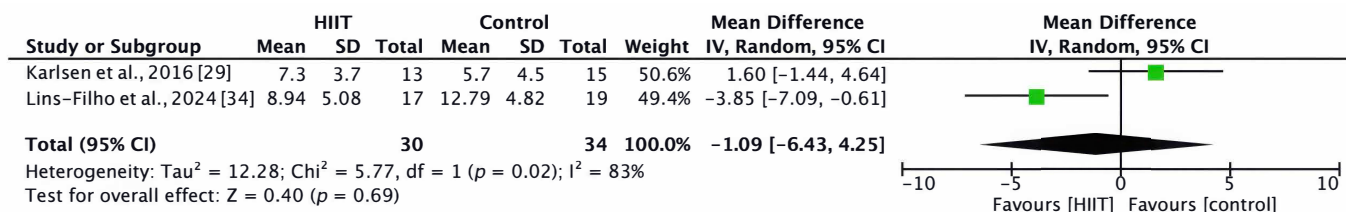


Figure 7. Forest plot of the meta-analysis showing the mean difference in daytime sleepiness levels, as assessed by ESS questionnaire, between the experimental group (HIIT) and the control group. Green squares represent individual studies (size reflects weight); horizontal lines show 95% CI; black diamond indicates overall effect.

3.4.3. Sleep Apnea and Hypopnea Episodes

Three studies involving 100 participants were included in the analysis, utilizing PSG, a tool, to measure the AHI as an indicator of breathing disturbances during sleep after HIIT. The results (Figure 8) showed a statistically significant reduction in AHI scores in the HIIT group compared to the control group (mean difference, -28.31 ; 95% CI (-34.39 to -22.22); $p < 0.00001$), with low heterogeneity ($I^2 = 19\%$).

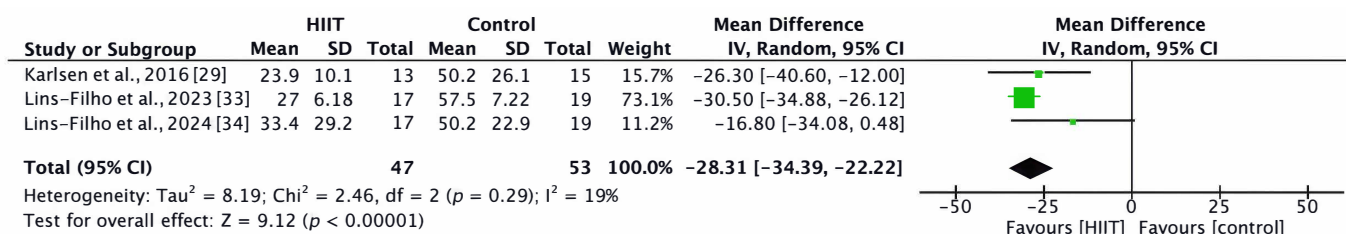


Figure 8. Forest plot of the meta-analysis showing the mean difference in AHI, assessed using polysomnography, between the experimental group (HIIT) and the control group. Green squares represent individual studies (size reflects weight); horizontal lines show 95% CI; black diamond indicates overall effect.

3.5. Publication Bias

The Funnel plot assessment for publication bias showed symmetry with equal distribution around the mean effect size. This analysis was conducted for the effects of HIIT on sleep quality, daytime sleepiness, and the Apnea–Hypopnea Index during sleep.

4. Discussion

Sleep problems are prevalent among obese patients, often presenting as poor sleep quality and OSA due to fat accumulation around the neck and airway. This leads to sleep fragmentation and daytime fatigue [4,5]. Chronic inflammation, triggered by cytokines like $\text{TNF-}\alpha$ and IL-6, and hormonal imbalances involving melatonin, cortisol, leptin, and ghrelin further disrupt sleep [6]. Addressing these issues is vital for improving sleep quality and overall health in obese individuals.

HIIT, which alternates between high-intensity exercise and low-intensity rest, effectively reduces body fat and increases energy expenditure in obese populations [12]. It also enhances mental health by releasing endorphins and serotonin, which reduce stress and anxiety. Recent findings further highlight the psychological benefits of HIIT on sleep quality. A 2025 pilot randomized controlled trial in women with probable post-traumatic stress disorder (PTSD) reported improved sleep outcomes following HIIT-based cycling, with reductions in anxiety and hyperarousal symptoms mediating these improvements [36]. Additionally, HIIT regulates sleep-related hormones by increasing melatonin and lowering cortisol, promoting deeper sleep with fewer awakenings [20].

Standard HIIT routines typically consist of aerobic or resistance exercises carried out at 80% to 95% of an individual's HRmax, alternated with recovery periods at 50% to 70% HRmax. These protocols can differ in intensity, length, and exercise mode, including activities such as cycling, treadmill workouts, or bodyweight circuit training [13]. Most HIIT programs utilize integrated exercises that activate multiple muscle groups at once, rather than targeting isolated muscles, in order to improve overall functional performance and increase energy output.

A review by Min et al. (2021) [22] showed that HIIT improves sleep quality through reduced PSQI scores and increased sleep efficiency. However, it did not focus on obese individuals, whose physiological responses may differ. Recent RCTs have emphasized the need for targeted research on HIIT's impact on sleep in obese populations. The present meta-analysis conducted in this study confirmed that HIIT reduces total PSQI scores, reflecting improved sleep quality. Subscale analysis revealed significant improvements in sleep duration, habitual sleep efficiency, and daytime dysfunction. However, no significant changes were observed in subjective sleep quality, sleep latency, sleep disturbances, or use of sleep medication.

The reduction in total PSQI scores highlights the positive effects of HIIT on overall sleep satisfaction and quality. Sleep duration improved significantly, indicating that HIIT helps individuals achieve adequate sleep for physical and mental recovery. This improvement is likely driven by reduced stress and increased regulation of serotonin and endorphins [20]. Longer sleep durations also promote deeper restorative phases, essential for cellular and metabolic health. Habitual sleep efficiency, which measures the proportion of time spent sleeping versus time in bed, showed significant improvement due to decreased cortisol and increased melatonin secretion [18,37]. These changes minimize nighttime awakenings and support continuous sleep in individuals with obesity and related sleep disorders. Daytime dysfunction improved significantly, reflecting better restorative sleep, reduced fatigue, and increased alertness. HIIT enhances energy and cognitive performance by improving circulation and promoting dopamine release, which boosts focus and productivity.

However, some PSQI subscales, such as subjective sleep quality and sleep latency, did not show significant differences between groups. Subjective sleep quality may be influenced by individual perceptions and expectations of exercise outcomes, causing variability in results. Similarly, improving sleep latency may require additional behavioral or stress management interventions beyond physical exercise. Sleep disturbances, often influenced by external factors, also remained unchanged, as did the use of sleep medication. Reducing reliance on sleep aids may require psychological or medical support.

Subgroup analysis revealed that both shorter and longer HIIT sessions improved sleep quality. HIIT sessions lasting 30 min or less led to significant reductions in total PSQI scores, making shorter workouts an effective option for individuals with limited time. However, longer sessions resulted in even greater reductions, likely due to increased energy expenditure and enhanced hormonal regulation [22]. Despite these benefits, extended exercise sessions may also increase the risk of injury, particularly if performed without proper technique or rest periods. These findings demonstrate the flexibility of HIIT as a sleep intervention, allowing for tailored exercise regimens based on individual needs, time constraints, and physical capacity.

Analysis of ESS showed a slight reduction in daytime sleepiness in the HIIT group, although the difference was not statistically significant. This may be due to multifactorial contributors to daytime alertness, such as baseline sleep duration, psychological distress, or undiagnosed comorbidities, which are not fully addressed by physical training alone. A significant reduction in AHI was observed, indicating fewer breathing disturbances

and improved sleep quality in the HIIT group. This is particularly important for obese patients, who are at higher risk of OSA due to airway obstruction and chronic inflammation [15]. Reduced AHI reflects the alleviation of key risk factors and contributes to deeper, uninterrupted sleep.

Furthermore, recent evidence in pediatric populations highlights implementation challenges in applying HIIT protocols outside supervised settings. For example, a 6-week exploratory study in children with obesity found that use of a HIIT-based app resulted in low adherence, modest engagement (≈ 2.5 sessions/week), and no significant improvements in body composition or sleep behaviors, likely due to low exercise volume and limited parental involvement [38]. These findings suggest that supervision, volume, and family support are critical factors influencing HIIT outcomes, particularly in younger or high-risk populations.

These findings highlight the potential of HIIT as a nonpharmacological intervention for improving sleep quality in obese individuals and offer valuable insights for health-care professionals in developing personalized health recommendations. However, several methodological limitations should be acknowledged. Many of the included studies had small sample sizes, limiting statistical power and generalizability. There was considerable variation in participant characteristics, including age, sex, obesity severity, and baseline sleep quality, which may have influenced the intervention effects. Additionally, inconsistencies in the design of HIIT protocols, such as frequency, intensity, duration, recovery modality, and supervision, contributed to high heterogeneity in some outcomes. Differences in outcome assessment tools, including self-reported versus objective sleep measures, and a lack of long-term follow-up further limit the ability to draw firm conclusions. Future research should aim to use standardized protocols, larger and more diverse populations, and consistent outcome measures to better understand the effects of HIIT on sleep in this population.

5. Conclusions

This study demonstrated that HIIT is an effective nonpharmacological approach for improving sleep quality in individuals with obesity. Significant improvements were observed in total PSQI scores, sleep duration, habitual sleep efficiency, and daytime dysfunction. A reduction in AHI was also noted, suggesting a potential benefit in lowering OSA severity. Although some subscales showed no significant change, the overall results support the clinical applicability of HIIT.

Clinicians may consider prescribing supervised HIIT protocols 2–3 times per week, with sessions lasting 20–30 min at 80–95% of HRmax, interspersed with active recovery at 50–70% of HRmax for 2–4 min. Exercise modalities such as cycling, treadmill walking, or resistance-based circuits may be appropriate, depending on individual capacity. Pre-exercise screening and guidance on proper technique are essential to ensure safety and adherence.

In summary, HIIT is a practical and adaptable strategy with strong potential for clinical integration in sleep health management among obese populations.

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Abbreviations

1RM	one-repetition maximum
AHI	Apnea–Hypopnea Index
BMI	body mass index
CI	confidence interval
ESS	Epworth Sleepiness Scale
GSQ	good sleep quality
H-HIIT	healthy high-intensity interval training
H-nonHIIT	healthy non-high-intensity interval training
HIIT	high-intensity interval training
HRmax	maximum heart rate
IL-10	Interleukin 10
IL-6	Interleukin 6
MICT	moderate-intensity continuous training
MIIT	moderate-intensity interval training
MD	mean difference
NCDs	noncommunicable diseases
NS	not significant
O-HIIT	overweight high-intensity interval training
O-nonHIIT	overweight non-high-intensity interval training
ODI	Oxygen Desaturation Index
OSA	obstructive sleep apnea
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PSG	polysomnography
PSQ	poor sleep quality
PSQI	Pittsburgh Sleep Quality Index
PTSD	post-traumatic stress disorder
RAST	Running-Based Anaerobic Sprint Test
REM	rapid eye movement
REVMAN	Review Manager
RT	resistance training
RoB 2	Risk of Bias 2 Tool
TNF- α	tumor necrosis factor alpha
TRX	total resistance exercises

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