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# Efficacy of exercise as a treatment for Obstructive Sleep Apnea Syndrome: A systematic review

Benjamin Bollens[a,*], Grégory Reychler[a,b]

[a] Cliniques universitaires Saint-Luc, Physical and Rehabilitation Medicine Department, Avenue Hippocrate, 10, 1200 Brussels, Belgium
[b] Cliniques universitaires Saint-Luc, Pneumology Department, Avenue Hippocrate, 10, 1200 Brussels, Belgium

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ABSTRACT

*Introduction:* Obstructive Sleep Apnea Syndrome (OSAS) is a prevalent condition associated with numerous adverse health consequences. Exercise therapy was described as a valuable OSAS treatment alternative to continuous positive airway pressure.
*Objective:* The objective of the present systematic review was to assess the efficacy of exercise in reducing OSAS severity and associated comorbidities.
*Setting:* We queried MEDLINE and SCOPUS and ScienceDirect databases with the following keywords: "sleep apnea" and "sleep disordered breathing" for the population and "physical activity", "fitness" and "exercise" for the intervention.
*Results:* Eight studies including a total number of 354 patients showed that OSAS severity was significantly reduced after intervention. This reduction was associated with significant improvement in cardio-vascular fitness, sleep quality and quality of life. Conversely, this effect was not directly related to body weight reduction.
*Conclusion:* This systematic review suggests that physical activity should be recommended as a treatment for OSAS patients. However, further research is necessary to demonstrate this long-term efficiency with a higher level of confidence and to better understand the underlying physiological mechanisms.

## 1. Introduction

Obstructive Sleep Apnea Syndrome (OSAS) is a condition characterized by repetitive obstruction of the upper airway during sleep that is associated with a decrease in oronasal airflow, oxygen desaturation and arousals.[1]

OSAS is a common sleep disorder. The estimated prevalence is 22% in men and 17% in women and increases progressively with age.[2] Obesity is considered the strongest predictor of OSAS even if smoking and alcohol consumption are also linked to the syndrome.[2,3] OSAS is associated with a wide range of health consequences such as daytime sleepiness and cognitive impairment. Moreover, it increases cardiovascular morbidity, inducing a higher risk of stroke, atrial fibrillation, coronary disease and congestive heart failure.[4]

Continuous positive airway pressure (CPAP) is recommended as the first-line treatment for moderate to severe OSAS.[5–7] CPAP has been shown to decrease health comorbidities, [7] to reduce symptoms as daytime sleepiness and snoring, and to improve cardiovascular indices.[6] However, its long-term effectiveness is often limited by poor patient compliance related to nasal discomfort, mask leak, congestion and claustrophobia.[6–8]

Lifestyle interventions combining diet and exercise are efficient to reduce body weight in obese patients, inducing a subsequent decrease in OSAS severity.[9,10] However, it was recently demonstrated that the benefit of physical activity on OSAS was not directly related to body weight reduction.[11–13] Two meta-analyses showed the interest of exercise therapy in treating OSAS without focusing on weight loss.[12,13] The studies were included when changes in cardiorespiratory fitness were reported,[12] or based on specific exercise program characteristics (duration ≥ 2 months, session duration ≥ 30 min and frequency ≥ 2 times a week).[13]

The aim of the present systematic review was to assess all updated evidence about the effectiveness of exercise program in reducing OSAS severity and improving subsequent comorbidities, without restrictions in terms of exercise program characteristics.

* Corresponding author.
*E-mail address:* Benjamin.bollens@uclouvain.be (B. Bollens).

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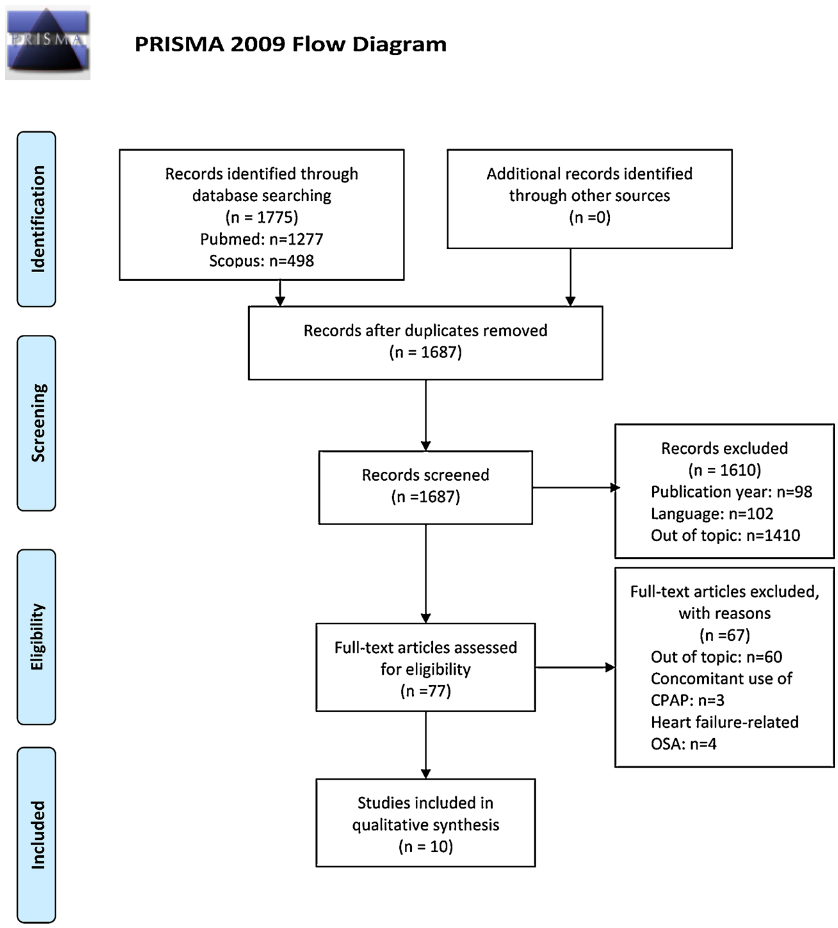


**Fig. 1.** Flowchart of study selection.

## 2. Methods

### 2.1. Search strategy

We adopted Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to perform this systematic review. The trial was registered in the PROSPERO database (CRD42015029443).

Studies were identified from MEDLINE, SCOPUS and ScienceDirect databases. The search terms were included in an equation based on PICO method: "sleep apnea" and "sleep disordered breathing" for the population, "physical activity", "fitness" and "exercise" for the intervention. Neither intervention nor comparator were specified into the equation to be not too restrictive.

To be included, studies had to meet the following inclusion criteria based on the PICO method:

- Population: adult patients (≥ 18 years old) with primary OSAS (heart failure-related OSAS patients populations were excluded)
- Intervention: exercise therapy program (studies reporting additional intervention with CPAP or concomitant diet were excluded)
- Comparison: all other treatment, placebo or no comparator
- Primary or secondary outcome: reduction of Apnea-Hypopnea Index (AHI)
- Study design: randomized and nonrandomized controlled trials; uncontrolled before-and-after studies (case reports were excluded)
- Publication year: 1995-2017
- Language: English or French

### 2.2. Data analysis and quality assessment

Literature was independently screened and reviewed by the two authors (BB and GR). Titles and abstracts were analyzed and irrelevant papers were excluded. Full texts of potentially eligible papers were explored based on the inclusion criteria. Disagreements between authors were resolved by discussion and consensus. Bibliographic references of articles were also reviewed. Quality appraisal was conducted using the Critical Review Form – Quantitative Studies, relating to study description, internal and external validity and which evaluates the study methodology on a total score of 16.[14] Severity of OSAS, measured by AHI, was defined as the primary outcome. Quantitative effects of exercise on other markers of sleep efficiency, body composition, fitness and subjective parameters were also collected in the different trials. To be included in the analysis, outcomes had to be listed in at least 2 selected studies.

## 3. Results

### 3.1. Study selection

The process of study selection is described in Fig. 1. A total of 1775 references were screened. After exclusion of duplicate studies, 1687 papers were reviewed and a total of 8 articles met the inclusion criteria.

### 3.2. Study characteristics

#### 3.2.1. Design and population

Seven randomized controlled trials (RCT) and 1 controlled case-series study including a total number of 354 patients were identified

**Table 1**
Methodological characteristics of the different selected articles.

| Authors | Study design | Patients | | | | Intervention | | | | Control |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Number | Age (years) | Weight (kg) | Baseline AHI | Exercise program | Co-intervention | Duration (weeks) | Drop-outs | |
| Redolfi (2015) [15] | RCT, cross-over | 8 | 56 ± 11 | 89.8 ± 13.6 | 58.0 ± 28.6 | Aerobic exercises | – | 1 | 0 | No intervention |
| Mendelson (2015)[16] | RCT | 44 (IG:22; CG:22) | IG:63.8 ± 8.0<br>CG:59.6 ± 11.8 | NT | IG:24.8 ± 12.6<br>CG:21.6 ± 12.2 | Aerobic exercises | – | 4 | 10 (IG:5; CG:5) | No intervention |
| Cavagnolli (2014)[17] | Controlled case-series study | 32 (IG:17; CG:15) | IG:40.5 ± 10.4<br>CG:32.2 ± 10.2 | NT | IG:25.7 ± 5.3<br>CG:3.5 ± 0.5 | Aerobic exercises | – | 8 | 12 (IG:7; CG:5) | Healthy population |
| Herrick (2014)[18] | RCT | 144 (IG:97; CG:47) | 81.8 ± 8.1 | NT | IG:20.2 ± 1.4 | Resistance training + light walking | Social activity | 7 | ? | No intervention |
| Desplan (2014)[19] | RCT | 13 (IG:13; CG:13) | ? | NT | IG:40.6 ± 19.4<br>CG:39.8 ± 19.2 | Aerobic exercises + resistance training | Education program | 4 | 4 (IG:2; CG:2) | Education program |
| Schütz (2013)[20] | RCT | 45 (IG:15; CG1:15; CG2:15) | IG:42.3 ± 8.3<br>CG1:38.6 ± 8.1<br>CG2:42.3 ± 6.2 | NT | IG:22.8 ± 12.8<br>CG1:25.1 ± 10.5<br>CG2:30.8 ± 19 | Aerobic exercises + resistance training | – | 8 | 20 | CG1: CPAP<br>CG2: Oral appliance |
| Kline (2011) [21] | RCT | 43 (IG:27; CG:16) | IG:47.6 ± 1.3<br>CG 45.9 ± 2.2 | IG:105.6 ± 3.0<br>CG:99.3 ± 5.1 | IG:32.2 ± 5.6<br>CG:24.4 ± 4.3 | Aerobic exercises + resistance training | – | 12 | 5 (IG:3; CG:2) | Stretching |
| Sengul (2011) [22] | RCT | 25 | IG:54.4 ± 6.6<br>CG:48.0 ± 7.5 | NT | IG:15.2 ± 5.4<br>CG:17.9 ± 6.4 | Aerobic exercises + breathing | – | 12 | 5 | No intervention |

AHI: apnea-hypopnea index; RCT: Randomized Controlled Trial; IG: intervention group; CG: control group; IQR: interquartile range; CPAP: continuous positive airway pressure.
If not otherwise mentioned, results are presented as mean ± SD values.

**Table 2**
Critical Review Form – Quantitative Studies.

| Authors | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Redolfi 2015 [15] | – | + | + | – | – | + | – | + | + | + | – | – | – | + | + | + | 9 |
| Mendelson 2015 [16] | + | + | + | + | – | + | + | + | + | + | + | + | + | + | + | + | 15 |
| Cavagnolli 2014 [17] | + | + | – | – | – | + | + | + | + | + | + | + | + | + | + | + | 13 |
| Herrick 2014 [18] | + | + | + | + | – | + | – | + | + | + | – | – | + | + | + | + | 12 |
| Desplan 2014 [19] | + | + | + | + | – | – | + | + | + | + | + | + | + | + | + | + | 14 |
| Schütz (2013) [20] | + | + | + | + | – | + | + | + | + | + | + | + | + | + | + | + | 15 |
| Kline 2011 [21] | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | 16 |
| Sengul 2011 [22] | + | + | + | – | – | – | + | + | + | + | – | + | + | + | + | + | 12 |
| Mean ± SD | | | | | | | | | | | | | | | | | 13.2 ± 2.2 |

(+) = yes; (-) = no (conversely for item 4).
(1) purpose clearly stated (2) relevant literature reviewed; (3) appropriate design; (4) biases; (5) sample size justified; (6) sample described in detail; (7) informed consent obtained; (8) outcome measures valid; (9) outcome measures reliable; (10) statistical significance of results reported; (11) drop outs reported; (12) clinical importance reported; (13) statistical analysis methods appropriate; (14) appropriate conclusions ; (15) implications for clinical practice; (16) limitations described.

(Table 1). However, 2 of the 7 RCTS were considered of poor quality (Table 2). Only the values of the post-intervention and post-control periods were presented in the short-lasting cross-over design published by Redolfi et al[15]. The results of the control group were not detailed in the study of Herrick et al.[18] The mean quality score of all selected studies was 13.3 (2.2) out of 16 (Table2).

Moderate[11,16–18,20,22] or severe[15,19,21] OSAS was considered in all studies. Most trials focused on middle-aged patients and only one study included a geriatric population.[18] Primary intervention consisted in aerobic exercises in all but one study,[18] and was associated with resistance training in 3 cases.[6,19,21] Aerobic sessions usually included moderate-intensity exercises performed 3 to 7 times a week on a treadmill or a cycle-ergometer. Concomitant social activity [18] or education program [19] was mentioned in 2 studies. Duration of the exercise program ranged from 1 to 12 weeks. The control group was subjected to an education program,[19] stretching,[21] CPAP,[20] oral appliance [20] or no intervention.[15–18,22] The intervention group was compared with healthy subjects in Cavagnolli et al study.[17]

### 3.3. Results of the studies

#### 3.3.1. Sleep parameters

Sleep was always assessed using polysomnography (Table 3). AHI was considered as the primary outcome and decreased significantly in 6 studies with a reduction ranging from 2 [17] to 17.4 [15] events per hour in the intervention group. When assessed, oxygen desaturation index (ODI), defined as the number of arterial oxyhemoglobin saturation drops ≥ 4% per hour of sleep, showed a similar improvement to AHI. Intervention group showed a greater improvement than control group in all studies, excepted in the paper of Schütz et al comparing exercise therapy with the use of CPAP and oral appliance.[20] Conversely, total sleep time (TST) and mean or minimal $O_2$ saturation were not imporved throughout the different studies.

**Table 3**
Main effects of exercise on sleep parameters in the different selected studies.

| Authors | | AHI (events/h) | ODI | TST (min) | $O_2$ Saturation (%) |
|---|---|---|---|---|---|
| Redolfi | | Pre: 58.0 ± 28.6 | NT | Pre: 368 ± 60 | NT |
| (2015) [15] | | Post: 40.6 ± 21.8* | | Post: 386 ± 57 | |
| Mendelson | IG | Pre: 24.8 ± 12.6 | NT | Pre: 282.2 ± 61.3 | Pre: 86.4 ± 4.9 |
| (2015)[16] | CG | Post: 17.2 ± 9.4* | | Post: 284.1 ± 87.1 | Post: 85 ± 4.8 |
| | | Pre: 21.6 ± 12.2 | | Pre: 325.6 ± 43.9 | Pre: 83.2 ± 6.0 |
| | | Post: 21.8 ± 13.5 | | Post: 336.7 ± 50.9 | Post: 83.2 ± 8.2 |
| Cavagnolli (2014)[17] | IG | Pre: 25.7 ± 5.3 | NT | Pre: 389.5 ± 12.7 | NT |
| | CG | Post: 23.7 ± 5.6 | | Post: 394.2 ± 5.9 | |
| | | Pre: 3.5 ± 0.5 | | Pre: 369.8 ± 12.6 | |
| | | Post: 10.1 ± 4.2 | | Post: 377 ± 9.7 | |
| Herrick | | Pre: 20.2 ± 1.39 | NT | NT | NT |
| (2014) [18] | | Post: 16.7 ± 0.96* | | | |
| Desplan | IG | Pre: 40.6 ± 19.4 | Pre: 23.1 ± 15.8 | Pre: 421.5 ± 72.6 | NT |
| (2014) [19] | CG | Post: 28.0 ± 19.3* | Post: 17.6 ± 13.2* | Post: 417.3 ± 81.0 | |
| | | Pre: 39.8 ± 19.2 | Pre: 24.9 ± 12.4 | Pre: 404.4 ± 81.3 | |
| | | Post: 45.4 ± 22.5 | Post: 30.1 ± 23.1 | Post: 433.2 ± 61.8 | |
| Schütz | IG | Pre: 22.8 ± 12.8 | NT | NT | NT |
| (2013) [20] | CG1 | Post:18.7 ± 10.5 | | | |
| | CG2 | Pre: 25.1 ± 10.5 | | | |
| | | Post: 1.9 ± 1.2* | | | |
| | | Pre: 30.8 ± 19 | | | |
| | | Post:9.6 ± 10.3* | | | |
| Kline | IG | Pre: 32.2 ± 5.6 | Pre: 24.5 ± 4.2 | Pre: 402.2 ± 6.7 | Pre: 79.6 ± 1.4 |
| (2011) [21] | CG | Post: 24.6 ± 3.1* | Post: 21.5 ± 3.7* | Post: 406.5 ± 8.7 | Post: 79.9 ± 1.5 |
| | | Pre: 24.4 ± 4.3 | Pre: 16.8 ± 4.2 | Pre: 410.6 ± 7.7 | Pre: 80.4 ± 1.9 |
| | | Post: 28.9 ± 6.5 | Post: 23.2 ± 5.8 | Post: 400.3 ± 13.6 | Post: 78.7 ± 2.0 |
| Sengul | IG | Pre: 15.2 ± 5.4 | NT | Pre: 361.3 ± 55.3 | Pre: 83.9 ± 4.5 |
| (2011) [22] | CG | Post: 11 ± 5.3* | | Post: 361.2 ± 80 | Post: 83.6 ± 4.5 |
| | | Pre: 17.9 ± 6.4 | | Pre: 388.1 ± 57.3 | Pre: 82.5 ± 5.4 |
| | | Post: 17.3 ± 11.2 | | Post: 351.8 ± 89.6 | Post: 84 ± 4.5 |

AHI: apnea-hypopnea index: ODI: oxygen desaturation index; TST: total sleep time; IG: intervention group; CG: control group; NT: not tested; IQR: interquartile range.

* statistically significant. If not otherwise mentioned, results are presented as mean ± SD values.

### 3.3.2. Physical parameters

Patient body composition was modified by physical activity in all studies, with a global trend towards improvement in body weight, body mass index (BMI), fat percentage, waist and neck circumferences (Table 4). Increase in $VO_2$ peak and metabolic equivalent of task (MET) demonstrated the efficacy of the exercise program by improving patient cardio-vascular fitness.[19,22] Moreover, muscular strength was significantly improved in the study evaluating the 1-repetition maximum (1-RM) of different trained muscular groups.[18]

### 3.3.3. Subjective parameters

Daytime sleepiness and sleep quality were respectively assessed with the Epworth Sleepiness Scale (ESS) and the Pittsburgh Sleep Quality Index (PSQI), while quality of life (SF-36) was evaluated using a questionnaire (Table 5). All subjective parameters were systematically and significantly improved at the end of the intervention throughout the studies, except for SF-36 in one trial.[20] Sengul et al mentioned a significant improvement in quality of life, but the values of SF-36 and FOSQ were not reported in the paper.[22] General health perception was presented in Table 5 for 2 studies,[19,20] but all sub-items of the SF-36 exhibited similar improvement in the papers with the exception of role limitation – emotional and mental health in Desplan et al.[19]

## 4. Discussion

This systematic review included 8 studies and highlighted the efficacy of a physical activity program in reducing the severity of OSAS, with a significant decrease in AHI in 6 out of the selected studies. This beneficial effect was obtained concomitantly with an improvement in cardio-vascular fitness and in muscular strength of the OSAS patients. Results were less consistent on body composition even if a global trend towards improvement was observable in all the selected papers.

The decrease in AHI obtained through the exercise program ranged from 2 to 17.4 events per hour in the different selected studies. This result is globally similar with values reported in previous meta-analyses under the same condition, but largely inferior to the improvements related to dietary weight loss in obese patients, with AHI reduction ranging from 16 to 23.1 for the global OSAS population.[10,23] However, this effect remains clinically relevant since each 1-unit increase in AHI was associated with a 6% increase of stroke risk in mild-to-moderate OSAS male patients.[24]

Methodological characteristics of the included studies can be considered as fair, with a mean score of 13.2 on the Critical Review Form – Quantitative Studies. Indeed, only 5 good-quality RCTs were identified, which restricts the level of scientific confidence. The sample size was small in the majority of studies, and the simultaneous use of a co-intervention (social activity, education program) may be considered as a confounding factor in the assessment of exercise efficacy per se. The long-term effects of the physical activity program on OSAS severity is poorly addressed by the present systematic review, with the follow-up exceeding 12 weeks in only one study.

Several differences are reported in the design of our systematic review, as compared with previous meta-analyses[12,13] Heart failure-related OSAS patients were excluded to obtain a homogenous population. Studies including concomitant intervention with CPAP were not selected to avoid any bias. Our review aimed to focus on the specific effects of exercise training on OSAS severity by excluding a potential CPAP effect. Characteristics of the exercise program were not restricted in terms of duration, intensity or sessions frequency. Quality appraisal was evaluated using the Critical Review Form – Quantitative Studies, while assessments were previously limited to quantitative tools in Iftikhar et al. Outcomes listed in at least 2 selected studies were systematically assessed in our review, whereas secondary outcomes were limited to BMI, sleep efficiency, daytime sleepiness and

**Table 4**
Main effects of exercise on physical parameters in the different selected studies.

| Authors | | Body composition | | | | | Fitness | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Weight (kg) | BMI (kg $m^{-2}$) | Fat | Waist (cm) | Neck (cm) | $VO_2$ peak | MET (kcal $kg^{-1}$ $min^{-1}$) | 1-RM |
| Redolfi (2015) [15] | | Pre: 89.8 ± 13.6<br>Post: 89.1 ± 13.7 | NT | NT | NT | Pre: 42.7 ± 2.8<br>Post: 42.8 ± 3.1 | NT | NT | NT |
| Mendelson (2015) [16] | IG<br>CG | Pre: 81.1 ± 14.7<br>Post: 80.6 ± 14.7<br>Pre: 85.9 ± 15<br>Post: 85.8 ± 14.9 | NT | NT | NT | In the morning :<br>Pre: 42.7 ± 3<br>Post: 42.3 ± 3*<br>Pre: 40.6 ± 2.4<br>Post: 40.7 ± 2.4 | NT | NT | NT |
| Cavagnolli (2014) [17] | | NT | NT | NT | NT | NT | NT | NT | NT |
| Herrick (2014) [18] | | NT | NT | NT | NT | NT | NT | NT | Chest press (kg):<br>Pre: 45.0 ± 20.7<br>Post: 60.9 ± 28.1*<br>Leg press (kg):<br>Pre: 91.3 ± 62.5<br>Post: 128.9 ± 76.3* |
| Desplan (2014) (19) | IG<br>CG | NT | Pre: 29.9 ± 3.4<br>Post: 29.1 ± 3.1*<br>Pre: 31.3 ± 2.5<br>Post: 31.3 ± 2.2 | Pre (kg): 30 ± 9.4<br>Post (kg): 27.8 ± 9.3*<br>Pre (kg): 28.9 ± 6.5<br>Post (kg): 30.2 ± 6.3 | Pre: 99<br>(IQR:96-104)<br>Post: 96<br>(IQR:93-102)*<br>Pre: 104<br>(IQR:100-109)<br>Post: 104<br>(IQR:96-110) | Pre: 40.7 ± 3.5<br>Post: 39.2 ± 2.6*<br>Pre: 41 ± 2.5<br>Post: 41.5 ± 3 | Pre (ml $min^{-1}$ $kg^{-1}$): 21.3 ± 5.6<br>Post (ml $min^{-1}$ $kg^{-1}$): 22.9 ± 5.6*<br>Pre (ml $min^{-1}$ $kg^{-1}$): 23.2 ± 6<br>Post (ml $min^{-1}$ $kg^{-1}$): 19.8 ± 4.6 | Pre: 3.6 ± 1.9<br>Post: 4.6 ± 1*<br>Pre: 3.3 ± 1.7<br>Post: 2.9 ± 1.2 | NT |
| Schütz (2013) [20] | IG<br>CG1<br>CG2 | NT | Pre: 28.1 ± 1.6<br>Post: 29 ± 2.3<br>Pre: 25.9 ± 5.3<br>Post: 27.2 ± 4.9<br>Pre: 29.3 ± 1.7<br>Post: 29.9 ± 2.6 | NT | NT | Pre: 43.8 ± 2.4<br>Post: 43.5 ± 2<br>Pre: 42.7 ± 2<br>Post: 41.3 ± 2.3<br>Pre: 43 ± 1.9<br>Post: 42.5 ± 2 | NT | NT | NT |
| Kline (2011) [21] | IG<br>CG | Pre: 105.6 ± 3<br>Post: 104.7 ± 3.1<br>Pre: 99.3 ± 5.1<br>Post: 98.7 ± 5 | NT | Pre (%): 42.1 ± 1.9<br>Post (%): 41.0 ± 1.9*<br>Pre (%): 40.6 ± 1.9<br>Post (%): 40.8 ± 1.9 | Pre: 110.8 ± 2.3<br>Post: 110.2 ± 2.3<br>Pre: 104.4 ± 3.8<br>Post: 105.8 ± 3.9 | Pre: 40.7 ± 0.6<br>Post: 40.9 ± 0.6<br>Pre: 39.5 ± 0.9<br>Post: 39.8 ± 1 | NT | NT | NT |
| Sengul (2011) [22] | IG<br>CG | NT | Pre: 29.8 ± 2.7<br>Post: 29.2 ± 3.1<br>Pre: 28.4 ± 5.4<br>Post: 28.3 ± 5.5 | Pre (%): 28.4 ± 4.0<br>Post (%): 26.9 ± 3.3<br>Pre (%): 24.8 ± 3.1<br>Post (%): 25.8 ± 2.4 | Pre: 104.2 ± 5.5<br>Post: 104.4 ± 6.8<br>Pre: 103.5 ± 14.8<br>Post: 101.2 ± 11.6 | Pre: 41.1 ± 1.5<br>Post: 42.1 ± 2.8<br>Pre: 41.3 ± 3.5<br>Post: 41.6 ± 3.1 | Pre (ml $min^{-1}$): 15.4 ± 3.6<br>Post (ml $min^{-1}$): 17.5 ± 5.6*<br>Pre (ml $min^{-1}$): 16.6 ± 4.9<br>Post (ml $min^{-1}$): 18.4 ± 3.5 | Pre: 4.4 ± 1<br>Post: 5.4 ± 1.1*<br>Pre: 4.8 ± 1.4<br>Post: 5.3 ± 1 | |

BMI : body mass index ; MET : metabolic equivalent of task ; 1-RM: 1-repetition maximum; IG: intervention group; CG: control group; NT: not tested; IQR: interquartile range.
* statistically significant. If not otherwise mentioned, results are presented as mean ± SD values.

**Table 5**
Main effects of exercise on subjective parameters (questionnaires) in the different selected studies.

| Authors | | ESS | PSQI | SF-36 |
|---|---|---|---|---|
| Redolfi (2015) [15] | | NT | NT | NT |
| Mendelson (2015) [16] | | NT | NT | NT |
| Cavagnolli (2014) [17] | | NT | NT | NT |
| Herrick (2014) [18] | | NT | NT | NT |
| Desplan (2014) [19] | IG CG | Pre: 13.6 ± 4.5 Post: 8 ± 5.7* Pre: 8 ± 5.7 Post: 9.4 ± 5.8 | Pre: 8.9 ± 3.1 Post: 6.2 ± 1.5* Pre: 8 ± 3.1 Post: 8.1 ± 3.8 | General Health Perception Pre: 46.4 ± 22.3 Post: 63.6 ± 9.5* Pre: 54.1 ± 12.6 Post: 52.3 ± 14 |
| Schütz (2013) [20] | IG CG1 CG2 | Pre: 14.1 ± 5.6 Post: 9.6 ± 4.2* Pre: 9.9 ± 5.2 Post: 6.4 ± 4.1 Pre: 6 ± 4.3 Post: 5 ± 4.2 | NT | General Health Perception Pre: 64.2 ± 13.6 Post: 77.7 ± 13.4 Pre: 61.2 ± 13.3 Post: 71 ± 18.9 Pre: 68.6 ± 22.6 Post: 71.7 ± 15.1 |
| Kline (2011)[21] | IG CG | NT | Pre: 6.2 ± 0.6 Post: 4.7 ± 0.5* Pre: 8.1 ± 1 Post: 8 ± 1 | NT |
| Sengul (2011) [22] | IG CG | Pre: 8.2 ± 6.1 Post: 7.0 ± 6.6* Pre: 3.4 ± 0.5 Post: 5.3 ± 4.2 | NT | No values* |

ESS: Epworth Sleepiness Scale; PSQI: Pittsburgh Sleep Quality Index; SF-36: Short-Form-36;
NT: not tested; IG: intervention group; CG: control group.
* statistically significant. Results are presented as mean ± SD values.

cardiorespiratory fitness in Iftikhar et al,[12] and to AHI, BMI, ESS, profile of mood states and quality of life in Aiello et al.[13]

Decrease in AHI did not seem associated with baseline weight of the patients, duration of the exercise program. Conversely, reduction in OSAS severity was the largest in the 2 studies including the most severely affected patients.[15,19] The number of selected studies was too small to dwell on the influence of exercise intensity and training session frequency on the efficacy of the intervention. Exercise programs were largely based on aerobic exercises, sometimes associated with muscular strengthening. Resistance training was the primary intervention in only one paper.[18] This study provided a tenuous OSAS improvement (AHI, ODI), that was still significant.

OSAS is largely associated with obesity.[5,6] Lifestyle interventions promoting a healthy diet and physical activity can affect weight and various cardio-metabolic risk factors in obese adults.[25] However, physical activity is less important than diet to reduce body weight in the short term.[26] The effects of exercise training are more heterogeneous and clinically significant weight loss is unlikely to occur with exclusive physical activity, unless the overall volume of exercise is very high. Physical activity seems mainly important to maintain body mass after initial weight loss.[27] Evidence suggests that aerobic training is more effective in decreasing fat than resistance training which results in a significantly more pronounced improvement in lean body mass. However, combined aerobic and resistance training is the most efficient program to affect anthropometric parameters in overweight patients.[28] The existing literature does not allow drawing similar conclusions in the treatment of OSAS.

Although the effects of physical activity are independent on body weight,[11,12] dietary intervention is the most efficient lifestyle modification in reducing OSAS severity in obese patients.[10,23] However, significant decrease in AHI related to exercise is achieved without significant weight loss, as observed in 3 studies included in the present systematic review,[21,15,16] but precise pathophysiological mechanisms remain unclear. Physical activity would lead to a significant reduction in visceral adipose tissue, which is a source of cytokines implicated in the inflammation of the upper airway muscles.[11] However, CRP levels are normal in non-obese patients with OSA, and do not change after 2 months of aerobic exercise training.[17] It has been suggested that physical activity may improve muscle tone of the upper airways, inducing positive effects on the drive to breathing.[29] Finally, exercise training is supposed to activate the musculo-venous pump, counteracting fluid accumulation in the legs during daytime and preventing nocturnal rostral fluid shift that contributes to the upper airway collapse.[15,16,30,31]

In conclusion, the present systematic review shows that physical activity is an efficient intervention in reducing OSAS severity, improving cardio-vascular fitness and quality of life in OSAS patients. Randomized controlled trials assessing the effects of exercise should be performed on a large sample size to confirm this efficiency with a higher level of confidence and to identify the underlying physiological mechanisms. Even if the improvement of OSAS severity obtained after exercise therapy could be maintained years after the intervention,[32] extensive data on long follow-up are still lacking. The optimal combination of endurance training and resistance exercises should also be better defined to optimize the development of exercise programs in OSAS patients.

## Guarantor statement

Benjamin Bollens takes responsibility for the content of the manuscript, including data collection and analysis.

## Author contributions

Benjamin Bollens takes responsibility for the integrity of the review and the accuracy of the data analysis. Grégory Reychler contributed substantially to data analysis and interpretation, and the writing of the manuscript.

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