



Diet Therapy of Obstructive Sleep Apnea Syndrome Treated with Positive Airway Pressure: A Systematic Review of Randomized Controlled Trials

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Abstract: The positive airway pressure (PAP) is a gold standard in therapy for obstructive sleep apnea (OSA) patients, though weight loss is among the most effective supportive therapeutic methods. The aim of the study is to conduct a systematic review of randomized controlled trials (RCTs) of diet therapy interventions for OSA patients treated with PAP. The systematic review was conducted based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and registered in the International Prospective Register of Systematic Reviews (PROSPERO) database (CRD42023398374). The 1436 records were screened and five records were included identified as RCTs available within PubMed and Web of Science databases until 1 February 2023. Two researchers independently conducted identification, screening, inclusion, and evaluation of RCTs, using the revised Cochrane risk-of-bias tool for randomized trials. The studies were conducted in groups with patients treated or intended to be treated with CPAP, while patients with moderate-to-severe or severe OSA were included. Within all included studies, an experimental diet was compared with a control group; however, various interventions were applied, including dietary intervention, which was compared with no intervention, and dietary and physical activity intervention, which was only compared with general advice. The applied intervention included various dietary approaches, such as various energy deficits or dietary health-promoting behaviors. The monitored variables included apnea–hypopnea index (AHI), sleep time, sleep efficiency, sleep latency, oxygen desaturation episodes, oxygen saturation, OSA type, Epworth Sleepiness Scale score, Pittsburgh Sleep Quality Index, and quality of life. For the majority of studies, some concerns were defined for the risk of bias; however, for one study the risk was high. Three studies supported the positive influence of diet therapy, one study somewhat supported it and one study did not support it. It may be stated that for excessive body mass individuals, even if PAP is applied, the diet therapy should be included in order to reduce body mass, reduce the symptoms of OSA, and improve the quality of life. This therapeutic option should be applied, even if no effect on OSA is noted, as body mass reduction have multiple positive effects, which may also influence the quality of life.

Keywords: obstructive sleep apnea (OSA); diet; diet therapy; positive airway pressure (PAP) therapy; dietary education; body mass reduction



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1. Introduction

The obstructive sleep apnea is a disturbance characterized by a fragmented and nonrestorative sleep, which results from episodes of either complete or partial collapse of the airway, accompanied by decrease in oxygen saturation or arousal from sleep [1]. In spite of the fact that its epidemiology is monitored from 90s only, currently it is observed that the prevalence of the obstructive sleep apnea may be estimated as 3–7% of general

population, with predisposing factors listed as: older age, male sex, excessive body mass, family history of obstructive sleep apnea, being after menopause (especially for women without hormone-replacement therapy), craniofacial abnormalities, tobacco smoking, and alcohol consumption [2].

If untreated, the obstructive sleep apnea may lead to both short-term and long-term health consequences; short-term consequences include excessive sleepiness during day, fatigue, nocturia, morning headache, irritability, and memory impairment, while long-term consequences include increased risk of cardiovascular diseases, metabolic disorders, cognitive impairment, and depression [3]. As a result, it also influences the quality of life, reducing both physical and mental functions [4].

In the treatment of obstructive sleep apnea, the positive airway pressure (PAP) is the gold standard; it is commonly applied as the continuous PAP (CPAP), which stabilizes the upper airway with constant positive pressure while using a mask interface, but also as the bi-level PAP, which uses various pressures for the inspiratory and expiratory cycle (for inhalation and exhalation) [5]. The systematic review and meta-analysis by Labarca et al. [6] revealed that in patients with obstructive sleep apnea and hypertension, the CPAP therapy reduces blood pressure, especially nighttime blood pressure. Similarly, the meta-analysis by Khan et al. [7] indicated that while applying CPAP for more than 4 h per night, the risk of major cardiovascular events is reduced by 57%.

Nonetheless, it must be also considered that for PAP or CPAP treatment, the adherence is crucial as it is indicated that in case of low adherence, the potential benefits of PAP therapy are not obtained [8]. In a large retrospective study, it was observed that low adherence is associated with increased hospital all-cause and cardiovascular-cause readmission [9]. Within the other retrospective study, it was observed that this therapy may result in a decrease in healthcare resource utilization, though this reduction is observable in patients who adhere to therapy [10]. The PAP or CPAP treatment adherence may differ between countries [11]; at the same time, other factors influencing adherence include hypertension, sleep posture, and apnea–hypopnea index (AHI) reduction obtained during treatment [12]. Moreover, barriers to obtaining required adherence include: inability to afford a PAP or PAP device (if not covered); perception of symptom reduction, resulting in belief in no need for treatment; and dissatisfaction with treatment [13], arising from physical barriers (including mask leaks, and dry throat and nose) and psychological barriers (including anxiety, claustrophobia and, insomnia) [14].

Taking this into account, in obstructive sleep apnea the other therapeutic methods are also applied and are sometimes even more important; examples include surgical treatment [15] and other methods applied mainly as supportive therapies, such as oral appliances, weight loss, or positional therapy [5]. Among the listed methods, the weight loss is indicated to be beneficial and recommended for all overweight or obese individuals with obstructive sleep apnea due to the fact that the association between excessive body mass and obstructive sleep apnea is obvious; thus, the potential of body mass reduction is significant [16]. Taking this into account, it is recommended within Clinical Guidelines for the Management and Long-term Care of Obstructive Sleep Apnea in Adults by the American Academy of Sleep Medicine for overweight and obese patients with obstructive sleep apnea to obtain weight loss [17].

This proposal was confirmed within the systematic review and meta-analysis by Carneiro-Barrera et al. [18], which assessed the effectiveness of weight loss and other lifestyle interventions for obstructive sleep apnea patients, as it proved that lifestyle interventions significantly reduce apnea–hypopnea index (AHI) and excessive daytime sleepiness. However, it must be emphasized that the systematic review mentioned [18] included both studies with and without PAP applied, as well as the various dietary and lifestyle interventions. The randomized controlled trials included by Carneiro-Barrera et al. [18], were applying various diets, which may be incomparable, including energy deficit of 500 kcal [19] or 800 kcal per day [20], individual sessions with dieticians based on food habit changes [21] or minor energy deficit and food habit changes [22], very low

calorie diets (VLCD) based on dedicated preparations [23,24], or intensive interventions developed for diabetic individuals based on dedicated preparations [25].

Taking this into account, there is a need to compare the effectiveness of various diet therapy interventions for obstructive sleep apnea syndrome patients treated with PAP as a gold standard in therapy [5]. Based on the present knowledge, the aim of this study was to conduct a systematic review of randomized controlled trials (RCTs) of diet therapy interventions for obstructive sleep apnea syndrome patients treated with positive airway pressure.

2. Materials and Methods

2.1. Design and Registration of the Systematic Review

The protocol of the systematic review for literature searching, publications screening, studies inclusion, and data reporting was developed in accordance with the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) [26] statement. The systematic review was registered under no CRD42023398374 in the International Prospective Register of Systematic Reviews (PROSPERO).

The PubMed and Web of Science databases were screened to include RCTs published up to 1 February 2023. The included studies were related to the diet therapy of obstructive sleep apnea syndrome treated with PAP.

2.2. Electronic Search Strategy and Eligibility Assessment

The electronic literature searching strategies for PubMed and Web of Science databases are presented in Table 1. The initial searching was conducted to find manuscripts published in English that presented the original studies.

Table 1. Electronic literature searching strategies for PubMed and Web of Science databases applied within this study.

Database	Electronic Literature Searching Strategy
PubMed	((obstructive sleep apnea[Title/Abstract]) OR (obstructive sleep apnea[Title/Abstract]) OR (OSA[Title/Abstract]) OR (OSAS[Title/Abstract]) OR (OSAHS[Title/Abstract]) OR (sleep-disordered breathing[Title/Abstract])) AND (diet OR nutrition OR nutrient OR nutrients)
Web of Science	(Topic)=((obstructive sleep apnea) OR (obstructive sleep apnea) OR (OSA) OR (OSAS) OR (OSAHS) OR (sleep-disordered breathing)) AND (All fields)=((diet) OR (nutrition) OR (nutrient) OR (nutrients))

Afterwards, the screening and inclusion were conducted based on the following inclusion criteria:

- Study conducted in adult participants;
- Study conducted in a population of patients with obstructive sleep apnea diagnosed;
- Study conducted in patients treated with PAP;
- Study of any kind of dietary intervention;
- Effect of dietary intervention compared with the effect observed for control group with no dietary intervention or with any other kind of dietary intervention;
- Obstructive sleep apnea monitored using any objective or subjective method of assessment;
- Study presenting results of RCT.

The following exclusion criteria were applied:

- Study conducted in population of pregnant or lactating women;
- Study conducted in population with any concurrent disease diagnosed, other than excessive body mass (overweight/obesity);
- Study conducted in population with any mental health problems, eating disorders, or intellectual disabilities;
- Study conducted in animal model.

The population, intervention/exposure, comparator, outcome, and study design (PICOS) criteria were applied within the study as presented in Table 2.

Table 2. Population, intervention/exposure, comparator, outcome, and study design (PICOS) criteria applied within this study.

PICOS Criteria	Inclusion	Exclusion
Population	Adult patients with obstructive sleep apnea diagnosed and treated with positive airway pressure	Pregnant or lactating women, populations with any concurrent disease diagnosed other than excessive body mass, such as mental health problems, eating disorders, or intellectual disabilities
Intervention/exposure	Any kind of dietary intervention	Not described dietary intervention
Comparison	Effect compared with effect observed for control group with no dietary intervention or any other kind of dietary intervention	No comparison with control or reference groups
Outcome	Any objective or subjective method of assessment of obstructive sleep apnea	No valid method of assessment of obstructive sleep apnea applied
Study design	Randomized controlled trials (RCTs) published in peer-reviewed journals	Not published in English, animal model studies

The duplicated records were manually removed after searching. Two researchers independently analyzed the titles of articles, abstracts of articles (records included based on titles), and full texts of articles (records included based on abstracts) on the basis of inclusion and exclusion criteria. Until consensus was achieved, any disagreement was discussed if necessary. The full texts of the articles defined as potentially eligible based on titles and abstracts were searched within electronic databases and libraries and, if necessary, the corresponding authors were contacted.

Moreover, in order to identify the RCTs with diet therapy for obstructive sleep apnea syndrome patients conducted only for participants treated with PAP, the corresponding authors were contacted, if necessary. They were asked about the studied group in order to include only those studies in which all participants were treated with PAP; those with participants treated without PAP, with mixed populations, or with no defined mode of therapy were excluded [20,22,24,27–35].

The procedure of identification, screening, and inclusion of RCTs applied within the study is presented in Figure 1.

2.3. Data Extracion and Risk of Bias Assessment

After including studies, the following information was extracted from each retrieved article:

- General characteristics of the study and studied population, including: country; detailed location of the study; general description of the studied population; period of the study; number of participants (males and females); age; and inclusion and exclusion criteria for the study;
- Intervention applied, including: studied groups; description of dietary interventions; duration of intervention; and monitored variables;
- Results and conclusions of the study.

Two researchers independently extracted information and, until consensus was achieved, any disagreement was discussed, if necessary. In order to find the required information, the articles full texts were searched and the corresponding authors were contacted, if necessary, while the data provided on request are indicated within the study.

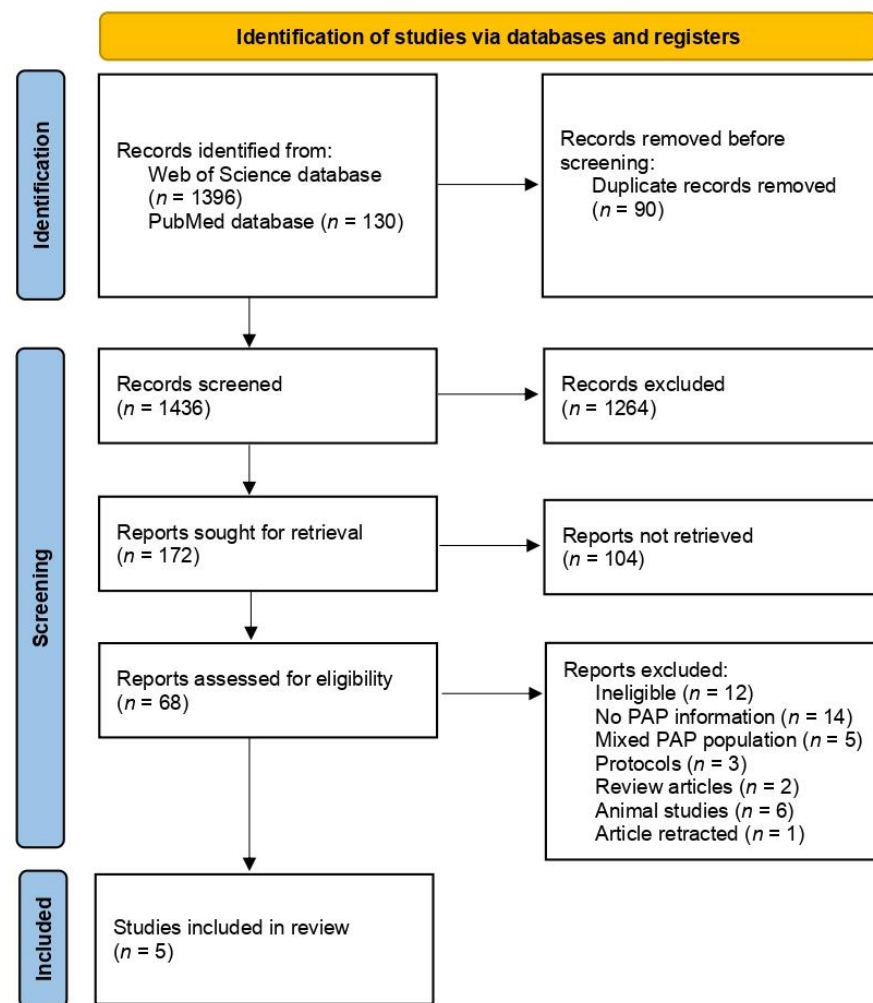


Figure 1. Procedure of identification, screening, and inclusion of randomized controlled trials applied within this study.

The included studies were evaluated using the revised Cochrane risk-of-bias tool for randomized trials [36], along with the RoB 2 tool [37]. Bias was classified as: low risk; some concerns; and high risk of bias based on individual assessments for 5 domains (randomization process, deviations from the intended interventions, missing outcome data, measurement of the outcome, and selection of the reported result) with final overall risk also assessed [38]. Two researchers independently evaluated studies and, until consensus was achieved, any disagreement was discussed, if necessary.

3. Results

The general characteristics of the randomized controlled trials included in the study [23,39–42] and studied populations are presented in Table 3. Only studies clearly defined as those conducted in a population of patients with PAP treatment applied were intended to be included; thus, numerous studies with mixed populations with and without PAP treatment were excluded [22,32–34]. Similarly, if not obstructive sleep apnea was monitored, but the concurrent diseases and symptoms or other factors only, it was not included [43–45]. All the included studies were conducted in developed European countries: Spain [40,41], Sweden [23], the UK [39], and Italy [42]. The studies were conducted in groups with patients treated with CPAP [23,39–41] or intended to be treated with CPAP [42]; patients with moderate-to-severe [23,39,41] or severe obstructive sleep apnea were included [40,42]. The additional elements taken into account within the general characteristics of the studied groups were male gender [23,41], obesity [40,42], and being

scheduled for bariatric surgery [42]. The populations studied within the included trials were of a medium size of either less than 50 [40] or more than 50 participants [23,39,41,42]. The studied participants were mainly in their 40s [23,40,42] or 50s [41]. Among the additional inclusion criteria, there was a criterion based on body mass index (BMI); only overweight and obese participants [41], obese participants [23,39,40], or obesity class two and three participants were qualified [42]. Similarly, for some studies the inclusion criteria included having CPAP treatment conducted for at least 6 months [12,41] or not smoking [42].

The interventions applied within the randomized controlled trials included in the study and accompanied by the conclusions of the study regarding the influence of diet therapy are presented in Table 4. The conclusions of the study and the influence of diet therapy were formulated based on the results and conclusions formulated within the randomized controlled trials included in the study (Supplementary Table S1). Within all included studies, an experimental diet was compared with the control group; however, various interventions were applied, including: dietary intervention, which was compared with no intervention [23,42], and dietary and physical activity intervention, which was compared with general advice [39–41]. At the same time, the applied intervention included various dietary approaches, such as various energy deficits [23,40,42] or dietary health-promoting behaviors [39,41]. The monitored variables included apnea–hypopnea index (AHI) [23,40–42], sleep time [23,40,41], sleep efficiency [40,41], sleep latency [41], oxygen desaturation episodes [39,41], oxygen saturation [23,41], obstructive sleep apnea type (positional/not) [40], Epworth Sleepiness Scale score [23,40,41], Pittsburgh Sleep Quality Index [41], and quality of life (EuroQol EQ5D-3L VAS) [39].

The assessment of the risk of bias, conducted based on the revised Cochrane risk-of-bias tool for randomized trials, within the randomized controlled trials included in the study, is presented in Table 5. For the risk of bias, the majority of studies defined some concerns [23,39,41,42] resulting from the randomization process (D1 domain) [39,42], deviations from the intended interventions (D2 domain) [23], or selection of the reported result (D5 domain) [23,39,40,42]. For one study, the risk of bias was assessed as high [40]; this risk resulted from the randomization process (D1 domain) and deviations from the intended interventions (D2 domain). The risk of bias was not associated with the results as only for one study did they not support the positive influence of diet therapy (a study for which some concerns were indicated) [42]; for another study, the results were defined as somewhat supporting the positive influence of diet therapy (another study for which some concerns were indicated) [39]. At the same time, three studies supported the positive influence of diet therapy, including both of those for which some concerns were indicated [23,41], and this study of a high risk of bias [40].

Table 3. General characteristics of randomized controlled trials included in this study and studied populations.

Ref.	Authors and Year	Country and Detailed Location	General Description of the Studied Population	Period of the Study	Number of Participants (Female)	Age	Inclusion and Exclusion Criteria
[23]	Johansson et al., 2009	Sweden, Stockholm	Male patients with moderate-to-severe obstructive sleep apnea treated with CPAP at the Obesity Unit at Karolinska University Hospital, Karolinska Institute	February–April 2009	66 (-)	Dietary intervention group: 47.5 ± 7.5 years Control group: 49.9 ± 7.1 years	Inclusion: men; 30–65 years; moderate to severe obstructive sleep apnea (AHI ≥ 15); CPAP treatment ≥ 6 months; BMI 30–40 kg/m ² Exclusion: contraindications for very low energy diets (~450–800 kcal/day) according to the SCOOP-VLED report; type 1 or type 2 diabetes; current use of a weight loss drug; previous bariatric surgery; recent angina pectoris or atrial fibrillation
[39]	Moss et al., 2014	UK, Sheffield	Patients with at least moderate obstructive sleep apnea treated with CPAP in sleep clinics at Sheffield Teaching Hospitals National Health Service Foundation Trust	February 2010–December 2011 *	60 (14) *	Lifestyle intervention group: 55 ± 10 years * Advice-only control group: 56 ± 12 years *	Inclusion: 18–85 years; at least moderate obstructive sleep apnea (AHI > 15; oxygen desaturation index > 15; ESS > 11); BMI > 30 kg/m ² ; CPAP treatment Exclusion: any contraindications to exercise testing and training; refusal to undertake the study commitments (e.g., exercise > 30 min ≥ three times per week)
[40]	López-Padrós et al., 2020	Spain, Barcelona	Patients with obesity and severe obstructive sleep apnea treated with CPAP in the Sleep Unit at the Bellvitge University Hospital	November 2014–April 2017 *	42 (4)	Weight-loss intervention group: 48.2 ± 6.9 years * Control group: 49.4 ± 6.6 years *	Inclusion: 25–60 years; severe obstructive sleep apnea (AHI > 30); BMI 30–40 kg/m ² ; CPAP treatment ≥ 6 months Exclusion: contraindications for physical activity or diet; cognitive impairment, psychiatric disorders that impeded patients' understanding of the program; severe diseases; major cardiovascular disease; clinical instability within the previous month; bariatric surgery; participation in another clinical trial
[41]	Carneiro-Barrera et al., 2022	Spain, Granada	Male patients with moderate-to-severe obstructive sleep apnea treated with CPAP from a hospital-based referral center in Granada, within the INTERAPNEA randomized controlled trial	April 2019–October 2020	89 (-)	Weight loss and lifestyle intervention group: 52.6 ± 7.1 years Control group: 55.3 ± 8.5 years	Inclusion: men; 18–65 years; moderate to severe obstructive sleep apnea (AHI ≥ 15); BMI ≥ 25 kg/m ² ; CPAP treatment Exclusion: any other primary sleep disorder; any mental disorder; any other severe organic disease, except for those comorbid to obstructive sleep apnea; regular use of neuroleptic, sedative or hypnotic drugs, or any other medication that may cause sleep disturbances or increased daytime sleepiness; current participation in any other weight loss program [46]
[42]	Schiavo et al., 2022	Italy	Patients with obesity and severe obstructive sleep apnea treated with CPAP and scheduled for bariatric surgery	January 2019–April 2021	70 (26)	Total: 42 ± 13.7 years	Inclusion: 18–65 years; BMI ≥ 35 kg/m ² ; severe obstructive sleep apnea (AHI ≥ 30); non-smokers or quit smoking at 3 months ago Exclusion: kidney and liver conditions that would make low-calorie ketogenic diet unsuitable; psychological problems that would make CPAP treatment problematic; BMI > 60 kg/m ²

* Data provided on request; AHI—apnea-hypopnea index; BMI—body mass index; CPAP—continuous positive airway pressure; ESS—Epworth Sleepiness Scale; INTERAPNEA—The Interdisciplinary Weight Loss and Lifestyle Intervention for Obstructive Sleep Apnea; SCOOP-VLED—Scientific Co-operation on Questions relating to Food—Very Low Calorie Diets.

Table 4. Interventions applied within randomized controlled trials included in this study, accompanied by the conclusions of this study for influence of diet therapy.

Ref.	Studied Groups	Description of Dietary Interventions	Duration of Intervention	Monitored Variables	Conclusions of the Study for Influence of Diet Therapy *
[23]	(1) Dietary intervention group (2) Control group	(1) Weight loss program: 7 weeks of very low energy liquid diet (~550 kcal/day) + 2 weeks of gradual introduction of normal food to reach ~1500 kcal/day, monitored by urinary ketosis examination and supported by group sessions supervised by dietitians (2) Their usual diet	9 weeks	Apnea–hypopnea index (AHI) Apnea–hypopnea index–supine (AHI-S) Percentage supine time Oxygen desaturation episodes \geq 4%/h of sleep Oxygen desaturation episodes \geq 4%/h of sleep–supine Arterial oxygen saturation Epworth Sleepiness Scale score	Supporting
[39]	(1) Lifestyle intervention group (2) Advice-only control group	(1) Supervised exercise sessions accompanied by dietary education and advice based on the principles of the eatwell plate model, developed on the basis of 3-day dietary record to identify dietary imbalance and set goals (2) Basic written lifestyle advice accompanied by the weight loss leaflet	12 weeks	Quality of life (EuroQol EQ5D-3L VAS)	Somehow supporting
[40]	(1) Weight-loss intervention group (2) Control group	(1) The very low calorie diet (600–800 kcal) with low-calorie liquid meal replacements for 15 days, followed by a 1200 kcal diet for 2.5 months, followed by a hypocaloric (1200–1800 kcal) Mediterranean diet for the remaining 36 weeks, accompanied by unsupervised physical activity after 15 days and by behavioral counselling (2) General oral and written information about diet and physical activity, accompanied by estimation of intake of nutrients at baseline, after 3 and 12 months	12 months	Sleep efficiency Deep sleep Superficial sleep REM sleep Apnea–hypopnea index (AHI) AHI-supine (AHI-S) AHI-non-supine (AHI-NS) AHI-S/AHI-NS ratio AHI-REM AHI-non-REM Supine time REM sleep time Deep sleep time Superficial sleep time OSA type (positional/not) Sleep time with SpO ₂ < 90 Epworth Sleepiness Scale score	Supporting

Table 4. Cont.

Ref.	Studied Groups	Description of Dietary Interventions	Duration of Intervention	Monitored Variables	Conclusions of the Study for Influence of Diet Therapy *
[41]	(1) Weight loss and lifestyle intervention group (2) Control group	(1) The interdisciplinary weight loss and lifestyle intervention comprising five components (nutritional behavior change, moderate aerobic exercise, smoking cessation, alcohol intake avoidance, and sleep hygiene), including group-based weekly sessions of 60–90 min led and supervised by professionals in each field (2) General advice on weight loss and lifestyle changes in a single 30-min session	8 weeks	Apnea–hypopnea index (AHI) Oxygen desaturation episodes $\geq 3\%$ /h of sleep Mean SpO ₂ SpO ₂ nadir Sleep time with SpO ₂ < 90 Sleep efficiency Sleep latency Wake after sleep onset Non-rapid eye movement stage 1 (N1) sleep Non-rapid eye movement stage 2 (N2) sleep Non-rapid eye movement stage 3 (N3) sleep N1 + N2 sleep REM sleep AHI-REM AHI-non-REM Pittsburgh Sleep Quality Index Epworth Sleepiness Scale score	Supporting
[42]	(1) Low-calorie ketogenic diet group (2) Control group	(1) Energy value of 1150–1250 kcal/day (4% carbohydrates, 71% fats, 25% proteins) within 2 plans (days 1–14 and 15–28) assigned individual foods with specified quantity and protein supplement provided (2) No diet	4 weeks	Apnea–hypopnea index (AHI)	Not supporting

* The conclusions defined as confirming (if confirmed positive influence of diet therapy) or not confirming (if not confirmed positive influence of diet therapy); AHI—apnea–hypopnea index; EuroQol EQ5D-3L—Euro-Quality of Life Questionnaire (five dimensions, three levels); REM—rapid eye movement; SpO₂—peripheral capillary oxygen saturation; VAS—Visual Analogue Scale.

Table 5. Assessment of risk of bias, conducted based on revised Cochrane risk-of-bias tool for randomized trials, within randomized controlled trials included in this study.

Ref.	D1	D2	D3	D4	D5	Overall Bias
[23]						
[41]						
[42]						
[43]						
[44]						

—Low risk; —some concerns —high risk; risk of bias domains: D1—arising from the randomization process; D2—due to deviations from the intended interventions; D3—due to missing outcome data; D4—in measurement of the outcome; D5—in selection of the reported result.

4. Discussion

As observed within the gathered studies, no negative effect of applied diet therapies was observed in the studied populations of obstructive sleep apnea syndrome patients treated with PAP, independently from the applied mode of diet therapy. Moreover, three studies supported the positive effect of diet therapy [23,40,41] and one study somewhat supported it [39], while only one study did not support it [44]. Taking this into account, it may be indicated that application of a diet therapy should be recommended and if possible, the PAP should not be applied alone; rather, it should be applied with the body mass reduction as it may provide additional benefits associated with reduced body mass, reduced symptoms of obstructive sleep apnea, and improved quality of life.

The observations formulated within the included studies [23,39–42] result from the association between obstructive sleep apnea syndrome and excessive body mass, which is among the condition's major predisposing factors [2]. It is associated with the role of pharyngeal narrowing and closure during sleep as its four pathogenetic mechanisms are indicated as resulting from narrow, crowded, or collapsible upper airway anatomical compromise, ineffective pharyngeal dilator muscle functioning, low threshold for arousal to airway narrowing, and unstable control of breathing during sleep [3]. As a result of pharyngeal narrowing and closure, whether complete or partial, the apnea or hypopnea, respectively, are observed, leading to disturbances in gas exchange, oxygen desaturation, hypercapnia, and sleep fragmentation [47]. The described changes do not only result from independent processes, but they may be influenced by being overweight and obese as the excessive body mass associated with central distribution of fat tissue leads to reduced lung volume and, as a result, influences the stability of respiratory control [47]. Similarly, it is indicated that the neck circumference is a factor associated with severity of obstructive sleep apnea syndrome; this issue is an independent risk factor for experiencing a severe course of the disease [48].

Based on the described mechanisms and taking into account the increasing prevalence of excessive body mass, especially in countries of a higher socioeconomic status [49], the increasing prevalence of obstructive sleep apnea may be also supposed for the future. Taking this into account, the researchers emphasize the need to screen excessive body mass populations for obstructive sleep apnea in order to treat affected individuals effectively [50].

However, it must be indicated that obstructive sleep apnea is not the only condition to result from excessive body mass; other diseases resulting from excessive body mass and obstructive sleep apnea may be similarly treated with body mass reduction as a supportive therapy. For example, hypertension can result from excessive body mass [51] and obstructive sleep apnea [52]. Similarly, for obese patients increased risk of stroke may

be stated while, depending on the metabolic consequences of obesity [53], obstructive sleep apnea can be associated with a high risk of stroke among patients with coronary artery disease [54]. Such associations between excessive body mass, the development of cardiovascular problems, and obstructive sleep apnea indicates that excessive body mass is not only the source of the problem, but also a means of finding a potential solution. At the same time, treatment for obstructive sleep apnea leads to the reduction in cardiovascular problems, indicating that the mentioned conditions should be treated in combination [55]. Similarly, it is indicated that obstructive sleep apnea is related to other diseases resulting from excessive body mass, such as diabetes; obstructive sleep apnea is associated with marked insulin resistance in adipose tissue triglyceride lipolysis and glucose uptake into skeletal muscles and adipose tissue [56]. However, it is emphasized that benefits from diet therapy in obstructive sleep apnea extend beyond the recognized benefits of weight reduction [57].

Taking this into account, it may be indicated that while PAP must be applied as the gold standard in obstructive sleep apnea therapy, the body mass reduction (not applied instead of PAP, but accompanying it) may correct existing problems by reduction in central fat tissue deposits and resultant lungs volume increase [47].

At the same time, it must be indicated that numerous factors predisposing obstructive sleep apnea development are fixed and unchangeable, such as older age, male sex, family history of obstructive sleep apnea, being post-menopausal, and craniofacial abnormalities, so the modifiable habits must be considered during therapy as excessive body mass, tobacco smoking, and alcohol consumption [2]. Taking this into account, behavioral therapy, including not only body mass reduction but also stopping smoking and reducing alcohol consumption, may be most recommended approach to support PAP treatment.

Although the study revealed interesting observations, some limitations should also be listed. The quantity of the included studies, as well as their quality and heterogenicity, are the major problems. Only five studies met the inclusion criteria, while a lot of studies were excluded; moreover, within the studied groups various therapeutic modes were applied. The small number of included studies are incomparable, with various dietary options studied and diverse variables monitored; thus, they cannot be treated as a homogenous sample of studies. Lastly, as shown in the conducted systematic review, there were some problems with the risk of bias within all the included studies.

5. Conclusions

Based on the gathered studies assessing the diet therapy interventions for obstructive sleep apnea syndrome patients treated with PAP, it may be stated that for excessive body mass individuals, even if PAP is applied, the diet therapy should be included in order to reduce body mass and the symptoms of obstructive sleep apnea and improve the quality of life. As the majority of studies indicated that diet therapy is beneficial as a supporting treatment and that body mass reduction may influence the symptoms of the disease, this therapeutic option should be applied; even if no effect on obstructive sleep apnea is noted, body mass reduction has multiple positive effects, which may also influence quality of life.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/app13085105/s1>, Supplementary Table S1. The results and conclusions formulated within the randomized controlled trials included to the study.

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