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SLEEP BREATHING PHYSIOLOGY AND DISORDERS • ORIGINAL ARTICLE

Bariatric surgery and obstructive sleep apnea: a systematic review and meta-analysis

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Abstract
Background Several studies evaluated the effect of bariatric surgery on obstructive sleep apnea (OSA) but findings have been inconsistent. The aim of this study was to conduct an updated systematic review and meta-analysis to investigate the effect of bariatric surgery on OSA.
Methods The databases for PubMed, CENTRAL, and Scopus were searched up to the 1st of December, 2021. Studies were included if they were cohort or case–control in design, included patients with diagnosis of OSA, the patients underwent any bariatric surgery, and the study performed postoperative polysomnography.
Results The total number of the included patients was 2310 patients with OSA from 32 studies. Our analysis showed that bariatric surgery was associated with significant reduction in BMI (WMD = − 11.9, 95%CI: − 13.4, − 10.4), apnea–hypopnea index (AHI) (WMD = − 19.3, 95%CI: − 23.9, − 14.6), and respiratory disturbance index (RDI) (WMD = − 33.9, 95%CI: − 42.1, − 25.7). The rate of OSA remission after the surgery was 65% (95%CI: 0.54, 0.76).
Conclusion Our results suggest that bariatric surgeries are effective in reducing obesity among patients with OSA in addition to OSA severity measures. However, the low rate of OSA remission suggests that the main etiology of OSA is not only obesity but also includes other important variables such as the anatomy of the jaw.

Keywords Human · Sleep · Obstructive sleep apnea · Treatment · Surgery

Introduction

An important global health issue affecting both adults and children is obesity whereby a body mass index (BMI) of greater than 30 kg/m^2 defines the condition. Obesity is a significant risk factor for a number of illnesses, including obstructive sleep apnea (OSA), osteoarthritis, cardiovascular disease, diabetes, and stroke [1]. It is one of the few modifiable risk factors for OSA and is regarded as the most significant and well-known risk factor.

OSA is characterized by recurrent episodes of partial or total upper airway obstruction during sleep. Patients who are obese are more likely to have OSA. With each unit increase in BMI, the likelihood of developing OSA increases by nearly 1.14 [2]. Patients with at least five apneic or hypopneic episodes per hour can be diagnosed with OSA. The severity of the apnea–hypopnea index (AHI) can be used to categorize OSA according to its severity. Patients are classified as having mild, moderate, or severe OSA, depending on their AHI (5–14, 15–29, or ≥ 30 events per hour) [2].

In order to lose weight permanently and sustainably while also lowering comorbidities associated with obesity, bariatric surgery is now generally recognized as a main option [3]. Following bariatric surgery for patients with morbid obesity, several studies have noted an improvement in or resolution of OSA [3]. The individual effects of weight loss on OSA are quite variable [4], which is likely a result of the different study designs employed. Additionally, there are not enough long-term follow-up studies using polysomnography (PSG) to accurately assess

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the effects of weight loss on OSA. Additionally, the most recent meta-analysis looking at how weight loss surgery affects OSA was completed in 2018 [5]. The study did not examine changes in sleepiness scales, the respiratory disturbance index (RDI), or the rate of OSA remission and only included a small number of articles. It would therefore be informative to conduct an updated systematic review and meta-analysis to determine how surgical weight loss affects OSA.

Methods

Protocol

This study was conducted in compliance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).

Search strategy

The databases for PubMed, CENTRAL, and Scopus were searched up to the 1st of December, 2021. The search was done using the following keywords and their related MeSH terms: (Bariatric Surgeries OR Bariatric Surgical Procedures OR Metabolic Surgery OR Stomach Stapling OR Sleeve Gastrectomy OR Laparoscopic Sleeve Gastrectomy OR Gastric Bypass OR Laparoscopic Gastric Bypass OR Gastric Banding OR Laparoscopic Gastric Banding) AND (OSA OR OSAHS OR Obstructive Sleep Apnea OR Obstructive Sleep Apnea Syndrome OR Sleep Apnea Hypopnea Syndrome OR Sleep Apnea Syndrome OR Upper Airway Resistance Sleep Apnea Syndrome). The search was done by AAT and RBA independently, and any discrepancy was solved by discussion. The search results were imported to Rayyan (https://www.rayyan.ai/), and duplicates were removed.

Study selection

The studies were included if they were cohort, case–control, or clinical trials in design; included patients with OSA diagnosis proved by polysomnography [6]; the patients underwent any bariatric surgery; and the study performed postoperative polysomnography. Case reports and series, animal studies, reviews, and non-English articles were excluded from this systematic review and meta-analysis. The search results were screened by AAT and RBA independently, and any discrepancy was solved by discussion. The exposure of interest was bariatric surgery including sleeve gastrectomy, gastric bypass, or gastric banding, while the outcomes of interest were body mass index (BMI), apnea–hypopnea index (AHI), respiratory disturbance index (RDI), Epworth sleepiness scale (ESS), and rate of OSA remission. AHI was defined as the number of apneas and hypopneas divided by the total sleep time. RDI included the number of apneas and hypopneas as well as the number of respiratory effort–related arousals per hour of sleep [7]. The AHI and RDI were measured by postoperative polysomnography. OSA remission was defined if continuous positive airway pressure (CPAP) use was no longer required by the patient based upon clinical decision.

Data extraction and quality assessment

The quality of the included observational studies was assessed using the Newcastle–Ottawa Scale (NOS) for observational studies [8], while the quality assessment of randomized and non-randomized clinical trials was assessed using and Cochrane Risk of Bias Assessment of Randomized Clinical Trials (ROB2) [9] and Risk of Bias in Non-Randomized Studies of Interventions (ROBINS-I) [10]. The NOS is composed of 3 components: selection, comparability, and outcome. The ROB2 is composed of 6 components: bias due to randomization, bias due to deviations from intended interventions, bias due to missing outcome data, bias in measurement of the outcome, and bias in selection of reported outcomes, whereas the ROB2 assessed 7 bias domains—bias due to confounding, bias in selection, bias in classification, bias due to deviation, bias due to missing data, bias in measurement of outcomes, and bias in selection of the reported result. The quality assessment was done by AAT and RBA independently, and it was checked by MMH and HBA, and any conflict was solved by discussion.

Data analysis

The mean and standard deviation from the included studies were used to assess the outcomes. The effect size that was used in the analysis was weighted mean difference (WMD) and its related 95% confidence interval (95%CI). The studies were pooled using the random effect model when I^2 was > 50%, while they were pooled using the fixed effect model when I^2 was < 50%. The OSA remission was assessed using rates and its related 95%CI. The rates were pooled using random effect model with double arcsine transformation. The Cochrane Q test and I^2 statistic were used to assess heterogeneity of the included studies. The analysis was done using Meta XL, version 5.3 (EpiGear International, Queensland, Australia).

Results

Search results

The search yielded 2279 articles, of which 235 were duplicates. From the remaining articles, 1780 articles were excluded because they were reviews, case reports, animal studies, or non-English articles. The remaining 255 articles were screened using their full text form, and 223 were excluded due to lack of data about the outcomes, not performing PSG before or after the bariatric surgery, and not including patients with OSA diagnosed by PSG. A total of 32 studies were included in this systematic review and meta-analysis [4, 11–41]. The detailed description of study inclusion process is described in Fig. 1.

Characteristics of the included studies

A total of 2310 participants were included from 32 studies. The mean preoperative BMI and postoperative BMI were 43.5 and 32.1, respectively. The mean AHI preoperatively was 35.0 events/hour, compared to the mean AHI postoperatively of 14.2 events/hour. The average rate of OSA remission was 64%. The quality of all the included observational studies was good with the lowest study scoring 5 out of 9. All of the included clinical trials had low risk of bias except one of them. Tables 1 and 2 describe the characteristics of the included studies.

The effect of bariatric surgery on BMI in patients with OSA

The model that examined how bariatric surgery affected BMI in patients with OSA revealed that the procedure was significantly linked to a drop in BMI (Fig. 2; random effect; WMD = − 11.9, 95%CI: − 13.4, − 10.4). This model displayed significant heterogeneity (P value = 0.00, I^2 = 95%).

The effect of bariatric surgery on AHI in patients with OSA

The analysis model included 23 studies that examined how patients with OSA responded to bariatric surgery. According to this model, weight loss surgery significantly decreased the AHI among patients with OSA (Fig. 3; random effect; WMD = − 19.3, 95%CI: − 23.9, − 14.6). This model had a significant heterogeneity (P value = 0.00, I^2 = 97%).

The effect of bariatric surgery on RDI in patients with OSA

The model analyzing the effect of bariatric surgery on RDI included 2 studies. In this model, bariatric surgery was significantly associated with a reduction in RDI in patients with OSA patients (Fig. 4; fixed effect; WMD = − 33.9, 95%CI: − 42.1, − 25.7).

The effect of bariatric surgery on sleepiness in patients with OSA

Six studies were included in the analysis model studying the effect of bariatric surgery on sleepiness among patients with OSA. According to the analysis, patients with OSA who underwent bariatric surgery reported significantly less sleepiness. This model had a significant heterogeneity (P value = 0.00%, I^2 = 98%) (Fig. 5).

The effect of bariatric surgery on OSA remission in patients with OSA

The model analyzing the effect of bariatric surgery on OSA remission included 19 studies. This model revealed that bariatric surgery was associated with an overall rate of remission of 65% (Fig. 6; random effect; 95%CI: 0.54, 0.76). The model had a significant heterogeneity (P value = 0.00, I^2 = 94%).

Publication bias

Publication bias funnel plot showed significant asymmetry. Figure 7 shows publication bias funnel plot.

Discussion

A significant proportion of the population suffers from OSA, which has a negative effect on comorbidities and quality of life. According to the findings of this meta-analysis, bariatric surgery led to improvements in BMI, AHI, RDI, and ESS, and a 65% rate of OSA remission.

Similar to our findings, earlier meta-analyses revealed that bariatric surgery was linked to a significant decline in BMI and AHI [5, 6]. These studies, however, did not demonstrate an improvement in the sleepiness scale, which is in contrast to our findings. This is understandable given that the current meta-analysis included more studies and a greater number of patients. Furthermore, the effect of these surgeries on RDI was not examined in the former studies. Although RDI and AHI are similar measures, RDI includes respiratory-related arousals, making it a more inclusive

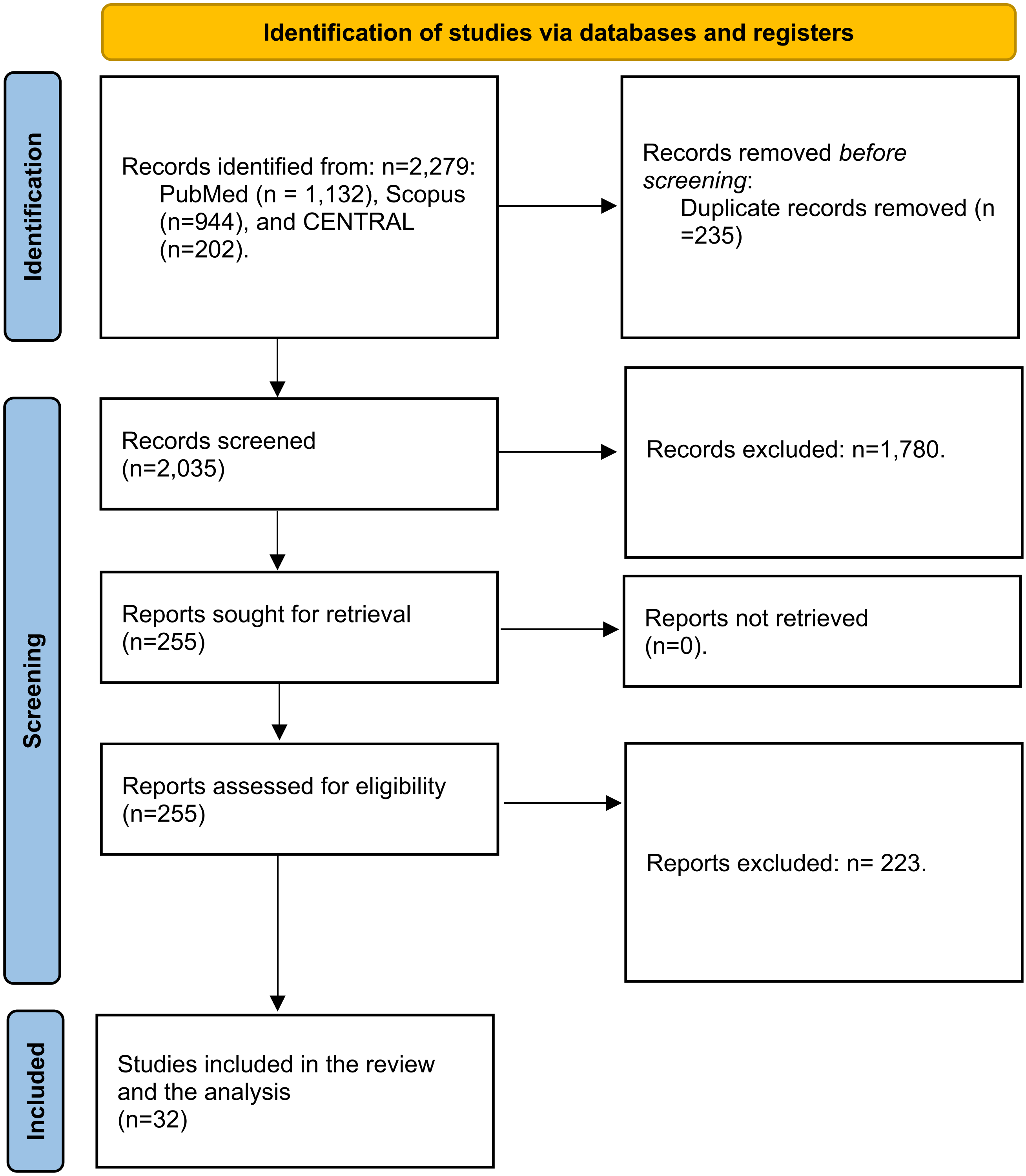

Fig. 1 PRISMA flow chart

measure of sleeping quality and sleeping disturbances [42]. Additionally, the rate of OSA remission was not examined in the earlier meta-analyses.

Despite the benefits on BMI, OSA measures, and sleepiness that this meta-analysis confirmed, the literature has raised a number of safety concerns [43]. Patients with

Table 1 The characteristics of the included observational study studies

Study name	Country	Design	Number of participants	BMI preoperatively	BMI postoperatively	AHI preoperatively	AHI postoperatively	Sleepiness preoperatively	Sleepiness postoperatively	Rate of remission	Quality assessment score
Hansen et al	Denmark	Prospective cohort	24	44.4 (5.2)	30.8 (4.8)	12.8 (13.8)	3.7 (4.4)	-	-	15/24	7
Zou et al	China	Retrospective cohort	44	31.1 (3.4)	24.4 (2.6)	22.4 (17.8)	7.1 (9.4)	-	-	16/44	7
De Raaff et al	Netherland	Retrospective cohort	205	46 (7.2)	33.7 (5.5)	32.3 (15–138)	8.5 (0–53.6)	-	-	131/205	6
Morong et al	Netherland	Retrospective cohort	91	44.8 (40.0–49.6)	35.7 (31.6–40.2)	21.2 (11.5–34.9)	6.3 (3.2–12.3)	-	-	32/91	7
Amin et al	USA	Prospective cohort	7	-	-	13 (6.9)	5 (4.3)	-	-	-	6
Rao et al	Singapore	Prospective cohort	228	45.2 (33–60)	30 (23–40.3)	38.1 (16.6–137.7)	13.2 (0.6–91.7)	-	-	188/228	6
Magne et al	UK	Retrospective cohort	44	46.1 (5.1)	33.4 (4.3)	52.8 (23.8)	11.9 (9.7)	-	-	31/44	7
Bae et al	Korea	Prospective cohort	10	39.9 (8.3)	26.9 (4.4)	51.0 (34.2)	9.3 (12.9)	-	-	5/10	6
Hariri et al	USA	Retrospective cohort	297	-	-	-	-	-	-	255/297	7
Fritscher et al	Canada	Retrospective cohort	12	55.5 (10.1)	34.1 (8.1)	46.5 (33–140)	16 (1–87)	-	-	12/12	
Timmerman et al	France	Retrospective cohort	36	47.4 (8.4)	36.3 (7.1)	45.8 (25.6)	11.3 (11.9)	7.2 (5.0)	3.3 (3.4)	26/36	7
Chen et al	China	Retrospective cohort	323	42.6 (7.7)	31.9 (5.9)	31.9 (28.6)	13.3 (15.8)	-	-	-	7
Lettieri et al	USA	Retrospective cohort	23	51.0 (10.4)	32.1 (5.5)	47.9 (33.8)	24.5 (18.1)	15.0 (4.9)	10.6 (4.0)	20/23	7
Rasheid et al	USA	Cohort	11	62 (3)	40 (2)	56 (13)	23 (7)	14 (2)	3 (1)	-	5
Guardino et al	USA	Retrospective cohort	8	49 (12)	34 (12)	55 (31)	14 (17)	-	-	5/8	5
Ravesloot et al	Netherlands	Prospective observational	195	45.0 (8.0)	35.0 (6.0)	49.1 (33.8)	22.7 (16.3)	-	-	113/195	8
Varela et al	USA	Retrospective cohort	56	-	-	35 (10)	3.4 (1.1)	13.7 (5.5)	5.4 (4.0)	56/56	7
Collen et al	USA	Prospective cohort	22 patients	51.1 (10.9)	32.5 (5.4)	48.2 (32.8)	24.5 (18.8)	-	-	1/22	9
Kara et al	Turkey	Prospective cohort	31	49.8 (8.5)	33.2 (8.2)	36.1 (27.1)	10.3 (11.8)	5.1 (3.7)	1.6 (1.6)	-	8
Kalra et al	USA	Retrospective cohort	19	-	-	20.5 (6.9)	6.1 (3.4)	73.18 (2.41)	80.23 (1.83)	-	7

Table 1 (continued)

Study name	Country	Design	Number of participants	BMI preoperatively	BMI postoperatively	AHI preoperatively	AHI postoperatively	Sleepiness preoperatively	Sleepiness postoperatively	Rate of remission	Quality assessment score
Chierakul et al	Thailand	Prospective cohort	24	51.6 (8.7)	38.2 (6.8)	87.6 (38.9)	28.5 (21.5)	8.7 (5.9)	4.7 (3.5)	-	7
Obeidat et al	Jordan	Prospective cohort	179	-	16.0 (16.0)	-	22.6 (26.3)	-	-	150/179	5
Peromaa-Haavisto et al	Finland	Prospective cohort	119	43.9	33.0	27.8	9.9	7.7	4.6	54/119	8
Jiao et al	China	Randomized clinical trial	39	30.7 (3.7)	24.2 (2.70)	13.0 (23.5)	3.0 (7.0)	-	-	-	8
Nastałek et al	Poland	Prospective cohort	Final sample: 44	45.0 (40.8–50.6)	-	44.9 (30.8–63.7)	29.2 (11.1–3.7)	-	-	-	6
Kaar et al	USA	Retrospective cohort	44	50.6 (8.1)	37.2 (5.1)	24.7	2.6	-	-	29/44	5

high BMI and OSA were found to have higher postoperative morbidity and mortality rates and more surgical complications [44]. However, a prospective study of 4776 patients revealed that only 4.3% of patients experienced negative effects and that the surgical mortality rate was only 0.3% [44]. In light of this, it is important to weigh the risk of bariatric surgery against the cumulative long-term risk of obesity and OSA among those patients. Anastomotic leak is one of the complications that affect patients with OSA frequently and is linked to a high mortality rate [45]. The high prevalence of hypertension and gastroesophageal reflux disease in OSA has been linked to this high risk [46]. Additionally, due to its capacity to raise intraluminal pressure within the gastrointestinal tract, postoperative CPAP use was linked to this complication [47]. Although there has been debate about the link between CPAP use and anastomotic leak in the literature, the fact that this complication is linked to high mortality highlights the significance of understanding patients' capacity to discontinue CPAP use.

Since weight loss and OSA remission are not linearly correlated, it is unclear how obesity affects the non-anatomical features of OSA [48]. Previous research demonstrated that if the critical closing pressure of the airway fell below − 4 cm H_2O, OSA would be eliminated along with a reduction in the collapsibility of the upper airways [48]. However, other characteristics, such as a poor response of the pharyngeal muscles, an oversensitive ventilatory system, and a low respiratory arousal threshold, have been shown to play a role in the pathogenesis of OSA [49]. Additionally, a significant portion of patients with OSA are compromised by positional obstructive sleep apnea (POSA), which is defined as OSA that occurs while the patient is supine [50]. However, losing weight has a greater effect on the non-positional than the positional aspect of OSA [51]. As a result, selecting patients according to the positional classification of OSA may result in higher remission rate of OSA after bariatric surgery.

Numerous studies have demonstrated that bariatric surgery improves sleep quality and daytime sleepiness, which is consistent with our findings [51]. After bariatric surgery, there may be a decrease in daytime sleepiness due to the improvement in nocturnal sleep brought on by the reduction of OSA and various inflammatory and metabolic abnormalities [52]. Additionally, bariatric procedures have been shown to lower depression and enhance quality of life [51]. Additionally, studies have shown that patients' depression improved only in those whose sleepiness scales had decreased, suggesting a correlation between the improvement in depression and the decrease in sleepiness following surgery [51].

This updated systematic review and meta-analysis shows that bariatric surgeries are effective in reducing BMI and AHI among OSA patients. However, this study has several limitations. First, the small sample size of the included

Table 2 The characteristics of the included clinical trial studies

Study name	Country	Design	Number of participants in placebo	Number of participants in bariatric surgery	BMI placebo	BMI bariatric surgery	AHI placebo	AHI bariatric surgery	Sleeping quality placebo	Sleeping quality bariatric surgery	Rate of remission in bariatric surgery	Quality assessment
Dixon et al	Australia et al	Randomized clinical trial	30	30	-	-	54.5 (43.6–65.4)	34 (21.9–46.2)	8.8 (6.5 to 11.0)	6.4 (4.7 to 8.1)	-	Low risk
Kardasis et al	Sweden	Randomized controlled trial	20	19	42.0 (6.2)	31.2 (5.3)	37.8 (27.7)	19.9 (21.5)	-	-	-	Low risk
Fredheim et al	Norway	Non-randomized controlled clinical trial	40	44	39.7	33.5	13	7.7			66%	Low risk
Feigel-Guiller et al	France	Prospective randomized controlled trial	33	30	43.4 (6.6)	41.0 (6.5)	43.5 (28.7)	40.7 (23.8)	-	-	6/30	Low risk
Bakker et al	USA	Non-randomized clinical trial	15	12	34.2 (30.4–39.0)	28.3 (25.3–37.5)	3.8 (1.2–10.6)	6.5 (1.9–12.8)	-	-	-	Moderate risk
Furlan et al	Brazil	Randomized clinical trial	24	13	38.1 (33.5–41.7)	26.4 (23.6–27.7)	17.7 (14.2–29.0)	3.2 (1.5–5.0)	-	-	70%	Low risk

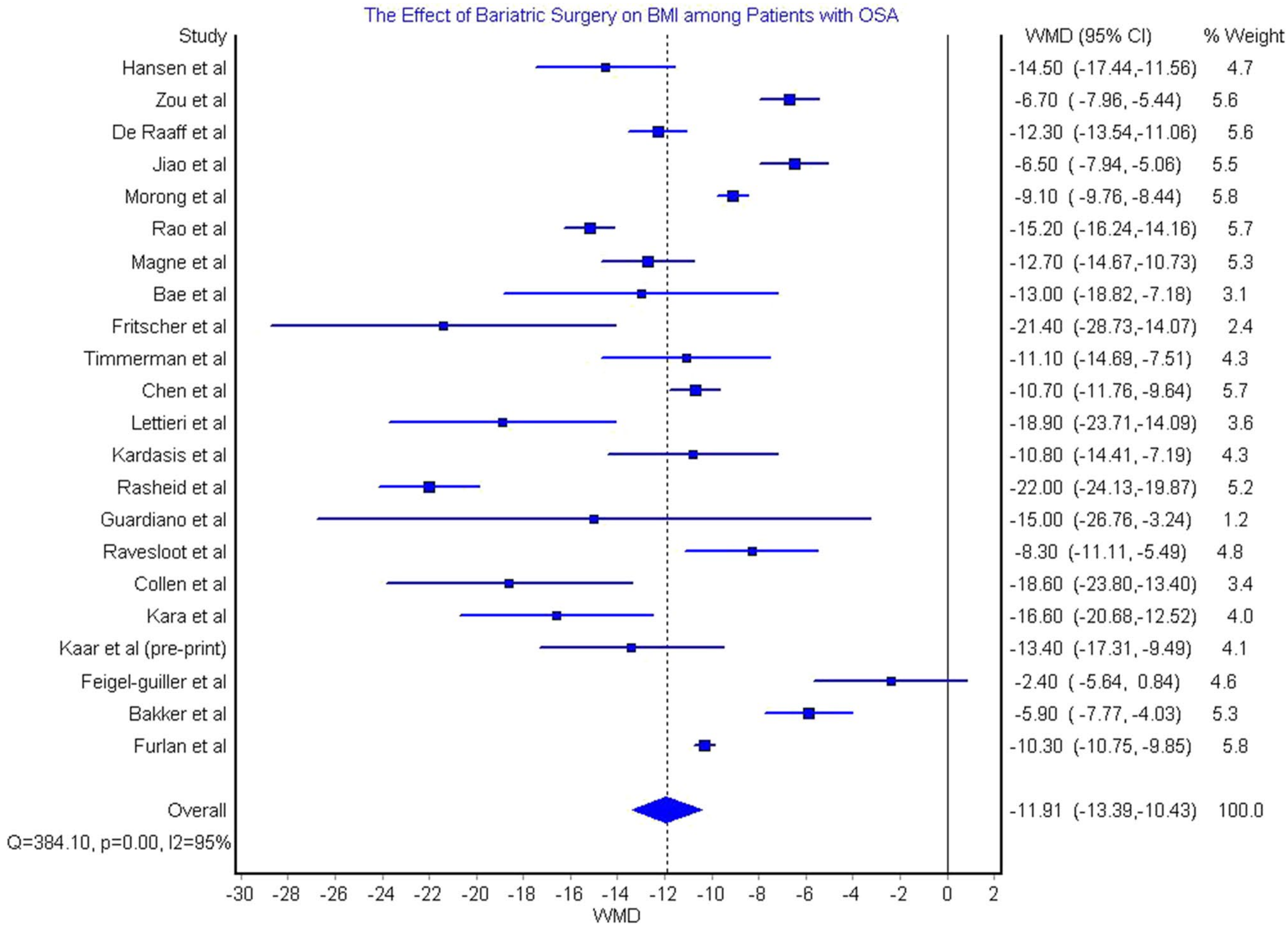

Fig. 2 The effect of bariatric surgery on BMI among OSA patients (WDM = postoperative BMI-preoperative BMI)

patients limits the generalizability of our results. Also, the model that assessed RDI included only 2 studies which limits our ability to draw significant conclusions. Second, we did not include non-English studies which also limits the generalizability of our results. The majority of the included studies did not adjust for confounding variables which may result in confounding bias. Furthermore, the included studies did not provide data about the OSA phenotypes which limited our ability to conduct sub-analyses according to the OSA phenotype. The high heterogeneity of our models may affect the reliability of our results which could be due to the difference in the characteristics of the included patients, OSA severity, and the bariatric procedure performed.

Conclusion

Systematic review and meta-analysis showed that bariatric surgeries are effective in reducing obesity among patients with OSA in addition to severity measures of OSA. However, the low rate of OSA remission suggests that other etiologies of OSA besides obesity remain.

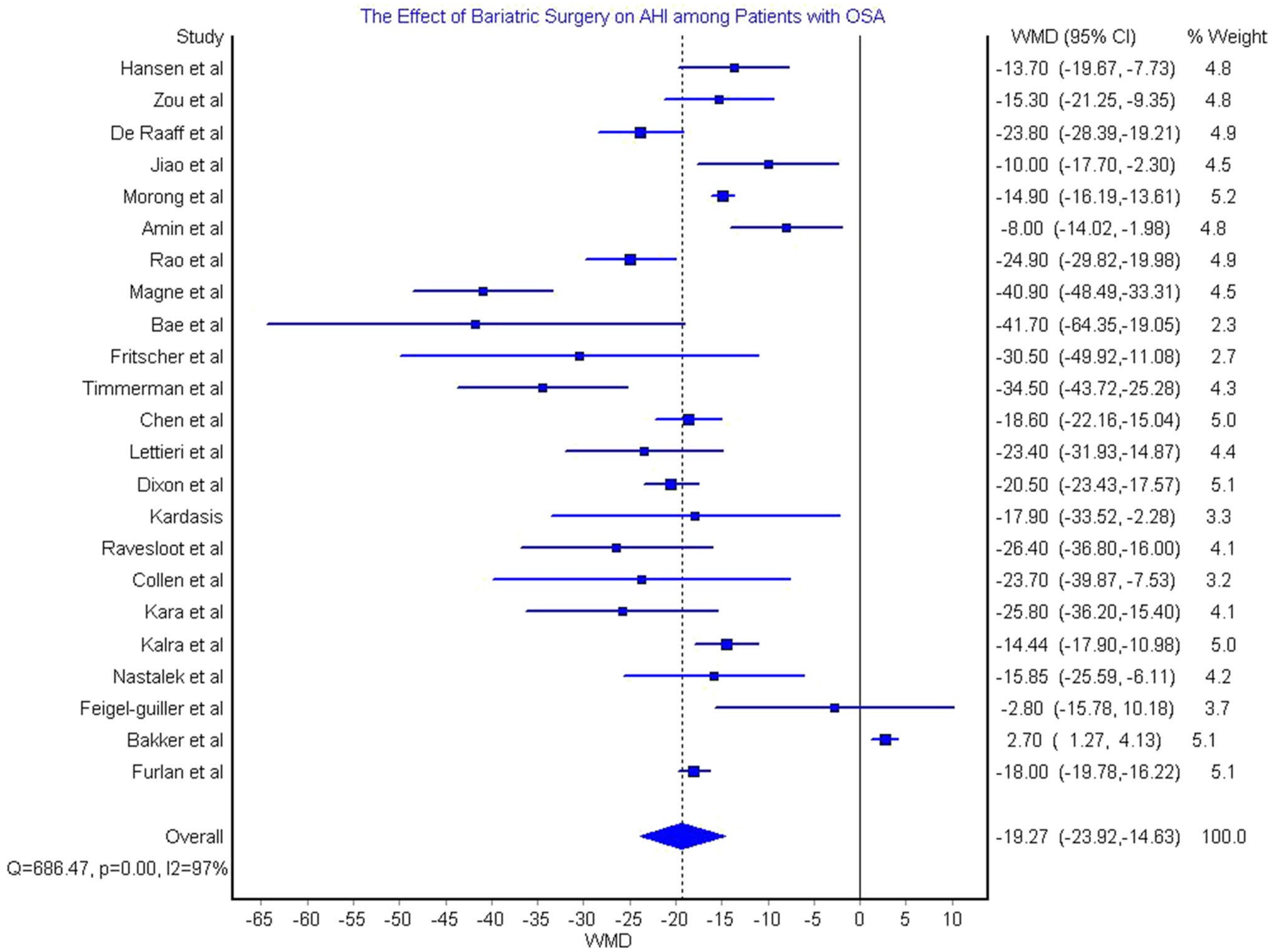

Fig. 3 The effect of bariatric surgery on AHI among patients with OSA (WDM = postoperative AHI-preoperative AHI)

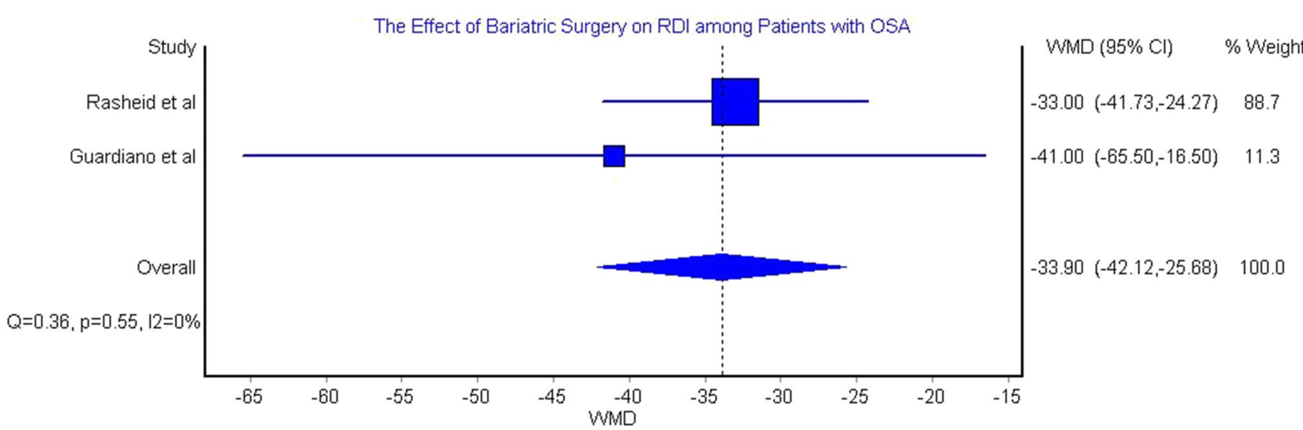

Fig. 4 The effect of bariatric surgery on RDI among patients with OSA (WDM = postoperative RDI-preoperative RDI)

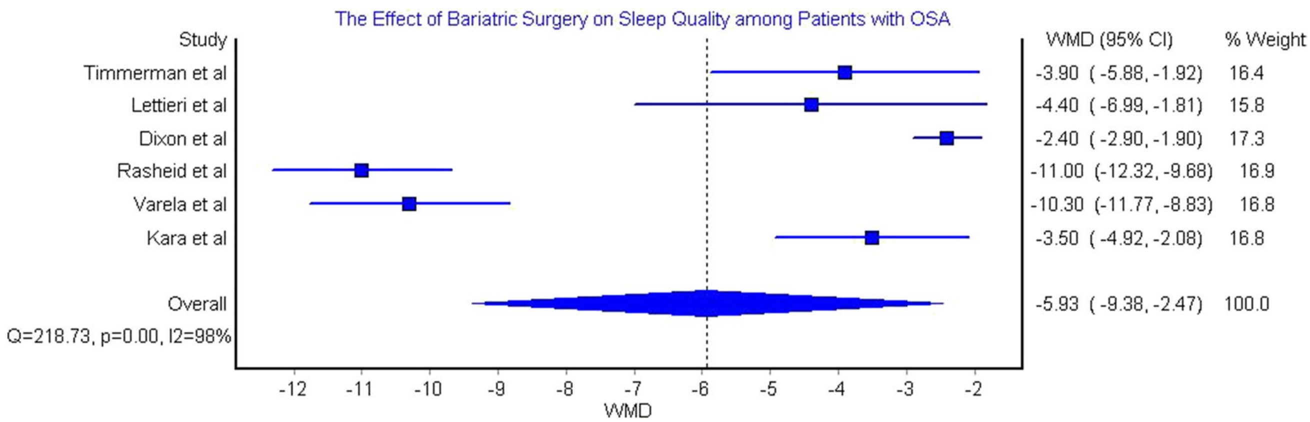

Fig. 5 The effect of bariatric surgery on Epworth sleepiness scale (ESS) among patients with OSA (WDM = postoperative ESS-preoperative ESS)

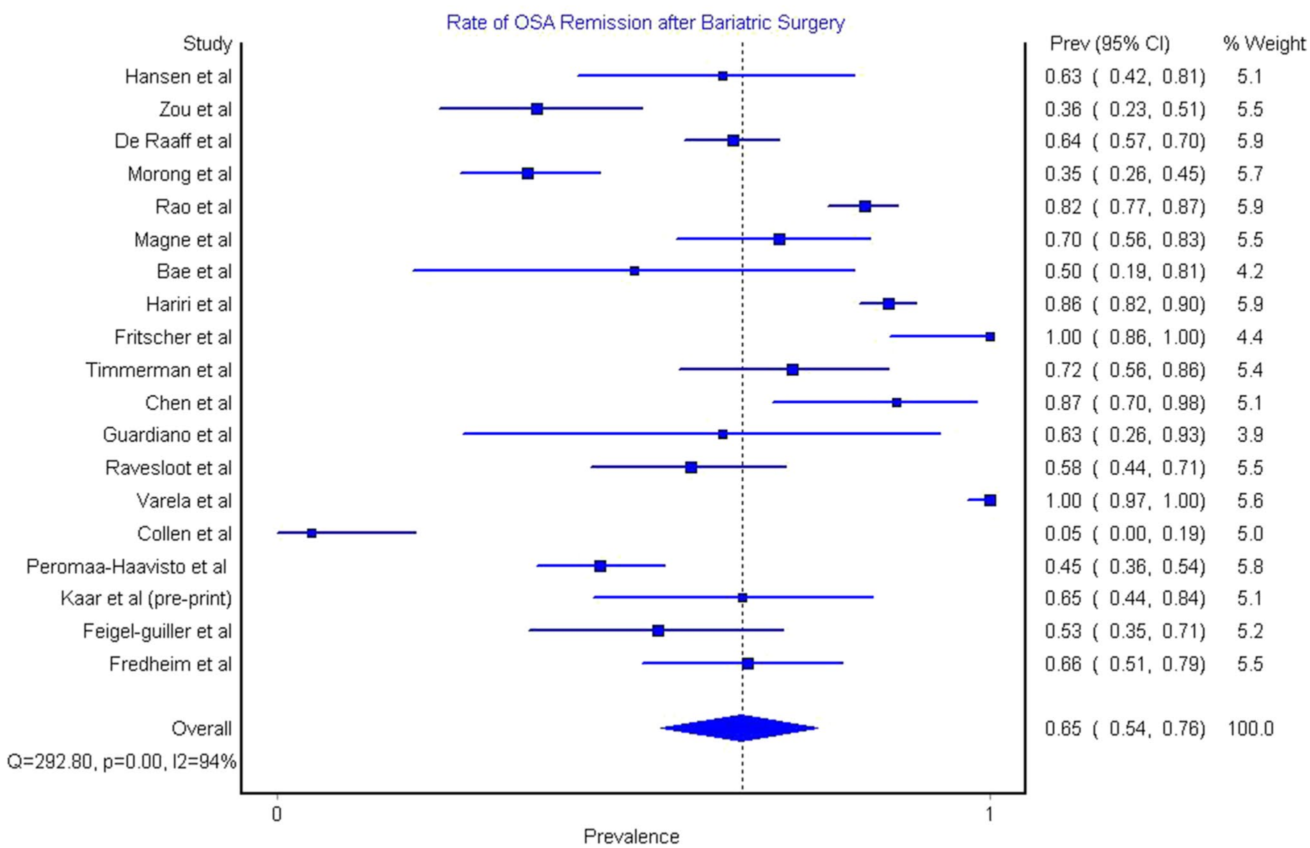

Fig. 6 The rate of OSA remission after bariatric surgery

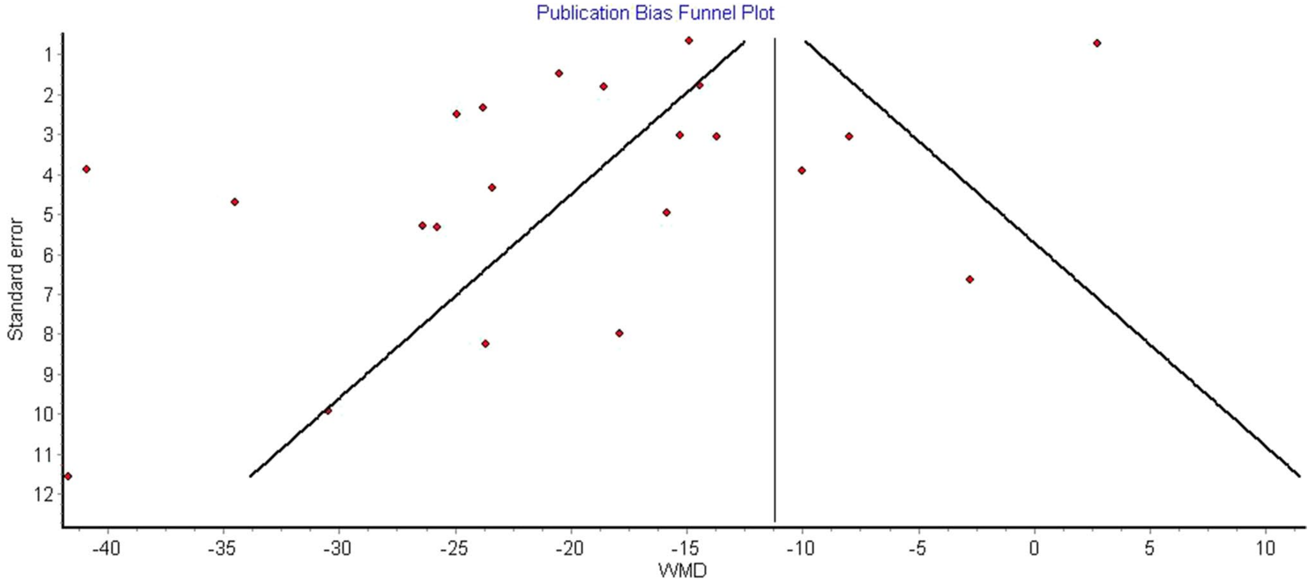

Fig. 7 Publication bias funnel plot

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s11325-023-02840-1.

Author contribution KA and AAT were involved in conceptualization; KA, AAT, RHA, MMH, and HBA were involved in data curation, formal analysis, investigation, methodology, project administration, resources, software, validation, visualization, and writing the original draft; KA, AAT, RHA, MMH, and HBA were involved in supervision and reviewing and editing the manuscript.

Data availability The data associated with this manuscript are available in the Supplementary Material.

Declarations

Ethical approval For this type of study, ethical approval is not required.

Informed consent For this type of study, informed consent is not required.

Conflict of interest The authors declare no competing interests.

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