QUALITY IN SPORT
eISSN 2450-3118 · Open Access · Peer-reviewed
apcz.umk.pl/QS Nicolaus Copernicus University in Toruń

Cite as: KUKLA, Monika, BULICZ, Anna, KMIECIK, Izabela, KOWALCZYK, Olga, KOZŁOWSKI, Sebastian, ZDUNEK, Marta, STODULSKI, Maciej, KASPRZYCKA, Izabela, DZIARNOWSKA, Joanna, and FIKS, Justyna. Role of Different Exercise Modalities in the Management of Obstructive Sleep Apnea: A Narrative Review. Quality in Sport. 2026;63:73106. https://doi.org/10.12775/QS.2026.63.73106

ARTICLE TIMELINE
Received: 06.06.2026. Revised: 29.06.2026. Accepted: 05.07.2026. Published: 14.07.2026.

The journal has been awarded 20 points in the parametric evaluation by the Polish Ministry of Higher Education and Science (Annex to the announcement of 05.01.2024, No. 32553). Unique Journal Identifier: 201398. Scientific disciplines assigned: Economics and finance (Field of social sciences); Management and Quality Sciences (Field of social sciences).
Punkty Ministerialne z 2019 – aktualny rok 20 punktów. Załącznik do komunikatu Ministra Szkolnictwa Wyższego i Nauki z dnia 05.01.2024 Lp. 32553. Posiada Unikatowy Identyfikator Czasopisma: 201398. Przypisane dyscypliny naukowe: Ekonomia i finanse (Dziedzina nauk społecznych); Nauki o zarządzaniu i jakości (Dziedzina nauk społecznych).

Role of Different Exercise Modalities in the Management of Obstructive Sleep Apnea: A Narrative Review

Monika Kukla

ORCID https://orcid.org/0009-0006-1136-4194

E-mail monikakukla10@gmail.com

Medical University of Lodz, Al. Kościuszki 4.90-419 Lodz. Poland

Anna Bulicz

ORCID https://orcid.org/0009-0008-7336-7096

E-mail anna.bulicz@stud.umed.lodz.pl

Medical University of Lodz, Al. Kościuszki 4.90-419 Lodz. Poland

Izabela Kmiecik
ORCID https://orcid.org/0009-0005-9905-3704
E-mail izabela.kmiecik@stud.umed.lodz.pl
Medical University of Lodz, Kościuszki 4, 90-419 Lodz, Poland

Olga Kowalczyk
ORCID https://orcid.org/0009-0003-6908-7618
E-mail olga.kowalczyk1@stud.umed.lodz.pl
Medical University of Lodz, Kościuszki 4, 90-419 Lodz, Poland

Sebastian Kozłowski
ORCID https://orcid.org/0009-0000-1892-1869
E-mail sebastian.jan.kozlowski@gmail.com
Medical University of Lodz, Kościuszki 4, 90-419 Lodz, Poland

Marta Zdunek
ORCID https://orcid.org/0009-0006-4920-4460
E-mail marta.zdunek18@gmail.com
University Clinical Hospital No. 2, Medical University of Lodz, Zeromskiego 113, 90-549 Lodz, Poland

Maciej Stodulski
ORCID https://orcid.org/0009-0001-1614-3511
E-mail maciej.stodulski1999@gmail.com
Municipal Hospital of St. John Paul II, Jana Amosa Komeńskiego 35, 82-300 Elbląg, Poland

Izabela Kasprzycka
ORCID https://orcid.org/0009-0009-9416-4156
E-mail i.k.kasprzycka@gmail.com
Medical University of Lodz, Kościuszki 4, 90-419 Lodz, Poland

Joanna Dziarnowska
ORCID https://orcid.org/0009-0001-7615-8408
E-mail joannadziarno@gmail.com
Medical University of Lodz, Kościuszki 4, 90-419 Lodz, Poland

Justyna Fiks
ORCID https://orcid.org/0009-0003-3833-7194
E-mail justynafiks08@gmail.com
Medical University of Lodz, Kościuszki 4, 90-419 Lodz, Poland

Corresponding Author
Monika Kukla, monikakukla10@gmail.com

Abstrakt

Background. Obstructive sleep apnea (OSA) is a common breathing disorder associated with excessive daytime sleepiness, impaired quality of life, and increased cardiovascular and metabolic risk. Although continuous positive airway pressure (CPAP) remains the first-line treatment, long-term adherence is often suboptimal, prompting interest in adjunctive therapies.

Aim. To evaluate the effects of different exercise modalities on outcomes in OSA and assess their role as adjunctive therapies.

Material and methods. A narrative review of the literature was conducted to identify studies evaluating aerobic exercise, resistance training, respiratory muscle training, and oropharyngeal exercises in adults with OSA. Outcomes included AHI, ESS, BMI, and CPAP adherence.

Results. Exercise-based interventions may improve both objective and subjective outcomes in patients with OSA. Aerobic exercise showed the most consistent reductions in AHI and improvements in daytime sleepiness, sleep quality, and cardiometabolic health. Combined aerobic and resistance training appeared more effective than resistance or aerobic training alone, particularly in reducing OSA severity and improving anthropometric outcomes. Respiratory muscle training showed promising effects on sleep-related symptoms, although its impact on AHI remains inconsistent. Oropharyngeal exercises showed the most consistent AHI reductions and may improve CPAP adherence by enhancing upper airway muscle function. Several beneficial effects were observed independently of significant weight loss.

Conclusions. Different exercise modalities appear to target distinct pathophysiological mechanisms of OSA and provide complementary therapeutic benefits. Exercise should be considered a valuable adjunct to standard OSA treatment, while further high-quality studies are needed to establish optimal exercise protocols and phenotype-based therapeutic strategies.
Keywords: obstructive sleep apnea; OSA; physical activity; aerobic exercise; resistance training; respiratory muscle training; oropharyngeal exercises; CPAP; adjunctive therapy

1. Introduction

Obstructive sleep apnea is characterized by recurrent episodes of apnea and hypopnea, as well as deep sleep fragmentation, resulting from the partial or complete collapse of the upper airway [1].

According to the most complex global research by Benjafield i in. 2019r. nearly one billion adults aged 30-69 years are affected by OSA worldwide [2]. Recent reports suggest that the incidence of OSA continues to exhibit an upward trend, despite a high rate of underdiagnosis. The prevalence of OSA in the adult population is estimated to range from 9% to 38%, depending on the diagnostic criteria applied. These findings are primarily attributed to the progressive global obesity epidemic and the improved availability of home-based diagnostics, which uncover apnea cases in populations previously considered to be at low risk [3].

Obesity remains the most critical risk factor for OSA, although significant roles are also played by factors such as upper airway anatomy and neck circumference [4], [5]. OSA is associated with significant cardiovascular and metabolic morbidity [6], [7], [8], [9], [10], [11]. Patients frequently report excessive daytime sleepiness, impaired concentration, memory disturbances, and a reduced quality of life. Research demonstrates that patients with OSA have a 1.2- to 2.4-fold higher risk of causing a traffic accident compared to healthy individuals [12].

The pathogenesis of obstructive sleep apnea is multifactorial and remains a subject of intensive research. The contemporary understanding of this disorder highlights the interaction between anatomical predispositions and neuromuscular control impairment. Increasingly, greater attention in the literature is being focused on the PALM model (P-pressure, A-arousal threshold, L-loop gain, M-muscle responsiveness), which distinguishes four main endotypes of the disease: anatomical compromise, impaired upper airway muscle function, a low arousal threshold (a predisposition to awaken during brief episodes of apnea or hypopnea), and unstable ventilatory control, commonly referred to as high loop gain [13]. Furthermore, the pathogenesis of OSA may also involve nocturnal fluid shifts, as well as alterations in dopaminergic and serotonergic pathways [14], [15].

The Apnea-Hypopnea Index (AHI) remains the gold standard for diagnosing and assessing the severity of OSA. The AHI represents the total average number of apneas and hypopneas per hour of sleep. According to clinical guidelines, OSA is diagnosed at an AHI ≥ 5 with severity classified as mild (5–15), moderate (15–30), and severe (>30) [16]. In addition to objective parameters such as AHI, several studies assessed patient-reported outcomes (PROs), including daytime sleepiness measured by the Epworth Sleepiness Scale (ESS) and subjective sleep quality assessed by the Pittsburgh Sleep Quality Index (PSQI).

Currently, the management of OSA encompasses continuous positive airway pressure (CPAP), physical exercise, weight reduction, the use of oral appliances, and various surgical interventions[17], [18]. CPAP remains the gold standard for the treatment of moderate-to-severe OSA, as it most effectively reduces the AHI among the aforementioned modalities, improves daytime sleepiness and quality of life, and exerts favorable effects on blood pressure and metabolic parameters [19]. However, long-term adherence to the therapy remains suboptimal, with patients frequently reporting discomfort associated with the device, mask intolerance, and difficulties adapting to the treatment [20], [21]. In recent years, physical activity has gained increasing recognition as a key adjunctive therapy for OSA. Beyond its well-documented impact on cardiovascular and metabolic health, growing evidence indicates that regular training can enhance sleep quality, reduce daytime sleepiness, and mitigate OSA severity through mechanisms extending beyond weight loss alone [22], [23], [24].

The aim of this review is to evaluate the effects of different exercise modalities on AHI, ESS, body mass index (BMI), and CPAP adherence in patients with obstructive sleep apnea.

2. Research materials and methods

This narrative review was conducted in accordance with established methodological principles for narrative literature reviews in biomedical research. A literature search was performed using major scientific databases, including PubMed, Scopus and Google Scholar to identify studies investigating the effects of different exercise modalities on obstructive sleep apnea and their potential impact on adherence to continuous positive airway pressure therapy. Publications were searched using combinations of the following keywords: “obstructive sleep apnea”, “OSA”, “OSAS”, “sleep-disordered breathing”, “aerobic training”, “resistance training”, “exercise intervention”, “respiratory muscle training”, “inspiratory muscle training”, “oropharyngeal exercises”, “myofunctional therapy”, “CPAP”, “AHI”, “Epworth Sleepiness Scale”, “sleep quality”, and “Pittsburgh Sleep Quality Index”. The review focused on articles published in English since 2020, including meta-analyses, randomized controlled trials (RCTs), and systematic reviews. Additional relevant publications were identified through manual screening of the reference lists of selected articles.

Inclusion criteria were studies evaluated the effects of aerobic exercise, resistance training, respiratory muscle training, or oropharyngeal exercises on selected OSA-related outcomes, including the AHI, ESS, BMI, and adherence to CPAP therapy.

Exclusion criteria included articles unrelated to OSA outcomes, studies involving pediatric populations, studies valuating exercise interventions exclusively in participants without OSA, and non-peer-reviewed publications. One study analising children and adult population was inclued, but this study focused only on adult group outcomes [25]. Articles without access to full-text publication were excluded.

The selected studies were subjected to qualitative analysis and narrative synthesis. Subsequently, the studies were categorized according to exercise modality to facilitate comparison of their effects on key clinical and therapeutic outcomes in patients with OSA.

3. Research results

A total of 21 studies met the eligibility criteria and were included in the final review. The studies were classified into four main categories according to the exercise modality investigated: aerobic exercise training(AE), resistance training (RT), respiratory muscles training (RMT), oral-pharyngeal muscles exercises (OE). Several studies investigated more than one intervention and were therefore included in multiple categories [26], [27], [28], [29], [30], [31].

The AE category included articles with exercices focused on isolated aerobic training aimed at improving cardiovascular and respiratory fitness. Seven studies were included [26], [28], [29], [31], [32], [33], [34].

The RT category divided into two subcategories: isolated RT and combined aerobic plus resistance training (RT + AE). The isolated RT subcategory includes three studies analyzing the effects of isolated resintance exercices such as strength machines; progressive overload, targeting major muscle and exercise for major muscle groups: bench press, shoulder press, biceps curl, triceps curl, lat pulldown, sit-ups, leg press, squat and calf raise [26], [35], [36]. The RT+ AE subcategory includes seven studies analyzing the effects of combined physical training focused on aerobic and strengh training in one training session [26], [28], [29], [31], [37], [38], [39].

The RMT category included six articles investigated IMT and/or EMT and/or diaphragm-focused excrcises [26], [27], [29], [30], [40], [41].

The OE category included articles with exercices aimed at improving the function of upper airway dilator muscles, including the tongue muscles, soft palate muscles, and pharyngeal muscles. Nine studies were included [25], [26], [27], [29], [30], [42], [43], [44], [45].

The distribution of studies according to exercise modality and study design is presented in Table 1.

A summary of the effects of the different exercise modalities on AHI, ESS, BMI, and CPAP adherence is presented in Table 2.

Table 1. The numbers of articles found for each exercise modality as well as a categorization by study type.

Exercise modality	**Study Type**	**Numbers of articles**
Aerobic exercise training	Metaanalises and systematic review	5
	Dose- responce metaanalisis	1
	RCTs	1
		Total: 7
Resistance training (isolated RT and RT+AE)	Metaanalises and systematic review	5
	Metaanalises	1
	RCTs	3
		Total: 9
	Metaanalises and systematic review	4

***Abbreviations**: **RCTs**,* Randomized control trials*; **RT**, resistance training; **RT+AE**, combined resistance training and aerobic training*

Respiratory muscle training	Umbrella review and meta-meta-analysis of systematic reviews	1
	Metaanalises	1
		Total: 6
Oropharangeal training	Metaanalises and systematic review	5
	Umbrella review and meta-meta-analysis of systematic reviews	1
	RCTs	2
	Metaanalises	1
		Total: 9

Table 2. Summary of the effects of different exercise modalities on OSA outcomes

Aerobic exercise				
Study	**AHI**	**ESS**	**BMI**	**CPAP adherence**
Lin C. [28]	+	+	+	NR
Lin X. [29]	+	+	+	NR
Martinez-Revuelta L. [31]	-	-	NR	NR
Pawar M. [33]	+	-	-	NR
Iftikhar I. [32]	+	+	NR	NR
Borges Y. [34]	NR	-	NR	NR
Siatkowski S.[26]	+	-	NR	NR
Resistance training				
Study	**AHI**	**ESS**	**BMI**	**CPAP adherence**
Isolated RT				
Siatkowski[26]	-	-	+	NR
de Almeida J. [35]	+	NR	NR	NR
da Silva R. [36]	-	NR	+	NR
RT +AE				
Siatkowski S. [26]	+	+	NR	NR
Araújo C. [39]	+	NR	-	NR
Ueno -Pardi L.[38]	+	+	+	NR
Lin C.[28]	+	+	+	NR
Lin X.[29]	+	+	+	NR
Peng J. [37]	-	+	NR	NR
Respiratory muscle training				
Study	**AHI**	**ESS**	**BMI**	**CPAP adherence**
Zuo C. **[41]**	-	+	+	NR
Justribó-Manion C. [27]	+	NR	NR	NR
Castellanos M. **[30]**	-	+	NR	NR
Torres-Castro R. **[40]**	-	+	NR	NR

S. Siatkowski**[26]**	+	-	+	NR
Lin X.**[29]**	+	+	NR	NR

Oropharyngeal exercises

Study	**AHI**	**ESS**	**BMI**	**CPAP adherence**
Xu Y.[43]	+	+	-	+
Selin [45]	+	-	NR	+
Justribó-Manion C. [27]	+	+	NR	NR
Ruenda[25]	+	-	-	NR
Poncin W. [42]	+	NR	NR	NR
Siatkowski S. [26]	+	-	NR	NR
Lin X.[29]	+	+	NR	NR
Arslan E. [44]	+	+	-	+
Castellanos M. [30]	-	+	NR	NR

Abbreviations*: **AHI**, Apnea-Hypopnea Index; **BMI**, body mass index; **CPAP**, continuous positive airway pressure; **ESS**, Epworth Sleepiness Scale.*

Symbol keys:.

SYMBOL	*MEANING*
+	Significant improvement
–	No statistically significant improvement
NR	Not reported

4. Discussion

The aim of this narrative review was to evaluate the impact and effectiveness of various forms of physical activity, as well as their influence on adherence to CPAP therapy, as part of an adjunctive, multimodal treatment approach for patients with OSA.

The available evidence suggests that exercise interventions can improve both objective and subjective outcomes in OSA, including reducing the AHI, improving sleep architecture, and decreasing daytime sleepiness. However, the magnitude and consistency of these effects vary depending on the type of intervention.

Among the analyzed modalities, aerobic exercise demonstrated the most consistent impact on sleep quality and cardiometabolic outcomes, with patients deriving even greater benefits when combined with resistance training. Oropharyngeal muscle exercises showed particular potential for alleviating symptoms and enhancing adherence to CPAP therapy. Conversely, resistance training and respiratory muscle training yielded less consistent results, particularly regarding reductions in the AHI.

These findings suggest that exercise interventions may target OSA through distinct pathophysiological pathways. Such a broad spectrum of complementary effects from different forms of physical activity provides a strong rationale for a detailed analysis of individual interventions in the subsequent sections of this review.

4.1 The Impact of AE on OSA

AE training can exert a significant, multi-level impact on the clinical status of patients with OSA.

The AHI

The majority of the analyzed reports (6 out of 7 studies) confirm a statistically significant effect of isolated aerobic training on reducing the AHI [26], [28], [29], [32], [33], [37]. This phenomenon is attributed, among other factors, to the stabilization of ventilatory control through a reduction in loop gain, as well as the limitation of nocturnal rostral fluid shifts. Regular AE improves cardiorespiratory fitness, which leads to a decrease in loop gain, characterized by the hyper-reactivity of the respiratory system to changes in oxygen and carbon dioxide partial pressures [46]. Lowering loop gain stabilizes respiratory drive during sleep, thereby preventing alternating episodes of hyperventilation and apnea [13], [46]. Additionally, the enhanced skeletal muscle pump activity and more efficient venous return during AE reduce the volume of fluid accumulating in the lower extremities during the day, thereby mitigating its nocturnal rostral shift when lying in the recumbent position [46]. This limits edema of the upper airway soft tissues, reducing external pressure on pharyngeal structures and lowering the critical pharyngeal collapse pressure [15]. This physiological change exhibits a stronger correlation with AHI reduction than a decrease in overall body weight alone [47], which may play a crucial role in patients with an anatomical phenotype (characterized by increased airway collapsibility and an enlarged neck circumference).

Interestingly, not all meta-analyses have demonstrated a significant reduction in the AHI following isolated aerobic training. In a study by Martínez-Revuelta et al., it was found that AE alone did not significantly improve the AHI ($p=0.15$), despite the statistically significant efficacy observed for RT + AE [31]. This discrepancy in results may stem from the heterogeneity of exercise protocols across the analyzed studies, differences in the disease phenotypes of the study populations, and the multifactorial pathophysiology of OSA.

Although AE exerts beneficial physiological effects, including improving cardiovascular fitness, reducing systemic inflammation, and altering fluid redistribution [48], it may not be sufficient to compensate for inherent structural constraints (e.g., mandibular or oropharyngeal morphology) in patients with a dominant anatomical phenotype. Furthermore, the AHI itself exhibits considerable night-to-night variability, rendering it potentially less sensitive to functional improvements compared to patient-reported enhancements in quality of life, as reflected by the ESS and PSQI indices [49], [50].

The ESS

A growing body of evidence confirms that AE significantly improves sleep quality and improves ESS scores in patients with OSA [28], [29], [32], [37]. Some meta-analyses demonstrate a greater, statistically significant decrease in the ESS among groups undergoing aerobic training compared to patients using CPAP [28]. This effect is attributed to the reduction in sleep fragmentation induced by AE [22]. The improvement in respiratory muscle function reduces the number of apnea-induced microarousals, which secondary translates into enhanced cognitive function and daytime concentration [51], [52].

Conflicting results (a lack of statistical significance for the ESS ($p>0.05$) were reported in 3 out of the 7 studies [31], [33], [34]. Pawar et al. suggest that this lack of significance could stem from limited statistical power due to a small sample size, as further indicated by a very large effect size for the ESS (*large effect size* = 0.97). This finding suggests a potentially clinically meaningful benefit that may have gone undetected due to methodological limitations [33]. Conversely, Borges et al. and Martínez-Revuelta et al. indicate that the absence of improvement in ESS scores might be attributed to short-term exercise interventions [31], [34]. The remaining analyzed studies involved longer periods of supervised aerobic exercise (>12 weeks) and observed improvements in daytime sleepiness, quality of life, and mood in individuals with mild-to-moderate OSA [28], [29], [32], [37].

The described discrepancies become crucial from the perspective of the dose-response relationship, suggesting the existence of minimum volume thresholds for aerobic exercise necessary to achieve improvements in outcomes. The literature recommends a minimum of 70–100 minutes of regular AE training per week (spread over 3–5 days) to elicit a therapeutic response [32]. Interestingly, this relationship is specific to individual sleep components. It has been shown that a moderate volume reduces wake after sleep onset (WASO), whereas the elongation of slow-wave sleep (SWS), which is critical for regeneration, requires a higher frequency of training stimuli, amounting to a minimum of 4 sessions per week [22].

The BMI

In the studies by Lin C. et al. and Martínez-Revuelta et al., it was observed that physical activity based on aerobic exercise significantly reduced BMI by 0,72 kg/m² ($p = 0{,}005$) [28], [31]. Subgroup analyses revealed no significant differences between isolated AE and combined AE+RT (intergroup $p = 0{,}22$) [28]. These findings were confirmed in a recent meta-analysis by Lin X. et al., which encompassed 991 patients [29]. The contrasting results in the study by Pawar et al. were attributed by the authors to the short duration of the intervention (mostly <12 weeks) [33]. Crucially, in a subset of patients from the experimental groups, improvements in OSA-related outcomes occurred despite the lack of a statistically significant reduction in BMI. This finding aligns with hypotheses regarding the mitigating effect of physical activity on OSA progression through mechanisms independent of weight loss, including enhancements in cardiovascular fitness, reductions in fluid redistribution, and the strengthening of neuromuscular control in the upper airway.

An additional benefit of systematic AE is its protective effect against metabolic disorders and cardiovascular complications. AE exerts potent antioxidant and anti-inflammatory actions, which directly counteract vascular endothelial dysfunction and the degeneration of peripheral nerves ,including those supplying the upper airway muscles, induced by nocturnal episodes of intermittent hypoxia [24]. Given that OSA constitutes an independent risk factor for metabolic and cardiovascular diseases, this effect carries substantial clinical significance [53].

In conclusion, the available literature suggests that regular AE can serve as a valuable adjunctive intervention in the management of patients with OSA, demonstrating potential for reducing the AHI (compared to no therapeutic intervention) and improving ESS scores. However, achieving these benefits appears to be strictly dose-dependent, with more pronounced improvements observed when an adequate training volume and frequency are maintained (a minimum of 3–4 sessions per week for a duration exceeding 12 weeks). Furthermore, numerous authors highlight the potential cardio- and metabolically protective effects of aerobic activity, which, through its anti-inflammatory properties, may mitigate the systemic complications of nocturnal hypoxia. Nevertheless, these findings warrant further substantiation in long-term prospective studies.

4.2 The Impact of RT on OSA

Analyzing the impact of RT on the course of OSA yields inconsistent conclusions. Among the three studies evaluating the effects of isolated RT on the disease course in patients with OSA, two randomized controlled trials confirmed a reduction in the AHI [35], [36]. In contrast, a meta-analysis by S. Siatkowski et. al. demonstrated no statistically significant improvement in this parameter. The authors attribute this discrepancy to the small number of included articles and high study heterogeneity [26]. Isolated RT also shows limited efficacy regarding anthropometric parameters and daytime sleepiness; in light of the available data, it partially contributes to a reduction in BMI but fails to reduce ESS scores [26], [36].

Due to the paucity of reports on the effects of isolated RT and the high heterogeneity of the available studies, the efficacy of isolated RT in reducing the AHI, ESS scores, and BMI cannot be unequivocally assessed [26], [35], [36].

Nevertheless, RT combined with AE may exert a beneficial effect in the integrated management of OSA [26], [28], [29], [31], [37], [38], [39]. A meta-analysis by J. Peng et al. [37], alongside subsequent meta-analyses by Lin X. [29] et al. and Lin C. et al. . [28], demonstrated that patients undergoing combined RT + AE training achieved a more significant reduction in the AHI compared to both the control group and the subgroup performing AE alone. Notably, this reduction in OSA severity occurs independently of changes in BMI [28], [37]. Combined training also yields favorable outcomes in improving ESS scores, occasionally surpassing the effects of isolated aerobic training [26], [28], [29], [38]. Furthermore, researchers emphasize the positive impact of physical activity (AE + RT) on cognitive functions and concentration, which may directly influence the scores obtained in the ESS questionnaire [38], [54], [55].

Nevertheless, in the context of anthropometric parameters alone, combined training also proves to be a more effective form of intervention, demonstrating a beneficial effect on BMI [28], [29], [31], [38].

A separate issue involves the implementation of physical activity in patients successfully treated with CPAP. In this population, the addition of exercise (both RT and RT + AE) does not generate further benefits in terms of additional reductions in AHI or ESS scores, as CPAP therapy already effectively optimizes respiratory parameters and mitigates OSA symptoms. However, despite the ongoing use of CPAP, the incorporation of RT + AE induces a significant increase in peak oxygen uptake (VO2peak) [26], [28]. Lin C. et al. observed an increase in VO2peak by o 3,46 ml/kg/min in the RT + AE group (following a protocol lasting over 12 weeks, among patients adherent to CPAP therapy), whereas no such effect was reported in the isolated AE group. The VO2peak parameter reflects cardiorespiratory fitness and oxygen utilization capacity, serving as a well-established predictor of cardiovascular events and all-cause mortality in the general population [56]. Nonetheless, the cardioprotective effect resulting from increased VO2peak in patients with OSA warrants further confirmation [28].

Despite the lack of unequivocal evidence regarding the efficacy of isolated RT, the findings suggest a synergistic effect when combining these modalities of exercise intervention to reduce the AHI, ESS scores, and BMI, which may help optimize the therapeutic response in patients with sleep apnea.

4.3 The Impact of RMT on OSA

In the context of non-pharmacological modalities for OSA management, RMT is garnering increasing interest as a promising adjunctive therapy. Although RMT improves respiratory strength, sleep quality, and cardiovascular function [27], [29], [30], [41], its impact on key clinical indicators, namely the AHI and ESS scores, remains a subject of ongoing debate.

The AHI and the ESS

The meta-analyses by Zuo C. et al., Torres-Castro R., and Castellanos M. did not observe an unequivocal improvement in the AHI, despite improvements in patient-reported symptoms and metabolic parameters. The authors suggest that this discrepancy may stem from the therapeutic effect of IMT being driven by non-anatomical mechanisms rather than the direct prevention of airway collapse [30], [40], [41].

Contrasting results were presented in the most recent meta-analyses from 2026 [26], [29]. In a meta-analysis by Siatkowski S. et al., a modest yet statistically significant reduction in AHI was demonstrated following 6–12 weeks of regular training utilizing devices that generate graduated respiratory resistance. Conversely, no significant improvement was observed regarding daytime sleepiness assessed by the ESS [26]. On the other hand, Lin X. et al., based on an analysis of four RCTs, demonstrated a concurrent reduction in both AHI and ESS [29]. Given the short intervention duration and small sample sizes, these findings should be interpreted with caution and certainly warrant further research to evaluate the therapeutic efficacy.

Interesting findings are provided by a meta-analysis by Castellanos M. et al., who compared the efficacy of isolated interventions—including IMT, OT, CPAP, and mandibular advancement devices—with combination therapies that paired these individual interventions with CPAP. They observed that the combined CPAP + IMT therapy yielded the greatest reduction in AHI, surpassing even CPAP alone [30]. However, due to the limited number of IMT studies included in the meta-analysis (2 RCTs), these results must be interpreted with caution.

The primary mechanism underlying the efficacy of RMT (particularly IMT) is believed to be an increase in the respiratory arousal threshold. By strengthening the inspiratory muscles, IMT reduces the perceived effort required to breathe against an obstructed airway. This allows patients to tolerate longer periods of airway obstruction without triggering cortical arousal, which leads to reduced sleep fragmentation and, consequently, decreased daytime sleepiness (improved ESS scores). Concurrently, better ventilatory control may alleviate sympathetic hyperactivity, which further explains the decline in the ESS index despite the absence of changes in the AHI. Accordingly, it appears that patients in whom a low arousal threshold plays a major role in the pathophysiology of the disease may derive the greatest benefit from RMT. However, this hypothesis warrants further investigation [41], [57].

The BMI

Furthermore, the meta-analyses by Zuo C. et. al. and Siatkowski S. et. al demonstrated a significantly lower BMI in the IMT group compared to the control group, as well as a substantial reduction in systolic blood pressure, particularly in patients with mild-to-moderate obstructive sleep apnea. These findings support the hypothesis that IMT improves diaphragmatic efficiency and respiratory muscle endurance, potentially increasing daily energy expenditure, promoting weight loss, and yielding tangible cardiovascular benefits.[26], [41]. Given that long-term outcomes regarding major adverse cardiovascular events were not included in the reviewed literature, this should constitute a key area for future research.

In conclusion, both RMT and IMT can serve as valuable adjunctive therapies for patients with OSA, particularly in terms of improving clinical symptoms and reducing cardiovascular risk. Due to the limited number of available studies on IMT and their inconclusive findings, there remains a clear need for further analyses in larger study populations. Future research should incorporate exercise interventions with standardized training protocols in combination with CPAP therapy. In the authors' opinion, addressing all these aspects when designing new studies will allow future research to unequivocally determine the impact of RMT as a combination therapy with CPAP in patients with OSA.

4.4. The Impact of OE on OSA

OE encompasses diverse approaches aimed at improving upper airway muscle function, including the muscles of the tongue, soft palate, pharynx, and facial muscles.

The AHI and ESS

Among the analyzed exercise modalities, OE provides the most consistent results regarding AHI reduction. The majority of the analyzed studies (8 out of 9) demonstrated a significant decrease in AHI scores following OE intervention compared to non-exercising control groups [25], [26], [27], [29], [42], [43], [44], [45]. Conversely, the addition of OE to standard CPAP therapy did not consistently translate into an incremental reduction in AHI compared to CPAP alone [25], [30], [43]. On the other hand, Selin et al. observed a significant reduction in AHI in the exercise group compared to baseline, whereas the control group treated exclusively with CPAP failed to maintain the beneficial effect after treatment cessation [45]. These findings suggest that OE may serve as a potential therapeutic alternative for selected patients who are intolerant to CPAP. Additionally, some authors indicate that combining OE with aerobic training may lead to a greater reduction in AHI than the utilization of isolated OE [44].

The impact of OE on ESS scores remains inconclusive. Although the majority of studies (6 out of 9) demonstrate a significant beneficial effect of OE on the ESS [29], [42], [43], [44], some trials have even observed a greater efficacy of OE compared to CPAP in reducing ESS scores [27], [30].

Interesting findings were presented by Xu Y. et al., who demonstrated an incremental improvement in ESS scores when OE was added to CPAP therapy compared to CPAP alone. Similar observations were made by elin Çakmakcı S. et al., who, despite not finding a statistically significant improvement in the ESS, demonstrated an enhanced sleep quality assessed via the PSQI. Conversely, Justribó-Manion et al. did not confirm the superiority of combination therapy over CPAP alone, despite demonstrating a more favorable effect of OE in reducing ESS scores compared to CPAP [27], [43], [45].

Two meta-analyses failed to observe a statistically significant beneficial effect of OE on the ESS, despite its favorable impact on the clinical symptoms of OSA [25], [26]. The authors attribute this lack of significance to high study heterogeneity and small sample sizes. Methodological limitations primarily include small sample sizes across the studied cohorts, heterogeneity in the utilized exercise protocols, and relatively short follow-up periods.

The underlying mechanism of action of OE has not yet been definitively elucidated. It is hypothesized that the clinical benefits of OE therapy stem from the remodeling of upper airway soft tissues, alongside improvements in neuromuscular activation and the coordination of the pharyngeal and tongue muscles. This leads to reduced pharyngeal collapsibility during sleep and enhanced upper airway patency. Consequently, this therapeutic strategy appears particularly poised to benefit patients exhibiting a hypotonic phenotype. However, due to the lack of studies evaluating the efficacy of OE therapy in patients with specific phenotypes, drawing further conclusions remains difficult. Furthermore, it must be emphasized that the observed associations are correlational in nature and do not confirm a causal relationship [13], [42].

A significant clinical issue is the potential impact of OE on CPAP treatment tolerance. Although direct evidence remains limited, the analyzed studies indicated increased CPAP adherence in groups regularly performing OE training [43], [44], [45]. These findings are also consistent with the observations of P. Huang et al. in their highly cited prospective study, where patients performing pharyngeal and tongue muscle exercises used CPAP therapy for an average of 1.1–1.2 hours longer per night compared to the control group after 6 months [58]. The mechanism underlying this phenomenon may stem from improved upper airway muscle tone, which decreases collapsibility and potentially reduces the required CPAP pressures. Additionally, enhanced sleep quality and the reduction of daytime symptoms may promote better adherence. However, it should be noted that these results involved a relatively small study cohort of 70 patients; hence, further cross-sectional studies with greater statistical power are warranted.
In contrast to the beneficial effects on respiratory parameters and selected quality of life indices, none of the analyzed studies demonstrated a significant impact of OE on BMI. This is consistent with previous research suggesting that the observed therapeutic benefits stem primarily from the local impact on upper airway function rather than from anthropometric changes.

4.5 Comparison of Exercise Modalities

Among the analyzed interventions, AE exerts the most comprehensive and systemic impact on the course of OSA by improving sleep architecture, reducing daytime sleepiness, and optimizing the cardiometabolic profile. Conversely, OE are characterized by the highest consistency of evidence in directly reducing the AHI, alongside a unique ability to improve adherence to CPAP therapy. RT appears to yield the greatest benefits when combined with AE, whereas RMT/IMT may serve as a valuable adjunctive treatment for selected patients presenting with a low arousal threshold. These findings suggest that the greatest therapeutic potential lies in customizing physical activity programs based on the dominant OSA phenotype and the patient's individual therapeutic goals.

4.6 Limitations and Future Research Directions

Limitations

The findings of this review should be interpreted in light of several significant limitations. First, the included studies exhibit substantial heterogeneity regarding intervention protocols, duration, and patient populations. Second, many trials involve small sample sizes and short follow-up periods, which limits the generalizability of the results and the assessment of the long-term efficacy of individual exercise interventions. Third, there remains a lack of direct comparisons between different modalities of exercise and their combined impact with CPAP therapy. Such comparisons would allow for a definitive determination of the benefits derived from training in combination therapy, as well as the development of tailored training protocols targeted at patients' greatest needs and achievable clinical benefits.

Additionally, most studies focused primarily on changes in polysomnographic parameters and clinical symptoms, whereas data concerning hard endpoints—such as cardiovascular events, hospitalizations, or mortality rates—remain limited.

Another substantial issue is the limited representation of patients with multimorbidity. Numerous trials excluded patients with heart failure, severe obesity, or other chronic conditions frequently co-occurring with OSA. Consequently, the generalizability of these findings to the patient population encountered in daily clinical practice remains constrained.

Future Directions

Future research should focus on addressing current gaps in the evidence. In particular, large-scale randomized controlled trials utilizing standardized training protocols are needed to enable a more precise evaluation of the efficacy of distinct physical activity modalities in OSA therapy. Furthermore, future studies should emphasize an approach based on patient phenotyping. A deeper understanding of the dominant pathophysiological mechanisms, such as increased upper airway collapsibility, high loop gain, a low arousal threshold, or impaired pharyngeal muscle activation, may facilitate more tailored selections of therapeutic interventions.

It is also worthwhile to investigate more thoroughly the interplay between various forms of physical activity and CPAP therapy, including their combined impact on treatment adherence and long-term clinical outcomes.

Future studies should also include enough participants with different levels of severity of OSA (mild, moderate and severe) to permit adequate assessment of the impact of traning therapy in OSA.

5. Conclusion

The results of this review suggest that future adjunctive OSA therapies should focus on personalizing exercise protocols according to the patient's dominant pathophysiological mechanisms and specific phenotype.

Disclossure: Authors do not report any disclosures.

Supplementary Materials: Not applicable.

Author Contributions:

Conceptualization: Monika Kukla

Methodology: Marta Zdunek, Anna Bulicz

Investigation: Izabela Kasprzycka, Sebastian Kozłowski

Resources: Anna Bulicz, Joanna Dziarnowska

Writing—original draft preparation: Sebastian Kozłowski,

Investigation: Monika Kukla, Justyna Fiks

Writing-rough preparation: Joanna Dziarnowska,

Writing—review and editing: Monika Kukla, Izabela Kmiecik

Visualisation: Izabela Kasprzycka, Maciej Stodulski

Supervision: Olga Kowalczyk, Justyna Fiks

Project administration: Monika Kukla, Olga Kowalczyk

All authors have read and agreed with the published version of the manuscript.

Funding: This research received no external funding

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgements: Not applicable.

Conflicts of Interest: The authors declare no conflicts of interest.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used Chat GPT (OpenAI) to improve grammar and language corrections. After using this tool, the authors have reviewed and edited the content as needed and accept full responsibility for the substantive content of the publication.

References

[1] E. Olszewska *et al.*, "Consensus Statements among European Sleep Surgery Experts on Snoring and Obstructive Sleep Apnea: Part 1 Definitions and Diagnosis," *J. Clin. Med.*, vol. 13, no. 2, Jan. 2024, doi: 10.3390/jcm13020502. https://pmc.ncbi.nlm.nih.gov/articles/PMC12787168/

[2] A. V. Benjafield *et al.*, "Estimation of the global prevalence and burden of obstructive sleep apnoea: a literature-based analysis," *Lancet Respir. Med.*, vol. 7, no. 8, pp. 687–698, Aug. 2019, doi: 10.1016/S2213-2600(19)30198-5. https://pmc.ncbi.nlm.nih.gov/articles/PMC7007763/

[3] G. Iannella *et al.*, "The Global Burden of Obstructive Sleep Apnea," May 01, 2025, *Multidisciplinary Digital Publishing Institute (MDPI)*. doi: 10.3390/diagnostics15091088. https://pmc.ncbi.nlm.nih.gov/articles/PMC12071658/

[4] S.-K. Park *et al.*, "GUIDELINE FOR THE MANAGEMENT OF OBESITY IN ADULT PATIENTS WITH OBSTRUCTIVE SLEEP APNEA Running title: Obesity Management in OSA," 2026. https://e-ceo.org/journal/view.php?id=10.21053/ceo.2025-00396

[5] S. Ahbab *et al.*, "Neck circumference, metabolic syndrome and obstructive sleep apnea syndrome; Evaluation of possible linkage," *Medical Science Monitor*, vol. 19, no. 1, pp. 111–117, Feb. 2013, doi: 10.12659/MSM.883776. https://pmc.ncbi.nlm.nih.gov/articles/PMC8340897/

[6] A. Battisha, A. Kahlon, and D. K. Kalra, "Sleep-Disordered Breathing and Hypertension—A Systematic Review," May 01, 2025, *Multidisciplinary Digital*

Publishing Institute (MDPI). doi: 10.3390/jcm14093115. https://www.mdpi.com/2077-0383/14/9/3115

[7] S. Tang, Q. Li, H. Yang, and Y. Liu, "Causal Associations Between Obstructive Sleep Apnea and Hypertension: Evidence From a Bidirectional and Multivariable Mendelian Randomization Analysis," *Int. J. Hypertens.*, vol. 2025, no. 1, 2025, doi: 10.1155/ijhy/8814506. https://www.frontiersin.org/journals/medicine/articles/10.3389/fmed.2026.1785996/full

[8] M. P. Mansukhani, B. P. Kolla, and V. K. Somers, "Hypertension and Cognitive Decline: Implications of Obstructive Sleep Apnea," Jul. 10, 2019, *Frontiers Media S.A.* doi: 10.3389/fcvm.2019.00096. https://pmc.ncbi.nlm.nih.gov/articles/PMC6636426/

[9] R. P. Ogilvie and S. R. Patel, "The Epidemiology of Sleep and Diabetes," Oct. 01, 2018, *Current Medicine Group LLC 1*. doi: 10.1007/s11892-018-1055-8. https://www.frontiersin.org/journals/nutrition/articles/10.3389/fnut.2026.1823259/full

[10] S. B. Gribsholt *et al.*, "Obstructive sleep apnoea and risk of dementia: a Danish population-based cohort study," *BMJ Neurol. Open*, vol. 7, no. 2, Aug. 2025, doi: 10.1136/bmjno-2025-001174. https://onlinelibrary.wiley.com/doi/10.1111/eva.70223?af=R

[11] G. R. Geovanini and G. Lorenzi-Filho, "Cardiac rhythm disorders in obstructive sleep apnea," Dec. 01, 2018, *AME Publishing Company*. doi: 10.21037/JTD.2018.12.63. https://jtd.amegroups.org/article/view/26009/html

[12] V. Luzzi *et al.*, "Correlations of Obstructive Sleep Apnea Syndrome and Daytime Sleepiness with the Risk of Car Accidents in Adult Working Population: A Systematic Review and Meta-Analysis with a Gender-Based Approach," Jul. 01, 2022, *MDPI*. doi: 10.3390/jcm11143971. https://pmc.ncbi.nlm.nih.gov/articles/PMC9319534/

[13] V. Lai, J. C. Carberry, and D. J. Eckert, "Sleep Apnea Phenotyping: Implicaions for Dental Sleep Medicine," *J. Dent. Sleep Med.*, vol. 6, no. 2, Apr. 2019, doi: 10.15331/jdsm.7072. https://www.researchgate.net/publication/332341610_Sleep_Apnea_Phenotyping_Implications_for_Dental_Sleep_Medicine

[14] M. Wieckiewicz *et al.*, "An exploratory study on the association between serotonin and sleep breathing disorders," *Sci. Rep.*, vol. 13, no. 1, Dec. 2023, doi: 10.1038/s41598-023-38842-y. https://www.nature.com/articles/s41598-023-38842-y

[15] A. Polecka, N. Olszewska, M. Pulido, and E. Olszewska, “Rostral fluid shifts and other mechanisms of interaction between obstructive sleep apnea and heart failure – a systematic review,” *Otolaryngologia Polska*, vol. 78, no. 5, pp. 10–17, Oct. 2024, doi: 10.5604/01.3001.0054.6742. https://otolaryngologypl.com/article/546742/en

[16] A. Malhotra *et al.*, “Metrics of sleep apnea severity: Beyond the apnea-hypopnea index,” *Sleep*, vol. 44, no. 7, Jul. 2021, doi: 10.1093/sleep/zsab030. https://pmc.ncbi.nlm.nih.gov/articles/PMC8271129/

[17] M. M. Lyons, N. Y. Bhatt, A. I. Pack, and U. J. Magalang, “Global burden of sleep-disordered breathing and its implications,” Jul. 01, 2020, *Blackwell Publishing*. doi: 10.1111/resp.13838. https://titula.universidadeuropea.com/bitstream/handle/20.500.12880/632/185.pdf?sequence=1&isAllowed=y

[18] W. Randerath *et al.*, “European Respiratory Society guideline on non-CPAP therapies for obstructive sleep apnoea,” *European Respiratory Review*, vol. 30, no. 162, Dec. 2021, doi: 10.1183/16000617.0200-2021. https://pmc.ncbi.nlm.nih.gov/articles/PMC9489103/

[19] I. H. Iftikhar *et al.*, “Comparative efficacy of CPAP, MADs, exercise-training, and dietary weight loss for sleep apnea: a network meta-analysis,” *Sleep Med.*, vol. 30, pp. 7–14, Feb. 2017, doi: 10.1016/j.sleep.2016.06.001. https://www.sciencedirect.com/science/article/pii/S1389945716300454?via%3Dihub

[20] P. V. Borker *et al.*, “Neighborhoods with greater prevalence of minority residents have lower continuous positive airway pressure adherence,” *Am. J. Respir. Crit. Care Med.*, vol. 204, no. 3, pp. 339–346, Aug. 2021, doi: 10.1164/rccm.202009-3685OC. https://pmc.ncbi.nlm.nih.gov/articles/PMC8513592/

[21] O. Contal *et al.*, “One-Year Adherence to Continuous Positive Airway Pressure With Telemonitoring in Sleep Apnea Hypopnea Syndrome: A Randomized Controlled Trial,” *Front. Med. (Lausanne).*, vol. 8, Apr. 2021, doi: 10.3389/fmed.2021.626361. https://www.frontiersin.org/journals/medicine/articles/10.3389/fmed.2021.626361/full

[22] P. Wang, Y. Chen, A. Zhang, C. Xie, and K. Wang, “Comparative efficacy of exercise modalities on sleep architecture in adults with sleep disorders: a systematic review and network meta-analysis of randomized controlled trials,” Oct. 01, 2025, *Elsevier B.V.* doi: 10.1016/j.sleep.2025.106680. https://www.sciencedirect.com/science/article/pii/S1389945725003557?via%3Dihub

[23] O. L. Lins-Filho *et al.*, "Effect of exercise training on subjective parameters in patients with obstructive sleep apnea: a systematic review and meta-analysis," May 01, 2020, *Elsevier B.V.* doi: 10.1016/j.sleep.2019.12.022. https://www.sciencedirect.com/science/article/pii/S1389945720300095?via%3Dihub

[24] I. C. Themistocleous, S. Hadjisavvas, E. Papamichael, C. Michailidou, M. A. Efstathiou, and M. Stefanakis, "Exploring Exercise Interventions for Obstructive Sleep Apnea: A Scoping Review," Sep. 01, 2025, *Multidisciplinary Digital Publishing Institute (MDPI)*. doi: 10.3390/jfmk10030253. https://pmc.ncbi.nlm.nih.gov/articles/PMC12286203/

[25] J. R. Rueda, I. Mugueta-Aguinaga, J. Vilaró, and M. Rueda-Etxebarria, "Myofunctional therapy (oropharyngeal exercises) for obstructive sleep apnoea," Nov. 03, 2020, *John Wiley and Sons Ltd*. doi: 10.1002/14651858.CD013449.pub2. https://pmc.ncbi.nlm.nih.gov/articles/PMC8094400/

[26] S. Siatkowski, J. Walencik, M. Sikora, and A. Żebrowska, "Efficacy of therapies based on muscle strength training among individual with obstructive sleep apnea - a systematic review and meta-analysis," Mar. 01, 2026. doi: 10.1016/j.rmed.2026.108702. https://www.sciencedirect.com/science/article/pii/S0954611126000703?via%3Dihub

[27] C. Justribó-Manion *et al.*, "Active conservative interventions for obstructive sleep apnea: An umbrella review and meta-meta-analysis of systematic reviews," *Sleep Med.*, vol. 138, p. 108665, Feb. 2026, doi: 10.1016/J.SLEEP.2025.108665. https://www.sciencedirect.com/science/article/pii/S1389945725023408

[28] C. F. Lin, N. H. Ho, W. L. Hsu, C. H. Lin, Y. H. Wang, and Y. P. Wang, "The effects of exercise training as a treatment component of obstructive sleep apnea in diverse patient groups: current understanding and focus areas," Nov. 01, 2024, *American Academy of Sleep Medicine*. doi: 10.5664/jcsm.11310. https://www.researchgate.net/publication/383179086_Effects_of_aerobic_exercise_and_resistance_training_on_obstructive_sleep_apnea_a_systematic_review_and_meta-analysis

[29] X. Lin *et al.*, "Comparative effects of weight-loss diet, exercise training, respiratory muscle training, and oropharyngeal muscle training in obstructive sleep apnea: a systematic review and network meta-analysis," *Front. Med. (Lausanne).*, vol. 13, Mar. 2026, doi: 10.3389/fmed.2026.1789371. https://www.frontiersin.org/journals/medicine/articles/10.3389/fmed.2026.1789371/full

[30] M. F. I. Castellanos, J. L. da Costa, L. M. Oliveira, J. de Oliveira, F. B. Zanatta, and C. C. Callegaro, “Comparative effectiveness of CPAP and isolated or combined non-invasive therapies for obstructive sleep apnea: A network meta-analysis,” *Sleep Med.*, vol. 141, p. 108795, May 2026, doi: 10.1016/J.SLEEP.2026.108795. https://www.sciencedirect.com/science/article/pii/S138994572600033X?via%3Dihub

[31] L. Martínez Revuelta, J. Flores-Fraile, Á. Zubizarreta-Macho, J. M. Montiel-Company, A. B. Lobo-Galindo, and P. Arrieta Blanco, “Relationship Between Obstructive Sleep Apnea and Sports—Systematic Review and Meta-Analysis,” Nov. 01, 2024, *Multidisciplinary Digital Publishing Institute (MDPI)*. doi: 10.3390/jcm13226814. https://europepmc.org/article/med/39597959#free-full-text

[32] I. H. Iftikhar, A. M. Reynolds, E. AlBisher, S. D. Youngstedt, and A. BaHammam, “Aerobic exercise training and obstructive sleep apnea: dose-response meta-analyses,” Dec. 01, 2024, *Springer Science and Business Media Deutschland GmbH*. doi: 10.1007/s11325-024-03158-2. https://link.springer.com/article/10.1007/s11325-024-03158-2

[33] M. Pawar, P. Venkatesan, S. Mysore, and G. Bhat, “Effectiveness of aerobic exercise training in patients with obstructive sleep apnea: a systematic review and meta-analysis,” Feb. 01, 2025, *Springer Science and Business Media Deutschland GmbH*. doi: 10.1007/s00405-025-09436-3. https://pmc.ncbi.nlm.nih.gov/articles/PMC12987821/

[34] Y. G. Borges *et al.*, “Oxidative stress and inflammatory profiles in obstructive sleep apnea: are short-term CPAP or aerobic exercise therapies effective?,” *Sleep and Breathing*, vol. 24, no. 2, pp. 541–549, Jun. 2020, doi: 10.1007/s11325-019-01898-0. https://link.springer.com/article/10.1007/s11325-019-01898-0

[35] J. R. V. de Almeida *et al.*, “Effects of resistance training on obstructive sleep apnea severity: a randomized controlled trial,” *Sleep Med.*, vol. 142, p. 108879, Jun. 2026, doi: 10.1016/J.SLEEP.2026.108879. https://www.sciencedirect.com/science/article/pii/S1389945726001188

[36] R. P. da Silva *et al.*, “The effects of resistance exercise on obstructive sleep apnea severity and body water content in older adults: A randomized controlled trial,” *Sleep Med.*, vol. 95, pp. 37–46, Jul. 2022, doi: 10.1016/J.SLEEP.2022.04.014. https://www.sciencedirect.com/science/article/pii/S1389945722001381

[37] J. Peng, Y. Yuan, Y. Zhao, and H. Ren, "Effects of Exercise on Patients with Obstructive Sleep Apnea: A Systematic Review and Meta-Analysis," Sep. 01, 2022, *MDPI*. doi: 10.3390/ijerph191710845. https://pmc.ncbi.nlm.nih.gov/articles/PMC9518429/

[38] L. M. Ueno-Pardi *et al.*, "Effects of exercise training on brain metabolism and cognitive functioning in sleep apnea," *Sci. Rep.*, vol. 12, no. 1, Dec. 2022, doi: 10.1038/s41598-022-13115-2. https://pmc.ncbi.nlm.nih.gov/articles/PMC9177702/

[39] C. E. L. Araújo *et al.*, "Effects of exercise training on autonomic modulation and mood symptoms in patients with obstructive sleep apnea," *Brazilian Journal of Medical and Biological Research*, vol. 54, no. 5, 2021, doi: 10.1590/1414-431x202010543. https://pmc.ncbi.nlm.nih.gov/articles/PMC7959152/

[40] R. Torres-Castro *et al.*, "Respiratory Muscle Training in Patients with Obstructive Sleep Apnoea: A Systematic Review and Meta-Analysis," Jun. 01, 2022, *Multidisciplinary Digital Publishing Institute (MDPI)*. doi: 10.3390/clockssleep4020020. https://pmc.ncbi.nlm.nih.gov/articles/PMC9036269/

[41] C. Zuo *et al.*, "Effects of Inspiratory Muscle Training on Obstructive Sleep Apnea: A Systematic Review and Meta-analysis," May 2026, doi: 10.1093/annalsats/aaoag041/8494362. https://academic.oup.com/annalsats/article/23/5/800/8494362

[42] W. Poncin, A. Willemsens, L. Gely, and O. Contal, "Assessment and rehabilitation of tongue motor skills with myofunctional therapy in obstructive sleep apnea: a systematic review and meta-analysis," *Journal of Clinical Sleep Medicine*, vol. 20, no. 9, pp. 1535–1549, Sep. 2024, doi: 10.5664/jcsm.11074. https://arodes.hes-so.ch/record/15587?ln=en&v=pdf

[43] Y. Xu, R. Yang, M. Yu, and X. Gao, "Efficacy of myofunctional therapy for obstructive sleep apnea: A systematic review and network meta-analysis," *Journal of Evidence-Based Dental Practice*, vol. 25, no. 3, p. 102137, Sep. 2025, doi: 10.1016/J.JEBDP.2025.102137. https://www.sciencedirect.com/science/article/pii/S1532338225000521

[44] E. Arslan and Ö. Şevgin, "The effects of Aerobic and oropharyngeal exercises on sleep quality of patients with obstructive sleep Apnoea syndrome: a randomized controlled study," *Sleep and Breathing*, vol. 28, no. 6, pp. 2729–2736, Dec. 2024, doi:

10.1007/s11325-024-03157-3. https://link.springer.com/article/10.1007/s11325-024-03157-3

[45] S. Çakmakcı, A. Özgen Alpaydın, S. Özalevli, İ. Öztura, and B. O. İtil, "The effect of oropharyngeal exercise in patients with moderate and severe obstructive sleep apnea using CPAP: a randomized controlled study," *Sleep and Breathing*, vol. 26, no. 2, pp. 567–574, Jun. 2022, doi: 10.1007/s11325-021-02423-y. https://link.springer.com/article/10.1007/s11325-021-02423-y

[46] C. J. Beatty *et al.*, "The impact of exercise training on the obstructive sleep apnea endotypes," *Sleep Med.*, vol. 139, Mar. 2026, doi: 10.1016/j.sleep.2025.108740. https://www.sciencedirect.com/science/article/pii/S1389945725024153?via%3Dihub

[47] M. Mendelson, O. D. Lyons, A. Yadollahi, T. Inami, P. Oh, and T. D. Bradley, "Effects of exercise training on sleep apnoea in patients with coronary artery disease: A randomised trial," *European Respiratory Journal*, vol. 48, no. 1, pp. 142–150, Jul. 2016, doi: 10.1183/13993003.01897-2015. https://publications.ersnet.org/content/erj/48/1/142

[48] E. Perger, E. M. Jutant, and S. Redolfi, "Targeting volume overload and overnight rostral fluid shift: A new perspective to treat sleep apnea," Dec. 01, 2018, *W.B. Saunders Ltd*. doi: 10.1016/j.smrv.2018.07.008. https://www.sciencedirect.com/science/article/pii/S1087079218300339

[49] A. S. Stöberl *et al.*, "Night-to-night variability of obstructive sleep apnoea." [Online]. Available: www.controlled-trials.com

[50] M. Roeder *et al.*, "Night-to-night variability of respiratory events in obstructive sleep apnoea: A systematic review and meta-analysis," *Thorax*, vol. 75, no. 12, pp. 1095–1102, Dec. 2020, doi: 10.1136/thoraxjnl-2020-214544. https://thorax.bmj.com/content/75/12/1095.long

[51] C. K. Law, F. M. Lam, R. C. Chung, and M. Y. Pang, "Physical exercise attenuates cognitive decline and reduces behavioural problems in people with mild cognitive impairment and dementia: a systematic review," *J. Physiother.*, vol. 66, no. 1, pp. 9–18, Jan. 2020, doi: 10.1016/j.jphys.2019.11.014. https://www.sciencedirect.com/science/article/pii/S1836955319301341

[52] K. A. Wilckens, K. I. Erickson, and M. E. Wheeler, "Physical Activity and Cognition: A Mediating Role of Efficient Sleep," *Behavioral Sleep Medicine*, vol. 16, no. 6, pp. 569–

586, Nov. 2018, doi: 10.1080/15402002.2016.1253013. https://pmc.ncbi.nlm.nih.gov/articles/PMC5466488/

[53] V. Bironneau *et al.*, “Sleep apnoea and endothelial dysfunction: An individual patient data meta-analysis,” Aug. 01, 2020, *W.B. Saunders Ltd*. doi: 10.1016/j.smrv.2020.101309. https://www.sciencedirect.com/science/article/pii/S1087079220300526?via%3Dihub

[54] A. F. Kramer and S. Colcombe, “Fitness Effects on the Cognitive Function of Older Adults: A Meta-Analytic Study—Revisited,” *Perspectives on Psychological Science*, vol. 13, no. 2, pp. 213–217, Mar. 2018, doi: 10.1177/1745691617707316. https://journals.sagepub.com/doi/10.1177/1745691617707316

[55] T. T. Goya *et al.*, “Exercise training reduces sympathetic nerve activity and improves executive performance in individuals with obstructive sleep apnea,” *Clinics*, vol. 76, 2021, doi: 10.6061/clinics/2021/e2786. https://pmc.ncbi.nlm.nih.gov/articles/PMC8382151/

[56] M. Mendelson *et al.*, “Maximal exercise capacity in patients with obstructive sleep apnoea syndrome: A systematic review and meta-analysis,” 2018, *European Respiratory Society*. doi: 10.1183/13993003.02697-2017. https://publications.ersnet.org/content/erj/51/6/1702697

[57] T. Zekis, E. Grammatopoulou, D. Tsimouris, V. Sakellari, and I. Patsaki, “The effectiveness of respiratory training as a preventive strategy against cognitive decline: a mini review,” 2026, *Frontiers Media SA*. doi: 10.3389/fresc.2026.1778837. https://www.frontiersin.org/journals/rehabilitation-sciences/articles/10.3389/fresc.2026.1778837/full

[58] P. Huang, Q. Tang, X. Yang, M. Li, and S. Li, “Effects of oropharyngeal exercises on CPAP compliance: A prospective intervention study,” *American Journal of Otolaryngology - Head and Neck Medicine and Surgery*, vol. 45, no. 4, Jul. 2024, doi: 10.1016/j.amjoto.2024.104274. https://www.sciencedirect.com/science/article/pii/S0196070924000607