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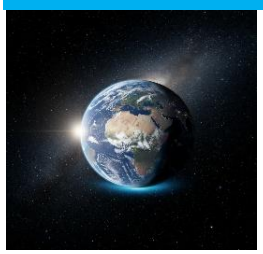

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Resistance training in Obstructive Sleep Apnea: current evidence, limitations, and future directions

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Abstract

Background: Obstructive sleep apnea (OSA) is a common, sleep-related breathing disorder associated with increased cardiovascular and metabolic risk. Continuous positive airway pressure (CPAP) remains the standard treatment; however, limited adherence and persistent symptoms in some patients caused growing interest in non-pharmacological supportive interventions, including physical activity. The role of resistance training as a distinct intervention in OSA remains poorly defined.

Aim: The aim of this narrative review was to summarize current evidence regarding the potential benefits, risks, and practical considerations of resistance training in adult patients with obstructive sleep apnea.

Methodology: A narrative review of studies involving adult patients with diagnosed OSA was conducted using major biomedical databases, focusing on resistance training performed alone or as part of combined exercise interventions.

Results: Available evidence suggests that resistance training, alone or combined with aerobic exercise, may improve sleep-related breathing parameters, sleep quality, daytime symptoms, muscle strength, and physical function. At the same time, available data highlight potential risks related to transient hemodynamic responses during high-intensity resistance exercise, orthopedic overload, and technique-related breathing disturbances.

Conclusions: Resistance training appears to be a promising adjunct to non-pharmacological management of OSA; however further well-designed randomized controlled trials are needed to clarify its long-term efficacy, safety, and optimal training parameters.

Key words: Obstructive sleep apnea; resistance training; non-pharmacological interventions.

Introduction

Obstructive sleep apnea (OSA) is a disease caused by repeated episodes of complete or partial upper airway obstruction at the pharyngeal level, lasting at least 10 seconds [1], despite preserved respiratory muscle activity. The primary diagnostic test for OSA is polysomnography preceded by a sleep-disordered breathing questionnaire and an assessment of daytime sleepiness. According to the third edition of the International Classification of Sleep Disorders (ICSD-3), OSA is considered clinically significant when the respiratory disturbance index (RDI) is ≥ 15 events per hour regardless of symptoms, or ≥5 events per hour in the presence of typical OSA symptoms [2]. It is estimated that OSA may affect 4% of men and 2% of women [3], but recent studies show that the disease prevalence may be higher depending on the definition of OSA and the studied population [2]. Symptoms of OSA include snoring, apneas and gasping for breath and excessive daytime sleepiness. OSA has also been shown to be associated with cardiovascular diseases such as arterial hypertension, stroke, myocardial infarction, heart failure and metabolic complications [1,2]. The main risk factor for OSA is obesity, which occurs in up to 70% of patients. Other risk factors are male gender, advanced age, anatomical abnormalities of the upper airway, Black race, alcohol consumption and smoking [1]. The primary treatment for OSA is continuous positive airway pressure (CPAP) therapy. Patients sleep each night with a mask that maintains the upper airway open by delivering positive airway pressure. The effectiveness of this therapy in reducing the number of apnea episodes, improving sleep parameters and reducing daytime sleepiness has been confirmed in clinical trials [4]. Despite its demonstrated effectiveness, CPAP has certain limitations in clinical practice. The main problem is poor compliance. CPAP is also associated with side effects, such as nasal bridge pain, eye redness, dry nose or mouth, nasal congestion, runny nose, sinusitis and nosebleeds [5,6]. Furthermore, studies have shown that in some patients CPAP does not eliminate daytime sleepiness symptoms, a condition referred to as residual excessive sleepiness (RES), which represents an important limitation of this treatment method [7]. In recent years, increasing attention has been given to non-pharmacological approaches supporting the treatment of OSA, particularly lifestyle modification and physical activity. This is due both to

the limitations of CPAP therapy and to a growing body of evidence indicating that appropriately tailored physical activity may positively affect OSA severity and overall patient health [8]. Resistance training may be an interesting form of intervention in this group of patients, as it helps improve body composition, increases muscle mass and strength and improves functional capacity, which is especially important in individuals with obesity and in older adults who are at increased risk of OSA [9,10]. Despite the growing interest in the role of physical activity in the treatment of OSA, most available studies focus on aerobic exercise or combined interventions, while data on resistance training as a separate form of intervention remain limited [11,12]. The aim of this study is to analyse the available scientific evidence on the benefits and potential risks of resistance training on adult patients with OSA, with consideration of its possible application in treatment and rehabilitation.

Materials and Methods

This study is a narrative review aimed at providing an integrative overview of current evidence regarding the potential benefits, risks, and practical considerations of resistance training in adult patients with OSA. A targeted literature search was performed in the PubMed, Scopus and Web of Science databases to identify relevant publications. The search covered studies published between January 2000 and March 2026. The following keywords were used in combinations: obstructive sleep apnea, OSA, strength training, resistance training, physical activity. The analysis included original studies, randomized clinical trials, observational studies and review articles involving patients aged ≥18 years with diagnosed OSA; articles examining strength or resistance training, either as a standalone intervention or as part of a combined therapeutic approach, as well as studies assessing the effects of physical activity on sleep parameters, clinical OSA symptoms, physical performance, or quality of life were included. Publications involving children and adolescents, studies not related to physical activity and without structured resistance-based exercise interventions, articles describing only pharmacological or surgical interventions, were excluded from the analysis. Article selection was performed based on relevance to the research objectives and thematic consistency with the scope of the review. Relevant information was extracted from selected studies and synthesized qualitatively. The following data were collected where available: study design and population characteristics, OSA severity criteria, description of exercise interventions, training duration and intensity, main clinical and functional outcomes, reported adverse events and safety considerations. Due to heterogeneity of study designs and outcome measures, formal quantitative synthesis was not

performed. Given the narrative nature of this review, no formal risk-of-bias assessment tool was applied. However, the methodological quality of the included studies was considered during interpretation of the results, with particular attention to study design, sample size, presence of control groups, and intervention characteristics.

The results of these studies are presented and discussed in the next section.

Evidence From Experimental and Clinical Studies

1. Resistance training as a main intervention

In recent years, a growing number of studies have been published examining the effects of various forms of physical activity on OSA, but the vast majority of these studies focus on aerobic training or combined programs. The only randomized study identified that specifically assessed the effects of resistance training on OSA is the study by da Silva et al. [13]. The study included 23 individuals aged 65-80 years with diagnosed OSA, with a respiratory event index (REI) between 20 and 45 events per hour of sleep, who had not followed previous recommendations (CPAP or oral appliance therapy) for more than one year. Participants were randomly assigned to a 12-week resistance training program or a control group that received healthy lifestyle recommendations. The training program consisted of two whole-body resistance training sessions two times per week, with at least 48 hours between sessions. Each session included exercises for the legs, arms, chest, back and abdominal muscles and the load was individually tailored to each individual. A statistically significant reduction in RDI was observed in the training group compared with the control group, without significant changes in body weight [13].

Combined aerobic + resistance programs

Most available interventional studies on the effects of physical activity on OSA are based on programs combining aerobic training with resistance training. Kline et al. [14] conducted a randomized trial assessing the effect of exercise training on reducing OSA severity and improving sleep quality in adults with OSA. The study included 43 individuals aged 18-55 years, who were overweight or obese and had moderate to severe OSA and were not receiving treatment. Participants were randomly assigned to a control group, which performed flexibility exercises twice a week for 12 weeks, and a training group, which performed aerobic exercise four times a week and resistance training twice a week for 12 weeks. A statistically significant

reduction in the severity of sleep-disordered breathing was observed compared to the control group, regardless of significant weight loss. Improvements in sleep quality were also observed [14].

In the study by Desplan et al. [15], the effect of a comprehensive rehabilitation program on reducing the severity of OSA was assessed in a pilot randomized clinical trial. 22 patients aged 35-70 years with moderate to severe untreated OSA were randomly assigned to a control group and an intervention group, which included supervised exercise training several times a week, consisting of aerobic exercise, resistance exercises, stretching exercises and postural-balance training. The rehabilitation program was shown to be associated with a significant reduction in OSA severity compared with the control group. Improvements in daytime symptoms, such as fatigue and sleepiness, were also achieved [15].

Another study that describes the effect of resistance training combined with aerobic exercise on adults with OSA is the study by Barnes et al. [16] 12 individuals were enrolled in the study. The program included resistance training three times a week for 16 weeks and aerobic exercise five times a week from weeks 5 to 16. Participants also followed a low-calorie diet. This was a pilot study and did not include a traditional control group, which limits the ability to clearly interpret the results. The authors observed improvements in selected clinical parameters [16].

Study (author)	**Participants (n, age)**	**OSA severity criteria**	**Intervention**	**Duration/frequency**	**Control group**	**Sleep-related outcome**
da Silva et al.	n=23, 65-80 years	REI 20-45 events/h	Whole-body resistance training	12 weeks, 2x/week	Healthy lifestyle advice	↓ RDI compared with control
Kline et al.	n=43, 18-55 years	Moderate to severe	Aerobic activity +AT, 2x/week resistance training RT	12 weeks, 4x/week	Low-intensity exercises	Reduction in OSA severity, sleep quality improvement
Desplan et al.	n=22, 35-70 years	Moderate to severe	Aerobic exercise, resistance exercises,	Short-term (duration not reported)	Education activity sessions	Reduction in OSA severity, reduction in

		stretching exercises and posturalbalance training			daytime sleepiness
Barnes et al.	n=12, middle-aged	Mild to moderate OSA	Resistance training, arrobic exercise	16, weeks RT 3×/week (16 wks) +group AE 5×/week (wks 5–16) + low-calorie diet	No control	No significant change in sleep disordered breathing.

OSA – obstructive sleep apnea, REI – respiratory event index, RDI - respiratory disturbance index, AE – aerobic training, RT – resistance training

Table 1. Characteristics of studies assessing resistance training and related interventions in patients with OSA

Respiratory muscle training

Although respiratory muscle training (RMT) is not classic whole-body resistance training, it is a form of resistance training that targets specific muscle groups that play a significant role in the pathophysiology of OSA. In the study by Kuo et al. 25 patients with OSA were assigned to a control group or a group that performed expiratory muscle resistance training (EMST) for 5 weeks. Expiratory muscle strength, sleep quality, daytime sleepiness and parameters of sleep-related breathing disorders were assessed before and after the intervention. The study demonstrated a reduction in OSA symptoms, particularly in individuals with moderate disease, improved sleep quality, and increased expiratory muscle strength [17].

In the study by Ertuk et al. [18], the effects of low- and high-intensity EMST on OSA severity were compared. 31 men aged 18-65 years with moderate OSA participated in the study. They were assigned to two groups: high-EMST and low-EMST. High-EMST was shown to be more effective in alleviating OSA symptoms than low-EMST. Furthermore, EMST was shown to improve expiratory muscle strength by reducing inflammation and oxidative stress in male patients with moderate OSA [18].

Benefits of resistance training in OSA

1. Reducing the severity of sleep-related breathing disorders

Available studies indicate that resistance training appears to be associated with a reduction in OSA severity, as measured by indices of sleep-disordered breathing. The most consistent evidence comes from the randomized study by Silva et al. [13], in which resistance training was used as a standalone intervention in older adults with moderate OSA and was associated with a reduction in the frequency of sleep-disordered breathing episodes. These findings suggest that resistance training may serve as an effective supportive intervention in the management of OSA in older adults, particularly when improving frailty and sarcopenia is also a therapeutic goal [13]. Indirect evidence for the role of resistance training in reducing the severity of OSA symptoms comes from studies in which resistance training was part of a combined intervention with aerobic exercise. Reductions in OSA severity were also observed with this intervention; however, in these studies it is difficult to attribute the observed effects exclusively to resistance training. The available data suggest that the resistance component may make a significant contribution to improving sleep parameters, especially in patients with limited aerobic exercise tolerance [14-16].

2. Improving the quality of sleep and daytime sleepiness

Resistance exercise may have a beneficial effect on subjective sleep quality and daytime sleepiness in patients affected by OSA. Interventional studies have demonstrated improved sleep quality following training programs including resistance exercises [14,15]. Daytime sleepiness is one of the characteristic symptoms of OSA and, together with other symptoms, may lead to a deterioration in quality of life [1].

3. Improvement in physical performance and muscle strength.

Patients with OSA are characterized by reduced physical fitness and poorer exercise tolerance, so the use of resistance training, whose natural effects include improvements in muscle strength and functional capacity, appears to be justified adjunctive therapy [9,19]. In a study by da Silva et al. [13], an increase in lower limb muscle strength was observed after a training intervention [13]. Increased physical fitness may indirectly affect exercise tolerance, daytime physical activity levels, and overall functional status of patients.

4. Metabolic and cardiovascular benefits.

Resistance training is considered an effective method for improving metabolic and cardiovascular parameters, which are often impaired in individuals with OSA. Regular

resistance exercise can lead to improved glycemic control, reduced insulin resistance, and beneficial changes in body composition, including a reduction in fat mass [20]. Moreover, resistance training has been shown to lower blood pressure and improve endothelial function, which is particularly important in individuals with OSA who are at increased cardiovascular risk [21].

5. Potential use in patients who do not tolerate CPAP

A significant advantage of resistance training is its potential use as an adjunct or alternative therapy in patients who do not accept CPAP treatment or demonstrate poor adherence to this method. Reports indicate that despite CPAP use, some patients experience persistent symptoms, such as excessive daytime sleepiness, prompting the search for complementary therapeutic strategies [22]. In this situation, resistance training may be a valuable element of non-pharmacological treatment, improving symptom control and overall performance in patients with OSA [13-16].

Risk and limitations of resistance training in OSA

Despite the growing interest in resistance training as a supportive component of OSA management, it should be emphasized that this intervention is not free of potential risks and limitations. Patients with OSA often present with increased cardiovascular risk, arterial hypertension, obesity, and reduced exercise tolerance, which requires caution in the planning and implementation of resistance training programs. The following subsection discusses the most important potential risks and limitations associated with the use of resistance training in this patient population.

1. Cardiovascular risk

Patients with OSA are characterized by an increased prevalence of arterial hypertension, coronary artery disease, and cardiac arrhythmias. OSA is associated with sympathetic nervous system hyperactivity and endothelial dysfunction; patients experience recurrent episodes of hypoxia and sleep arousals, which lead to a sustained increase in sympathetic nervous system activity, also during daytime [23]. Although regular resistance-based exercise may lead to a long-term reduction in blood pressure, it should be emphasized that resistance exercise is associated with significant transient hemodynamic changes, which may pose a clinical risk in adults with OSA and coexisting conditions [21,23]. Sudden increases in blood pressure are

observed during intense resistance training. Studies have shown that systolic blood pressure can exceed 300 mmHg in healthy individuals during high-load exercise [24]. In patients with OSA and comorbid cardiovascular disease, such increases may increase the risk of cardiac events. Moreover, OSA is related to an increased incidence of arrhythmias [23,25]. Resistance exercise may potentially promote the development of cardiac arrhythmias in the population. Therefore, resistance training in this group of patients should be performed with particular caution and appropriately adjusted in terms of exercise intensity and volume, then monitored and modified as necessary [21].

2. Orthopedic risk

Individuals with OSA are often overweight or obese, which increases the mechanical load on the musculoskeletal system during physical activity. Studies indicate that a higher body mass index (BMI) is a risk factor for musculoskeletal injuries during physical activity, particularly in the knee, ankle and shoulder areas [26]. Furthermore, obesity modifies gait biomechanics, which may result in abnormal load distribution and an increased risk of joint injuries during resistance training [27]. Although moderate physical activity is recommended in the treatment of obesity, excessively intense exercise without appropriate load progression and technique can lead to musculoskeletal strain, tendonitis, and joint pain, particularly in beginners or individuals with existing musculoskeletal disorders [28]. In resistance training, which involves generating significant mechanical forces, this risk may be further exacerbated, especially when using heavy loads, improper technique, and a lack of an individually tailored training plan.

3. Respiratory risks associated with exercise technique.

In patients with OSA, the method of performing resistance exercises is particularly important, as improper breathing technique can exacerbate the underlying mechanisms of the disease. A characteristic feature of resistance training is the tendency to hold one’s breath and perform the Valsalva maneuver, which involves breath-holding against a closed glottis and leads to increased intrathoracic pressure, a transient reduction in venous return, and hemodynamic changes. Studies have shown that the Valsalva maneuver during resistance exercise significantly increases the workload of the cardiovascular system and can lead to transient disturbances in cerebral perfusion [24]. OSA is a heterogeneous disease in which both anatomical factors and impaired ventilatory control, characterized by increased loop gain, play

an important role, potentially predisposing patients to abnormal respiratory responses under conditions of increased respiratory load [29].

Risk area	Relevance in OSA	Potential mechanism	Practical consideration
Hemodynamic responses	High prevalence of hypertension and cardiovascular disease	Transient BP rise during resistance exercise; Valsalva maneuver	Gradual load progression; avoid breath-holding
Respiratory instability	Impaired ventilatory control with increased loop gain	Abnormal respiratory responses under load	Emphasize controlled breathing
Musculoskeletal overload	Frequent obesity and reduced fitness	Increased joint loading; altered biomechanics	Exercise selection adapted to body mass
Lack of safety data	Few studies report adverse events	Unknown long-term risk profile	Clinical supervision recommended

OSA - obstructive sleep apnea, BP – blood pressure

Table 2. Potential risks and practical considerations of resistance training in patients with OSA

Discussion

This narrative review highlights both the potential and the current limitations of resistance training as an adjunctive intervention in obstructive sleep apnea (OSA). Available evidence reflects an emerging research field characterized by methodological heterogeneity and limited mechanistic understanding [8,11,13]. Most interventional trials combine resistance training with aerobic exercise and dietary interventions. While such multimodal programs reflect real-world rehabilitation practice, they obscure the independent contribution of resistance training [14–16]. Only a limited number of studies have evaluated resistance training as a standalone intervention [13], preventing precise quantification of its isolated therapeutic effect.

A major challenge in interpreting existing studies lies in the substantial variability of training protocols, participant characteristics, and outcome measures. Intervention duration, training

intensity, and progression strategies differ markedly between studies, and outcome assessment ranges from objective respiratory indices to subjective sleep quality measures [13–16]. Apparent inconsistencies in reported outcomes may therefore reflect methodological differences rather than true biological variability [11,14].

Several pathophysiological pathways may explain the potential impact of resistance training on the apnea–hypopnea index. Improvements in body composition may reduce peripharyngeal fat deposition, thereby decreasing upper airway collapsibility [20]. Even modest reductions in visceral adiposity can influence mechanical airway properties. Resistance training improves insulin sensitivity and reduces systemic inflammation [18,20], both of which are implicated in OSA pathophysiology and sympathetic overactivity [23]. Enhanced overall physical capacity may improve ventilatory control during sleep by influencing autonomic balance and chemosensitivity [23,29].

Aerobic exercise has been more extensively studied in OSA and has demonstrated modest reductions in AHI independent of significant weight loss [11,14]. Compared with aerobic training, resistance exercise may offer additional benefits related to muscle mass preservation, metabolic control, and functional capacity [9,20]. However, current evidence does not clearly demonstrate superiority of resistance training over aerobic exercise in reducing OSA severity. Future trials directly comparing isolated aerobic versus resistance protocols are warranted.

Although resistance training has been associated with favorable clinical and functional outcomes, its implementation requires careful consideration of safety. Acute cardiovascular responses, musculoskeletal overload, and improper breathing techniques represent the main risk domains [21,24,26,27,29]. The predominance of moderate-intensity, supervised protocols in existing trials may partially explain the low incidence of reported adverse events [13–15]. However, inconsistent adverse-event reporting limits definitive conclusions regarding long-term safety and hinders the development of clear clinical recommendations.

Resistance training in patients with OSA may warrant cardiovascular risk assessment, particularly in individuals with known uncontrolled hypertension, unstable coronary artery disease, significant arrhythmias, or advanced heart failure [21,23]. In such cases, medical consultation and supervised exercise initiation may be advisable. High-intensity protocols involving breath-holding should be avoided in patients with poorly controlled blood pressure

or cerebrovascular risk [24]. Gradual load progression and submaximal intensity are preferable in deconditioned or obese individuals to minimize orthopedic injury risk [26,27].

Resistance training should be considered within the broader context of OSA management. CPAP remains the primary treatment for moderate to severe disease [2,4,30], while exercise interventions primarily influence systemic physiology and functional capacity [8,14]. Consequently, resistance training may enhance overall disease management by improving physical fitness, metabolic health, and treatment adherence [7,22].

Effective implementation requires interdisciplinary cooperation between sleep specialists, physiotherapists, and exercise professionals, for which standardized clinical pathways are currently lacking [21].

Importantly, the current evidence regarding the effects of resistance training on OSA is limited both in terms of the number of studies and their methodological quality. There is a lack of randomized clinical trials evaluating resistance training as a standalone intervention, and most available studies involve combined programs in which resistance training is included as part of a training program, along with aerobic or stretching exercises. Such an intervention design makes it difficult to clearly assess the specific effect of resistance training on OSA severity. Furthermore, most available studies have short follow-up periods, which makes it difficult to assess the long-term effectiveness and safety of resistance training in patients with OSA. The current studies did not include an assessment of the intervention's safety, including monitoring hemodynamic parameters and potential complications. This limits the ability to fully assess the risks associated with resistance training in individuals with OSA, especially those with coexisting diseases.

Conclusions

The available evidence indicates that resistance training may be considered a complementary intervention in adults with obstructive sleep apnea, particularly in patients with metabolic dysfunction, sarcopenia, or poor tolerance to aerobic exercise. Current evidence suggests modest improvements in sleep-related breathing parameters and consistent improvements in physical performance and metabolic health. At the same time, it should be noted that the number of studies evaluating resistance training as a standalone intervention remains limited. An

important consideration is the safety of this form of physical activity. Adults with OSA are often burdened by increased cardiovascular risk, obesity and reduced exercise tolerance, which necessitates careful training planning, individualized load prescription, and particular attention to exercise technique. Further well-designed randomized controlled trials are needed to assess the long-term efficacy and safety of resistance training in patients with OSA and to define optimal training parameters in this population.

Disclosure Section

Statement of the authors' contribution

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Validation: Magdalena Mida, Julia Stołtny
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Writing—original draft preparation: Magdalena Lisik, Natalia Hajok
Writing—review and editing: Urszula Majda, Anna Maruszak, Magdalena Mida
Visualization: Natalia Hajok, Justyna Goryczka
Supervision: Urszula Majda
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