Effect of exercise training on sleep apnea: A systematic review and meta-analysis

Kenneth D. Aiello a, William G. Caughey a, Bhargava Nelluri b, Ashwini Sharma b, Farouk Mookadam b, Martina Mookadam c,

* Center for Biology and Society, Arizona State University, Tempe, AZ, USA
b Division of Cardiovascular Diseases, Mayo Clinic, Scottsdale, AZ, USA
c Department of Family Medicine, Mayo Clinic, Scottsdale, AZ, USA

Article info
Article history:
Received 12 January 2016
Received in revised form
30 March 2016
Accepted 16 May 2016
Available online 21 May 2016

Keywords:
Exercise
Exercise program
Aerobic exercise
Sleep apnea
Obstructive sleep apnea
Systematic review
Meta-analysis
Continuous positive airway pressure

Abstract
Introduction: Obstructive sleep apnea (OSA) is difficult to manage for those who are intolerant or non-compliant with standard facial mask treatment options. Current treatment options do not address the underlying cause of OSA. Exercise as a treatment option has been found to improve OSA indices.

Study objectives: To assess the efficacy of exercise on apnea/hypopnea index (AHI) in adult patients with OSA via a systematic review and meta-analysis. Additional objectives included evaluation of other indices of OSA and well-being in patients after completing an exercise regimen.

Measurements and results: Web of Science, MEDLINE, CINAHL, and Cochrane Central Register of Controlled Trials were searched based on a priori criteria of all studies evaluating the effect of an exercise program on various sleep apnea indices. Both PRISMA statement and MOOSE consensus statement were adhered to. Eight Articles (182 participants) were included: a meta-analysis using a random effects model showed, a decrease in AHI (unstandardized mean difference [USMD], -0.536, 95% confidence interval [CI], -0.865 to -0.206, I², 20%), reduced Epworth sleepiness scale (ESS) (USMD, -1.246, 95% CI, -2.397 to -0.0953, I², 0%), and lower body mass index (BMI) (USMD, -0.0473, 95% CI, -0.0375 to 0.280, I², 0%), in patients receiving exercise as treatment. Relative risks (RR) and odds ratios (OR) showed decreases in AHI (OR: 72.33, 95% CI, 27.906 to 187.491, RR: 7.294, 95% CI, 4.072 to 13.065) in patients receiving exercise as treatment.

Conclusion: Among adult patients with OSA, exercise as the sole intervention was associated with improved clinical outcomes.

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction
Obstructive sleep apnea (OSA) is commonly characterized by recurring upper airway obstruction during sleep [1]. Common predisposing factors for OSA include gender (male), craniofacial anomalies [2], and obesity [3]. Many health consequences are associated with OSA, including lethargy, memory loss, problems with thinking and judgment [4], disruption of normal metabolic functions [5], and cardiovascular disorders [6,7].

The measure of the severity of OSA is based on the number of apnea or hypopnea events per hour of sleep represented as apnea hypopnea index (AHI). Previous literature has established parameters for OSA; none/minimal OSA diagnosed as AHI <5 per hour, mild OSA diagnosed as AHI ≥5 and AHI <15, moderate OSA diagnosed as AHI ≥15 and AHI <30, and severe OSA diagnosed as AHI ≥30 [2]. The exact etiology of OSA is unknown and has led to multiple treatment and management options [8]. Previous studies have evaluated treating OSA symptoms via continuous positive airway pressure (CPAP) [9], mandibular adjustment [10,11], weight loss via diet [4,12], bariatric surgery [13–15], pharmacotherapy [16–18], and upper airway surgery [19–21]. However, long-term studies have shown that the therapeutic efficacy of these treatments do not address the underlying cause of OSA, evident by the AHI reduction then resurgence in AHI of participants who underwent treatment by CPAP [9], weight loss via reduced calorie intake [22,23], bariatric surgery [14], and mandibular adjustment [10,11,24].
Exercise programs to treat and manage OSA in patients have displayed promising results in reducing AHI and Epworth Sleepiness Scale (ESS) [25–29]. Further, exercise has been shown to reduce the severity of other disorders and/or diseases associated with OSA including diabetes [30], cardiovascular disease [31], hypertension [32], and obesity [33]. It is not fully understood how exercise reduces OSA symptoms, but previous reviews have indicated that the impact of exercise on OSA is not related to reduction of body weight or body mass index (BMI) in both epidemiologic [34] and experimental studies [35–37].

Previous reviews and meta-analyses evaluated different treatments on OSA patients: diet and lifestyle [38], supervised exercise [36], diet or diet and exercise [39], diet and/or supervised exercise [8], and intensive lifestyle intervention (low calorie or very low calorie diet, mandibular advancement) [40]. Additionally, in the literature we found studies that were excluded from previous reviews because the exercise programs were initially led by professionals and study personnel (supervised exercise programs), but ended as unsupervised exercise programs where the participants were solely responsible for their treatment [8].

The primary objective was to study the use of exercise (supervised and unsupervised) as management treatment for OSA by analyzing the difference in pre- and post-intervention AHI in adult patients with OSA. Secondary objectives included evaluating the effects of exercise on ESS, BMI.

2. Materials and methods

Five authors (K.A., B.N., A.S., F.M., and M.M.) identified studies in Cochrane Central Register of Controlled Trials (CENTRAL), MEDLINE (1993–2014), Web of Science (WOS), and CINAHL. The following search strategy was used: ([text word] exercise OR [text word] exercise program OR [text word] aerobic exercise OR [text word] physical activity OR [text word] muscle stretching exercise OR [text word] plyometric exercise OR [text word] resistance training OR [text word] running OR [text word] jogging OR [text word] swimming OR [text word] isometric exercise OR [text word] weightlifting OR [text word] weightbearing AND [text word] sleep apnea OR [text word] obstructive sleep apnea OR [text word] sleep disturbed braking. All reviewed articles and cross-referenced studies were screened for relevant data. Reference lists of included studies and previously published systematic reviews and meta-analyses on OSA and lifestyle interventions were hand searched. No language restrictions were applied. Any disagreement was resolved by consensus. All reviewed articles and cross-referenced studies were screened for relevant data. Authors also searched previously published studies, reviews, and meta-analyses on OSA and lifestyle interventions [8,36,38–41]. In the case of missing data, authors were contacted for additional unpublished data in order to complete the data set [42]. Inclusion criteria included: adult participants (age >18 years), OSA was diagnosed via polysomnography (PSG) via AHI ≥5, exercise program duration ≥2 months, frequency of exercise ≥2 sessions per week, exercise session ≥30 min, exercise as the sole intervention, patient cohort ≥9, and pre- and post-intervention changes in AHI, BMI, and ESS were reported. Randomized trials as well as observational studies were included with no restrictions on language or supervised or unsupervised exercise program.

Articles were excluded if OSA was not diagnosed via PSG, treatment was a combination of exercise and lifestyle intervention, subjects were diagnosed with heart failure (HF), neuromuscular disorders (NMD), and/or chronic pulmonary disease (COPD), were using dental sleep devices, and/or patients previously had undergone surgery. The Jadad score provides points for randomization (2), blinding (2), and patient dropouts (1), and was used to quality score and evaluate all randomized controlled trials (RCTs) (Fig. 1) [43]. The information collected from the relevant studies included: sampling framework(s), author(s), year article was published in journal (not e-pub date), PSG data, mean of cohort age, exercise duration, exercise frequency, exercise protocol, keywords, CPAP usage, and pre- and post-intervention AHI, ESS, BMI, profile of mood states, and well-being or quality of life question. The mean differences of AHI, BMI, ESS for pre- and post-intervention for both treatment and control groups were extracted for each study and graphically represented using forest plot graphs; this data was pooled using USMD due to the uniformity of scale and analysis [44] (Fig. 2). Two authors (K.A., B.C.) conducted independent statistical analysis to confirm the results. Heterogeneity was assessed using I² statistics and Cochrane’s Q statistic [45].

The parametric variables AHI, BMI, and ESS were represented as the mean and standard deviation despite the small sample sizes. To check for publication bias, funnel plots of effect size and standard error were constructed [46]. Funnel plots analyzed using the Beggs and Mazumdar rank correlation test did not suggest significant publication bias for the analysis conducted [47]. Both the PRISMA criteria [48] and the MOOSE guidelines [49] were followed (Fig. 3). All analyses were performed using MedCalc® (http://www.medcalc.org/) and R programming language. P-values less than 0.10 were considered significant based on the literature recommended threshold [50].

3. Results

The initial search yielded 8394 studies (6776 from MEDLINE, 308 from CENTRAL, 291 from CINAHL, and 1019 from WOS). After removing 812 duplicates, we conducted a title and abstract search in the remaining 7582 articles, which resulted in 1142 studies. After evaluating the abstracts of each study, we excluded 1126 studies for failing to the priori inclusion/exclusion criteria. Eight articles were excluded after a close reading of the text. The final analysis consisted of 8 articles and 180 participants [42,51–57] (Fig. 4). Seven references had pre- and post-intervention data for AHI and BMI [42,51–54,56,57], 5 studies included AHI and BMI data but were missing ESS data (Fig. 1). The most complete data set was used for analysis in the instance of duplicate reports or articles [54]. Variance between studies was accounted for by using fixed and random effects methods meta-analyses [58].

Studies’ baseline data including publication year, study design, total number of subjects, duration of exercise program, number of participants (% of males and females), age, and pre- and post-intervention BMI, AHI, and ESS were extracted. Six studies were RCTs [51–54,56,57] and 2 studies were single group intervention studies [42,55]. Both supervised and unsupervised exercise programs were used as treatment in the studies. Supervised exercise programs were used in 6 studies [51,52,54–57] and unsupervised exercise programs in 2 studies [42,53]. Treatment duration ranged from 2 months to 6 months. Treatment frequency ranged from 2 days a week to 7 days a week, from 30 min to 150 min each session. Exercise protocols ranged from aerobic exercise, e.g. walking/running on treadmill, stair climbing, Airdyne® machine, stationary bicycle, resistance training, and oropharyngeal exercises. Participants’ ages ranged from 32.2 to 54.4 years.

A total of 7 studies [42,51–54,56,57] compared mean AHI scores pre- and post-intervention for a control group and experimental group. One study [59] that measured respiratory disturbance index (RDI) was not included in the AHI meta-analysis. Comparison of the 2 groups found exercise was associated with a reduction in AHI after treatment (unstandardized mean difference [USMD], −0.536, 95% CI, −0.865 to −0.206, I², 20%). A total of 4 studies [53,54,56,57] compared mean ESS scores pre- and post-intervention for a control group and experimental group. Exercise was associated with
having a lower decrease in the total ESS after treatment (USMD, −1.246, 95% CI, −2.397 to −0.0953, I², 0%). A total of 4 studies [51,53,54,56,57] compared mean BMI scores pre- and post-intervention for a control group and experimental group. Exercise was not found to have statistically significant effect on BMI (USMD, −0.0473, 95% CI, −0.280 to 0.230, I², 0%).

Due to the results assessing AHI excluding RDI, an analysis was performed that excluded the study that measured pre- and post-intervention RDI only, fixed effects model ([USMD], −0.510, 95% CI, −0.783 to −0.237, I², 7%, p, <0.001), random effects model ([USMD], −0.515, 95% CI, −0.800 to −0.230, I², 7%, p, <0.001). Similar results were found when risk ratio (RR) and odds ratio (OR) were used to compare pre- and post-intervention results concerning AHI. Patients receiving exercise treatment had an AHI decrease of 4 when compared to patients not receiving exercise treatment (OR: 72.33, 95% CI, 27.906 to 187.491; RR: 7.294, 95% CI, 4.072).

4. Discussion

In this study, mean treatment outcomes of pre- and post-intervention data from 8 studies with 180 total participants were compared. The main findings highlight that exercise has an effect on reducing both AHI and ESS in patients with OSA. This conclusion remained consistent independent of different types of exercise, durations of exercise, frequency of exercise sessions, CPAP usage, and supervised or unsupervised treatment programs. This conclusion was supported via the moderate sample size and degree of heterogeneity.

A potential explanation cited for exercise reducing AHI in mild or severe OSAs focuses on the comorbidity of obesity and OSA [8,39]. Excess adipose tissue is the cause of the airway collapsing and apnea or hypopnea events occurring, and obesity is linked to increased adipose tissue in the pharyngeal airway [1]. Exercise can lead to weight loss and reduction in BMI [38], and studies have suggested that reduction in BMI is associated with reduction in the volume of adipose tissue in the pharyngeal airway [61]. However, our results support Iftikhar et al.'s [36] findings that exercise reduces AHI regardless of significant reduction in BMI. Previous studies have shown dramatic AHI reduction through low calorie diet [4,23,39] or diet modification [12,22,62], pharmacological treatment [16–18], exercise and lifestyle intervention [40,41], and surgery [14,15,21,61]. Though, as already mentioned, follow-up studies have shown that some of these treatments do not lead to long-term reduction in AHI [9,14,22,23].

The benefits of systematic reviews and meta-analyses lie in summarizing information and evaluating treatments; however, one of the pitfalls of meta-analyses is the assessing of information and validating methods [63]. As previously mentioned, analyses on different characteristics of participants and combination of

---

### Table: Baseline Characteristics of the Studies Included in the Final Meta-Analysis

<table>
<thead>
<tr>
<th>Author</th>
<th>Study Design</th>
<th>Number of Participants (% of males)</th>
<th>Age, mean (SD)</th>
<th>AHI, mean (SD)</th>
<th>RDI, mean (SD)*</th>
<th>BMI, mean (SD)</th>
<th>ESS, mean (SD)</th>
<th>Jadad Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ackel-D’Elia et al [51]</td>
<td>RCT</td>
<td>Exercise: 13 (100%)</td>
<td>Exercise: 48.4 (9.2)</td>
<td>Exercise: 42.3 (21.6)</td>
<td>Exercise: 28.0 (3.1)</td>
<td>Exercise: 14.0 (4.1)</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Control: 19 (100%)</td>
<td>Control: 49.5 (7.7)</td>
<td>Control: 40.5 (22.9)</td>
<td>Control: 28.5 (2.2)</td>
<td>Control: 13.0 (4.8)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cavagnolli et al [52]</td>
<td>RCT</td>
<td>Exercise: 10 (100%)</td>
<td>Exercise: 40.5 (10.4)</td>
<td>Exercise: 3.47 (1.6)</td>
<td>Exercise: 26.0 (3.4)</td>
<td>Exercise: NA</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Control: 10 (100%)</td>
<td>Control: 32.2 (10.2)</td>
<td>Control: 25.7 (17.1)</td>
<td>Control: 27.5 (19.2)</td>
<td>Control: N/A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Guimaraes et al [53]</td>
<td>RCT</td>
<td>Exercise: 16 (100%)</td>
<td>Exercise: 51.5 (6.8)</td>
<td>Exercise: 22.4 (4.8)</td>
<td>Exercise: 29.6 (3.8)</td>
<td>Exercise: 14 (5)</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Control: 15 (100%)</td>
<td>Control: 47.7 (9.8)</td>
<td>Control: 22.4 (5.4)</td>
<td>Control: 31.0 (2.8)</td>
<td>Control: 14 (7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kline et al [54]</td>
<td>RCT</td>
<td>Exercise: 27 (100%)</td>
<td>Exercise: 47.7 (6.7)</td>
<td>Exercise: 32.2 (29.0)</td>
<td>Exercise: 35.3 (6.2)</td>
<td>Exercise: 11.1 (0.9)</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Control: 16 (100%)</td>
<td>Control: 45.9 (8.8)</td>
<td>Control: 24.4 (22.4)</td>
<td>Control: 33.6 (5.6)</td>
<td>Exercise: 7.3 (0.9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schutz et al [55]</td>
<td>RCT</td>
<td>Exercise: 7 (100%)</td>
<td>Exercise: 42.3 (8.3)</td>
<td>Exercise: 22.8 (12.8)</td>
<td>Exercise: 28.1 (1.6)</td>
<td>Exercise: 14.1 (5.6)</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Control: 9 (100%)</td>
<td>Control: 38.6 (8.2)</td>
<td>Control: 25.1 (10.5)</td>
<td>Control: 25.9 (5.3)</td>
<td>Control: 9.9 (5.2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sengul et al [56]</td>
<td>RCT</td>
<td>Exercise: 10 (100%)</td>
<td>Exercise: 54.4 (6.5)</td>
<td>Exercise: 15.4 (5.4)</td>
<td>Exercise: 29.8 (2.6)</td>
<td>Exercise: 8.2 (6.1)</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Control: 10 (100%)</td>
<td>Control: 48.0 (7.4)</td>
<td>Control: 17.9 (6.4)</td>
<td>Control: 28.4 (5.4)</td>
<td>Control: 3.4 (5.1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Netzer et al [57]</td>
<td>Single group study</td>
<td>10 (91%)</td>
<td>52.2 (6.2)</td>
<td>*32.8 (22.1)</td>
<td>27.6 (3.5)</td>
<td>N/A</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Norman et al [58]</td>
<td>Single group study</td>
<td>8 (89%)</td>
<td>48.0 (9.0)</td>
<td>21.7 (9.0)</td>
<td>34.4 (3.7)</td>
<td>N/A</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

*Mean represented here is separated via exercise or control group and by each individual study.

Abbreviations: BMI=body mass index; SD=standard deviation; ESS=Epworth Sleep Scale; AHI=apnea hypopnea index; RDI=respiratory disturbance index; RCT=randomized controlled trial.
interventions have been performed: diet and lifestyle by Thoma-
souli et al. [38]; supervised exercise as treatment was analyzed by
Iftikhar et al. [36]; diet or diet and exercise as intervention was
analyzed by Anandam et al. [39]; diet and/or supervised exercise
was analyzed by Araghi et al. [8]; upper airway muscle tonus by
Valbuza [64]; and intensive lifestyle intervention (low calorie or
very low calorie diet, mandibular advancement) by Mitchell et al.
[40]. In this study, we compared pre- and post-intervention stan-
dard mean difference of AHI, BMI, and ESS and found that reduction
in OSA indices were similar regardless of the exercise protocol used.
Due to the similarity in results we cannot say which protocol,
duration, or frequency were the best [48]; however, our results
raise important questions about OSA treatment and management
options. The possible implications for treatment and management
of OSA from this study are: (1) exercise as the primary treatment
and management option for OSA; (2) the use of unsupervised ex-
ercise or telemedicine treatment for OSA; and (3) the use of low-
calorie diets and surgical interventions may not be required.

**Fig. 2.** Mean change in AHI, ESS, and BMI from baseline to end of treatment showing a decrease in AHI (unstandardized mean difference [USMD], \(-0.536, 95\%\) confidence interval ([CI], \(-0.865 to -0.206, I^2, 20\%\)), reduced Epworth sleepiness scale (ESS) (USMD, \(-1.246, 95\%\) CI, \(-2.397 to -0.0953, I^2, 0\%\)), and lower body mass index (BMI) (USMD, \(-0.0473, 95\%\) CI, \(-0.0375 to 0.280, I^2, 0\%\)), in patients receiving exercise as treatment. Abbreviations: BMI, Body Mass Index; SMD standardized mean difference, ESS, Epworth Sleep Scale, AHI, apnea hypopnea index; CI, confidence interval, N1, experimental group pre-intervention, N2, experimental group post intervention.
Obstructive sleep apnea is a disease that reduces sleep quality. See methods section. PubMed, Embase, Cochrane Library, Web of Science, and Cumulative Index to The study quality was reported in both a specific results section as well as the Table 3. We included randomized controlled trials, and single group intervention studies. Sensitivity analysis via summary table. Three tables and two figures were provided. Presented in discussion section. No funding was received in support of this study. 95% confidence intervals with all summary estimates. The heterogeneity was evaluated by I² and Q statistic. This conclusion is consistent with the growing body of studies that focus on exercise as treatment for OSA. Thus, possible future research could test exercise as treatment and management of OSA symptoms in non-obese individuals, and continued analyses on the cause of OSA. Table 2. A list of alternative explanations was discussed in discussion section. Guidelines for future research. Present in discussion section. No funding was received in support of this study. Here are the guidelines for future research: We included studies from different countries and with different exercise protocols. These conclusions are consistent with the growing body of studies that focus on exercise as treatment for OSA. The heterogeneity was evaluated by I² and Q statistic. Thus, possible future research could test exercise as treatment and management of OSA symptoms in non-obese individuals, and continued analyses on the cause of OSA.

These conclusions are consistent with the growing body of studies that focus on exercise as treatment for OSA. The heterogeneity was evaluated by I² and Q statistic. Thus, possible future research could test exercise as treatment and management of OSA symptoms in non-obese individuals, and continued analyses on the cause of OSA.

These conclusions are consistent with the growing body of studies that focus on exercise as treatment for OSA. The heterogeneity was evaluated by I² and Q statistic. Thus, possible future research could test exercise as treatment and management of OSA symptoms in non-obese individuals, and continued analyses on the cause of OSA.

These conclusions are consistent with the growing body of studies that focus on exercise as treatment for OSA. The heterogeneity was evaluated by I² and Q statistic. Thus, possible future research could test exercise as treatment and management of OSA symptoms in non-obese individuals, and continued analyses on the cause of OSA.

These conclusions are consistent with the growing body of studies that focus on exercise as treatment for OSA. The heterogeneity was evaluated by I² and Q statistic. Thus, possible future research could test exercise as treatment and management of OSA symptoms in non-obese individuals, and continued analyses on the cause of OSA.

These conclusions are consistent with the growing body of studies that focus on exercise as treatment for OSA. The heterogeneity was evaluated by I² and Q statistic. Thus, possible future research could test exercise as treatment and management of OSA symptoms in non-obese individuals, and continued analyses on the cause of OSA.

These conclusions are consistent with the growing body of studies that focus on exercise as treatment for OSA. The heterogeneity was evaluated by I² and Q statistic. Thus, possible future research could test exercise as treatment and management of OSA symptoms in non-obese individuals, and continued analyses on the cause of OSA.

These conclusions are consistent with the growing body of studies that focus on exercise as treatment for OSA. The heterogeneity was evaluated by I² and Q statistic. Thus, possible future research could test exercise as treatment and management of OSA symptoms in non-obese individuals, and continued analyses on the cause of OSA.

These conclusions are consistent with the growing body of studies that focus on exercise as treatment for OSA. The heterogeneity was evaluated by I² and Q statistic. Thus, possible future research could test exercise as treatment and management of OSA symptoms in non-obese individuals, and continued analyses on the cause of OSA.

These conclusions are consistent with the growing body of studies that focus on exercise as treatment for OSA. The heterogeneity was evaluated by I² and Q statistic. Thus, possible future research could test exercise as treatment and management of OSA symptoms in non-obese individuals, and continued analyses on the cause of OSA.

These conclusions are consistent with the growing body of studies that focus on exercise as treatment for OSA. The heterogeneity was evaluated by I² and Q statistic. Thus, possible future research could test exercise as treatment and management of OSA symptoms in non-obese individuals, and continued analyses on the cause of OSA.

These conclusions are consistent with the growing body of studies that focus on exercise as treatment for OSA. The heterogeneity was evaluated by I² and Q statistic. Thus, possible future research could test exercise as treatment and management of OSA symptoms in non-obese individuals, and continued analyses on the cause of OSA.

These conclusions are consistent with the growing body of studies that focus on exercise as treatment for OSA. The heterogeneity was evaluated by I² and Q statistic. Thus, possible future research could test exercise as treatment and management of OSA symptoms in non-obese individuals, and continued analyses on the cause of OSA.

These conclusions are consistent with the growing body of studies that focus on exercise as treatment for OSA. The heterogeneity was evaluated by I² and Q statistic. Thus, possible future research could test exercise as treatment and management of OSA symptoms in non-obese individuals, and continued analyses on the cause of OSA.

These conclusions are consistent with the growing body of studies that focus on exercise as treatment for OSA. The heterogeneity was evaluated by I² and Q statistic. Thus, possible future research could test exercise as treatment and management of OSA symptoms in non-obese individuals, and continued analyses on the cause of OSA.

These conclusions are consistent with the growing body of studies that focus on exercise as treatment for OSA. The heterogeneity was evaluated by I² and Q statistic. Thus, possible future research could test exercise as treatment and management of OSA symptoms in non-obese individuals, and continued analyses on the cause of OSA.

These conclusions are consistent with the growing body of studies that focus on exercise as treatment for OSA. The heterogeneity was evaluated by I² and Q statistic. Thus, possible future research could test exercise as treatment and management of OSA symptoms in non-obese individuals, and continued analyses on the cause of OSA.

These conclusions are consistent with the growing body of studies that focus on exercise as treatment for OSA. The heterogeneity was evaluated by I² and Q statistic. Thus, possible future research could test exercise as treatment and management of OSA symptoms in non-obese individuals, and continued analyses on the cause of OSA.

These conclusions are consistent with the growing body of studies that focus on exercise as treatment for OSA. The heterogeneity was evaluated by I² and Q statistic. Thus, possible future research could test exercise as treatment and management of OSA symptoms in non-obese individuals, and continued analyses on the cause of OSA.

These conclusions are consistent with the growing body of studies that focus on exercise as treatment for OSA. The heterogeneity was evaluated by I² and Q statistic. Thus, possible future research could test exercise as treatment and management of OSA symptoms in non-obese individuals, and continued analyses on the cause of OSA.

These conclusions are consistent with the growing body of studies that focus on exercise as treatment for OSA. The heterogeneity was evaluated by I² and Q statistic. Thus, possible future research could test exercise as treatment and management of OSA symptoms in non-obese individuals, and continued analyses on the cause of OSA.

These conclusions are consistent with the growing body of studies that focus on exercise as treatment for OSA. The heterogeneity was evaluated by I² and Q statistic. Thus, possible future research could test exercise as treatment and management of OSA symptoms in non-obese individuals, and continued analyses on the cause of OSA.

These conclusions are consistent with the growing body of studies that focus on exercise as treatment for OSA. The heterogeneity was evaluated by I² and Q statistic. Thus, possible future research could test exercise as treatment and management of OSA symptoms in non-obese individuals, and continued analyses on the cause of OSA.

These conclusions are consistent with the growing body of studies that focus on exercise as treatment for OSA. The heterogeneity was evaluated by I² and Q statistic. Thus, possible future research could test exercise as treatment and management of OSA symptoms in non-obese individuals, and continued analyses on the cause of OSA.

These conclusions are consistent with the growing body of studies that focus on exercise as treatment for OSA. The heterogeneity was evaluated by I² and Q statistic. Thus, possible future research could test exercise as treatment and management of OSA symptoms in non-obese individuals, and continued analyses on the cause of OSA.

These conclusions are consistent with the growing body of studies that focus on exercise as treatment for OSA. The heterogeneity was evaluated by I² and Q statistic. Thus, possible future research could test exercise as treatment and management of OSA symptoms in non-obese individuals, and continued analyses on the cause of OSA.

These conclusions are consistent with the growing body of studies that focus on exercise as treatment for OSA. The heterogeneity was evaluated by I² and Q statistic. Thus, possible future research could test exercise as treatment and management of OSA symptoms in non-obese individuals, and continued analyses on the cause of OSA.

These conclusions are consistent with the growing body of studies that focus on exercise as treatment for OSA. The heterogeneity was evaluated by I² and Q statistic. Thus, possible future research could test exercise as treatment and management of OSA symptoms in non-obese individuals, and continued analyses on the cause of OSA.

These conclusions are consistent with the growing body of studies that focus on exercise as treatment for OSA. The heterogeneity was evaluated by I² and Q statistic. Thus, possible future research could test exercise as treatment and management of OSA symptoms in non-obese individuals, and continued analyses on the cause of OSA.
larger treatment outcomes than similar larger more robust trials [64,65]; however, the reason for this phenomenon is unknown and some authors have proposed methods that utilize small studies for use in meta-analysis models [47,68]. Thus, future research is needed to examine if small trials are correlated with larger treatment.

It can be argued that in order to accurately determine whether exercise is associated with a reduction in OSA indices, a high number of patients diagnosed with OSA would have to be enrolled in an a RCT, have a low level of attrition, and conduct annual follow-up diagnoses. However, to enroll thousands of patients in a clinical trial of this magnitude would require years and could prove expensive to funding agencies.

Our meta-analysis represents the most recent literature on OSA and exercise; however, our study selection was restricted by our inclusion and exclusion criteria and was not exhaustively inclusive.
of all articles or studies on OSA, OSA and exercise, and OSA management. However, future meta-analysis may be conducted on the efficacy of supervised compared to unsupervised exercise as treatment, and a mixed treatment comparison of the current recommendations for management of OSA by The American College of Physicians.

5. Conclusion

In this meta-analysis of exercise as the sole treatment for OSA differences in AH1 between patients in exercise programs compared to those not enrolled in an exercise program were statistically significant. However, the reduction in OSA indices may need to be further explored via comparison of larger participant numbers, supervised and unsupervised exercise programs, frequency of treatment, treatment duration, and exercise protocols. Though lifestyle intervention, upper airway surgery, mandibular advancement, and CPAP have shown similar decreases in OSA indices, exercise programs as treatment reduce AH1 and the underlying causes of OSA.

Disclosure statement

This was not an industry supported study. The authors have no conflict of interest or financial involvement with this manuscript.

Acknowledgements

The authors wish to thank Michael Grover DO, Department of Family Medicine, Mayo Clinic Arizona for his insights and guidance.

References


