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

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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, 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. 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.

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].

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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* breathing. 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 $\geq$5, exercise program duration $\geq$2 months, frequency of exercise $\geq$2 sessions per week, exercise session $\geq$30 min, exercise as the sole intervention, patient cohort $\geq$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 I^2 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 Begg 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, I^2, 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