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Update on comparison of laparoscopic sleeve gastrectomy and laparoscopic Roux-en-Y gastric bypass: a systematic review and meta-analysis of weight loss, comorbidities, and quality of life at 5 years

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Abstract

Background Laparoscopic Sleeve Gastrectomy (LSG) and Laparoscopic Roux-en-Y Gastric Bypass (LRYGB) are the two most commonly performed bariatric surgeries for the treatment of obesity. This meta-analysis was performed with the aim of summarizing the available evidence on weight loss, remission of comorbidities, and quality of life in LRYGB and LSG, complementing the current literature.

Methods We searched PubMed, EMBASE and the Cochrane Library from January 2012 to June 2023 for randomized controlled trials and non-randomized interventional studies. We finally selected 18 eligible studies.

Results LRYGB resulted in greater weight loss compared with LSG at 5 years [WMD= -7.65 kg/m^2, 95% confidence interval (CI) -11.54 to -3.76, $P=0.0001$], but there exists high heterogeneity with I^2=84%. Resolution rate of type 2 diabetes mellitus (T2D) (OR = 0.60, 95%CI 0.41–0.87, $p=0.007$) and dyslipidemia (OR = 0.44, 95%CI 0.23–0.84, $p=0.01$) was higher in the LRYGB group than that in the LSG group at 5 years. There was no difference between LRYGB and LSG for remission of hypertension, and obstructive sleep apnea. No differences were observed in the QoL after LRYGB or LSG. Morbidity was lower in the LSG group (WMD = -0.07, 95% CI: -0.13, -0.02, $P=0.01$) than in the LRYGB group. No statistically significant difference was found in mortality between the two procedures.

Conclusion At 5 years after surgery, LRYGB resulted in greater weight loss and achieved better remission rate of T2D and dyslipidemia than LSG. However, LSG has a lower morbidity rate than that of LRYGB.

Keywords Bariatric surgery, Roux-en-Y gastric bypass, Sleeve gastrectomy, Laparoscopy

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Introduction

Obesity has become a global health issue, with nearly a third of the world's population now with obesity [1]. Obesity is capable of causing serious comorbidities, such as cardiovascular disease [2], type 2 diabetes [3], and various cancers [4]. There are multiple forms of obesity treatment, including dietary therapy, medications therapy and bariatric surgery [5]. However, long-term results have shown that bariatric surgery is the most effective management for obesity [6]. Bariatric surgery results in massive weight loss in a short period of time, and also leads to comorbidity remission, mortality decline and quality of life improvement [7].

LSG and LRYGB are the most recommended bariatric surgeries [8]. However, there is heated debate on the subject of which the two surgeries is more effective. LRYGB as a bariatric surgery was first described by Alan Wittgrove in 1994 [9]. Nowadays, as LRYGB is exceptionally effective at alleviating obesity-related medical conditions - including type 2 diabetes (T2D) it is one of the most widely adopted bariatric procedure and is known as one of the gold standard surgeries for people with obesity. While LSG is the most frequently performed bariatric surgery and becoming increasingly popular for people with obesity, some studies indicate that LRYGB will result in greater weight loss than LSG [10, 11], while others show that LSG is safer than LRYGB [12, 13] .

In recent years, many long-term follow up studies have been conducted on patients that underwent LSG and LRYGB. Given that long term results are not clear until 5 years post procedure, this systematic review and meta-analysis aims to update the comparison of LSG and LRYGB on weight loss, comorbidities remission and quality of life at 5 years after surgery.

Methods

The study protocol was written and registered on Prospero (CRD42023433754) before data extraction.

Eligibility criteria

Inclusion criteria are as follows: (1) Patients included in the studies were older than 18 years and had severe obesity (BMI>40 kg/m2 or >35 kg/m2 with obesity-related comorbidities); (2) Human studies reported in English; (3) At least one of the following endpoints was required: weight loss (expressed as %EWL), resolution rate of comorbidities (T2DM, dyslipidemia, hypertension, and obstructive sleep apnea), and quality of life; (4) Comparative studies between LRYGB and LSG.

Exclusion criteria are as follows: (1) non-human studies; (2) non-laparoscopic surgery; (3) studies that did not compare LRYGB with LSG; (4) case series and reports, reviews, letters, and editorials.

Outcomes assessed

The primary outcome was weight loss at 5 years after bariatric surgery. Secondary outcomes were: (1) remission of comorbidities including T2D, hypertension, dyslipidemia and obstructive sleep apnea at 5 years after surgery. Studies that clearly defined the criteria for comorbidities remission were included in the comorbidities analysis. Specifically, T2D remission was defined as HbA1c<6.5%, reduction or discontinuation of therapy. Hypertension was defined as decrease of blood pressure under same medication, reduction or discontinuation of therapy. The remission of dyslipidemia and obstructive sleep apnea was defined as reduction or discontinuation of therapy. 2). Quality of life changed 5 years after surgery, which was measured by gastrointestinal quality of life index (GIQLI) at 5 years. 3). morbidity and mortality after surgery.

Search strategy

We searched the PubMed, EMBASE, Cochrane Library covering January 2012 to June 2023. The search strategy included key words such as "gastric bypass", "Roux-en-Y Gastric Bypass", "LRYGB", "GB", and "sleeve gastrectomy", "LSG", "SG". Two assessors independently screened the titles and abstracts of each study. When a relevant study was identified, the full text was obtained for further evaluation.

Data abstraction

Two reviewers independently screened the searched titles, abstracts, and full texts after the inclusion and exclusion criteria. Data was extracted independently by two reviewers. The data extracted from each study included study characteristics (author, country, year of publication, study type), patient demographics (average age, %female, sample size, average pre-surgery weight and post-surgery weight), type of bariatric surgery, and outcomes. Disputes that occurred at the title and abstract screening stages were resolved by a third reviewer. Discrepancies that arose at the full-text or data abstraction stage were resolved through consensus discussions between the reviewers, or if necessary, a third reviewer was consulted to adjudicate disagreements.

Quality assessment

The methodological quality of the included non-randomized controlled trial studies was determined using the NOS (Newcastle–Ottawa Scale) [14] and Risk of Bias in Non-Randomized Studies of Interventions (ROBINS-I) [15]. Each article was evaluated in the following three aspects: object selection, inter-group comparability, and outcome measurement. Articles with scores<6 were considered low-quality articles. The methodological quality of the included randomized controlled trial (RCT) was determined using Cochrane Collaboration's tool for risk of bias [16]. The risk of bias in RCTs is categorized as low risk, unclear risk, and high risk. Disagreements between reviewers regarding the quality of included studies were resolved through consensus or by involving a third reviewer.

Statistical analysis

Weighted mean differences (WMD) with 95% confidence intervals (CI) were used to analyze continuous data, while odds ratios (ORs) with 95% CIs were used for the statistical analyses of dichotomous data. OR was calculated by the ratio of the number of remissions in the LSG group to the number of non-exposed people in the LSG group divided by the ratio of the number of remissions in the LRYGB group to the number of non-exposed people in the LRYGB group. Heterogeneity was represented by I^2 (low heterogeneity at values < 30%, moderate heterogeneity at values 30–50%, and high heterogeneity at values > 50%). The random-effects model was used for the analysis of studies with high heterogeneity, and the fixed effects model was used for studies with low or moderate heterogeneity. In addition, sensitivity analysis was performed to evaluate the effect of included studies on the combined results for outcomes with significant heterogeneity. Publication bias was evaluated visually by creating funnel plots and Begg's test was conducted on outcomes which included more than 10 studies. All statistical analysis and meta-analysis were performed on RevMan version 5.2 (The Cochrane Collaboration, The Nordic Cochrane Centre, Copenhagen, Denmark) and Stata 17.0 version (Stata Corporation, College Station, TX, USA).

Results

Study characteristics

The flow diagram of our literature search is shown in Fig. 1. A total of 2061 articles were identified from the database, of which 556 studies were excluded after duplication, text screening, and discussion. 18 articles were included in our analysis; 8 of them are RCTs, 4 of them are prospective cohort studies, and 6 of them are retrospective cohort studies [17–34]. A total of 1776 patients in the LSG group and 1679 patients in the LRYGB group were included in the studies. The collected studies were conducted between 2012 and June 2023 in 13 countries, including Finland, France, Switzerland, The USA, Spain, Sweden, New Zealand, China, Venezuela, Italy, The Netherlands, and Lebanon. The characteristics of the included studies are shown in Table 1. The methodological quality of the included non-RCT studies is shown in Table 2 and Fig. 2 and 3. The risk of bias for the RCTs is presented in Fig. 4.

Primary outcome: percentage excess weight loss (%EWL)

Patients in the LRYGB group had significantly greater weight loss than patients in the LSG group by 7.67 kg/m² at 5 years (WMD=-7.67,95% CI -11.53 to -3.82, $P < 0.00001$; I^2=84%; 1890 patients; 15 trials).

Subgroup analysis performed according to this study revealed that LRYGB resulted in more significant weight loss than LSG at 5 years in RCTs (WMD=-17.82,95% CI -28.25 to -7.38, $P = 0.0008$; I^2=84%; 452 patients; 5 trials) (Fig. 5). The statistical heterogeneity was high (I^2=84%, $P < 0.0001$), so the random-effects model was used. Furthermore, a sensitivity analysis was conducted (Fig. 6). The heterogeneity was significantly reduced after excluding the three studies [17, 19, 20]. I^2 of 12 include studies and 3 RCTs were reduced from 84 to 59% and 84–0%, respectively (Fig. 7). Additionally, funnel plots and Begg's test were performed to evaluate publication bias. A visual assessment of the funnel plot indicated the presence of slight publication bias (Fig. 8). However, Begg's test was not statistically significant($p = 0.125$) (Fig. 9). Another subgroup was performed by separating BMI into the 30–39 subgroup and the 40–49 subgroup. It showed no significant difference between LRYGB and LSG in the BMI 30–39 subgroup (WMD=-6.41, 95% CI -12.16- to -0.66, $P = 0.24$; I^2=28%; 187 patients; 2 trials) and the 40–49 subgroup (WMD=-2.17, 95% CI -2.72- to -1.62, $P = 0.05$; I^2=58%; 688 patients; 5 trials)(Fig. 10).

Secondary outcomes

Obesity-related comorbidities remission

Type 2 diabetes

Of the 18 articles, the rate of remission for T2D was reported by 8 trials ($n = 755$). Our pooled analysis showed that LRYGB achieved a superior rate of resolution for T2D remission at 5 years (OR = 0.55, 95%Cl 0.39–0.80, $p = 0.001$, I^2=0%,9 trials, $n = 793$). Subgroup analysis of RCT studies revealed that at 5 years, LRYGB had a significantly higher T2D remission rate (OR = 0.51, 95%Cl 0.32–0.82, $p = 0.005$, I^2=0%, 5trials, $n = 362$).

Hypertension

The rate of remission for hypertension was reported by 9 trials ($n = 755$). There was no significant difference in the rate of remission for hypertension between LRYGB and LSG at 5 years (OR = 0.82, 95%Cl 0.58–1.15, $p = 0.24$, I^2=25%, 9 trials, $n = 755$). In addition, pooling data from RCTs showed there was no significant difference in the rate of remission for hypertension between LRYGB and LSG (OR = 0.86, 95%Cl 0.56–1.33, $p = 0.50$, I^2=36%, 5 trials, $n = 409$).

Dyslipidemia

The rate of remission for dyslipidemia was reported by 8 trials ($n = 567$), including RCTs and cohort studies. The

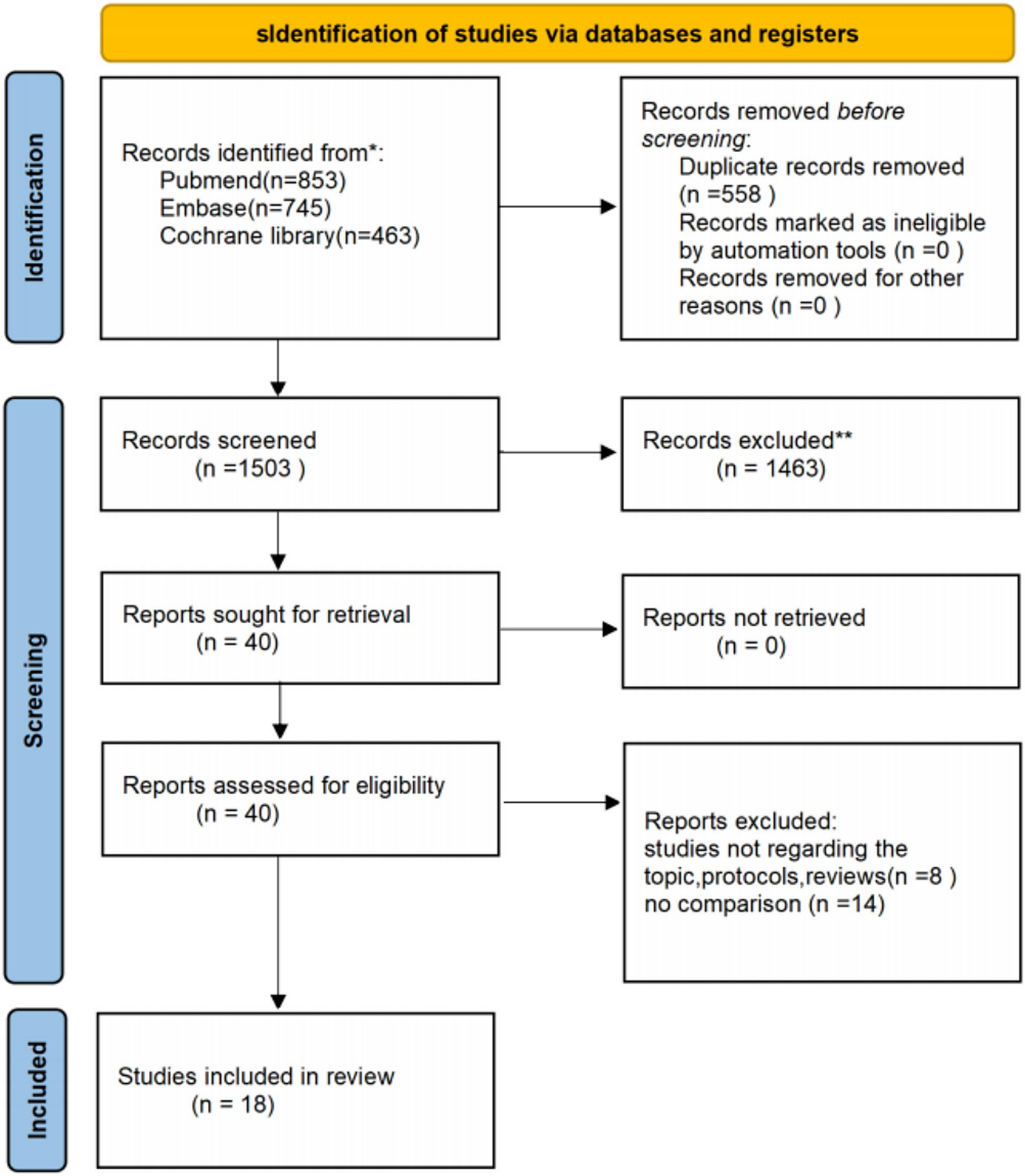


Fig. 1 Flow diagram of study selection

results showed that LRYGB has better remission than LSG after surgery at 5 years (OR=0.44, 95%Cl 0.23–0.84, p=0.01, I^2=52%, 8 trials, n=567). The statistical heterogeneity was high (I^2=52%, P=0.04), so the random-effects model was used. Furthermore, a sensitivity analysis was conducted (Fig. 11), which showed that LRYGB was superior to LSG for remission for dyslipidemia. However, it showed no significant difference after we exclusively pooled data from RCTs (OR=0.54, 95%Cl 0.24–1.22, p=0.14, I^2=19%,4 trials, n=238).

Table 1 Characteristics of included studies

Author (year)	Country	Study type	Sample size		Average age(years)		Female(%)		Average preop weight(kg/m^2)		Average post operative Weight(kg/m^2)	
			LSG	LRYGB	LSG	LRYGB	LSG	LRYGB	LSG	LRYGB	LSG	LRYGB
Zhang (2014)	China	RCT	32	32	29.3 ± 9.8	32.2 ± 9.2	62.5	56.25	NR	NR	NR	NR
ignat(2016)	France	RCT	55	45	35.1 ± 9.7	35.2 ± 9.4	78.2	86.7	128.6 ± 18.3	129.5 ± 21.2	NR	NR
Peterli(2018	Switzerland	RCT	107	110	43.0 ± 11	42.1 ± 11.2	72	71.8	123.5 ± 19.4	124.8 ± 19.8	NR	NR
Schauer(2017)	USA	RCT	47	49	49 ± 8	49 ± 8	66	66	100.4 ± 16.8	106.8 ± 14.9	81.9 ± 15.0	83.4 ± 15.3
salminen (2018)	Finland	RCT	98	95	48.5 ± 9.6	48.4 ± 9.3	71.9	67.2	130.1 ± 21.5	134.9 ± 22.5	NR	NR
Casajoana (2019)	Spain	RCT	15	15	49.2 ± 9.1	51.0 ± 7.7	66.7	53.3	102 ± 10.8	103 ± 10.8	84.4 ± 17.0	74.7 ± 9.9
Laurenius(2022)	Sweden	RCT	15	23	47 ± 11	49 ± 9	46	50	118.9 ± 19.6	119.3 ± 15.2	101.1 ± 16.1	91.9 ± 12.8
Murphy(2022)	New Zealand	RCT	58	56	45.5 ± 6.4	46.6 ± 6.7	45	59	126.7 ± 24.5	123.4 ± 21.3	103.3 ± 16.8	89.8 ± 18.1
Leyba (2014)	Venezuela	Prospective cohort	27	47	34.6 ± 9.2	38 ± 9.9	83.3	80	NR	NR	NR	NR
lee(2015)	China Tai Wan	Prospective cohort	116	218	36.0 ± 9.1	36.1 ± 9.3	74.6	73	NR	NR	NR	NR
Perrone (2016)	Italy	Prospective cohort	162	142	41.8 ± 4.6	43.8 ± 4.6	60.5	78.9	NR	NR	NR	NR
Dogan(2016)	The Netherlands	Retrospective cohort	245	245	39.7 ± 10.0	41.2 ± 9.7	82	82	NR	NR	NR	NR
Aridi 2018	Lebanon	Retrospective cohort	400	175	36.4 ± 12.7	41.9 ± 10.3	60	46.3	120.1 ± 23.8	130.3 ± 27.0	NR	NR
Castro 2020	Spain	Retrospective cohort	83	152	43.5 ± 10.2	44.1 ± 11.6	75.9	78.9	117.4 ± 25.4	115.1 ± 24.1	NR	NR
Calvo(2020)	Spain	Retrospective cohort	104	122	44.3 ± 9.9	42.1 ± 10.0	67.3	77.4	NR	NR	NR	NR
Level(2021)	Venezuela	Prospective cohort	63	70	38 ± 11	36 ± 8	77.8	87.1	NR	NR	NR	NR
Soong(2021)	China Tai Wan	Retrospective cohort	99	32	33.0 ± 10.0	30.5 ± 9.6	34.7	51.6	NR	NR	NR	NR
Belluzzi(2023)	USA	Retrospective cohort	62	41	72.2 ± 2.2	72.1 ± 2.7	70.7	67.7	NR	NR	NR	NR

Table 2 Quality of assessment of included studies measured by Newcastle–Ottawa scale

Author	Selection				Comparability of cases and Controls on Bias of Design of Analysis	Outcome			Score
	Adequate case defination	Representative of cases	Selection of controls	Definations of controls		Ascertainment of exposure	same method of ascertainment for cases and controls	Non-response rate	
Leyba et al.	☆	☆	☆	☆	☆☆	☆	☆	☆	9
Lee et al.	☆	☆	☆	☆	☆☆	☆	☆	—	8
Perrone et al.	☆	☆	☆	☆	☆☆	☆	☆	☆	9
Dogan et al.	☆	☆	☆	☆	☆	☆	☆	—	7
Aridi et al.	☆	☆	☆	☆	☆	☆	☆	—	7
Castro et al.	☆	☆	☆	☆	☆☆	☆	☆	—	8
Calvo et al.	☆	☆	☆	☆	☆☆	☆	☆	—	8
Level et al.	☆	☆	☆	☆	☆	☆	☆	—	7
Soong et al.	☆	☆	☆	☆	☆☆	☆	☆	—	8
Belluzzi et al.	☆	☆	☆	☆	☆☆	☆	☆	—	8

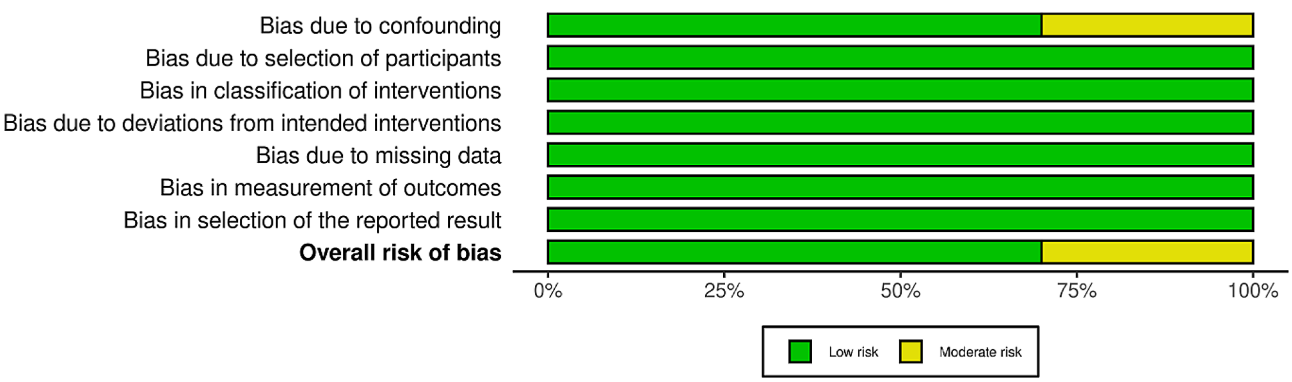


Fig. 2 Risk of bias graph of non-RCT studies

Obstructive sleep apnea
The rate of remission for obstructive sleep apnea was reported by 4 trials ($n=219$). LRYGB is better than LSG in obstructive sleep apnea remission at 5 years (OR=0.46, 95%Cl 0.21–0.98, $p=0.04$, $I^2=0\%$,4 trials, $n=219$).

Quality of life
There was no significant difference between the two types of surgeries after 5 years in quality of life, which was measured by the GIQLI [35] (RR=-1.59, 95% CI -6.18– 3.00, $P=0.50$) (Fig. 12). The statistical heterogeneity was high ($I^2=59\%$, $P=0.09$). Thus, a sensitivity analysis was conducted, which showed the rationality and reliability of our results. (Fig. 13)

Morbidity and Mortality
The results showed that the LSG group has a lower morbidity rate than the LRYGB group (WMD=-0.07, 95% CI: -0.13, -0.02, $P=0.01$, $I^2 = 80\%$, 13 studies, $n=2695$) (Fig. 14). No statistically significant difference in mortality was found between the LSG and LRYGB groups. （Fig. 15)

Discussion
Nowadays, obesity has become a global burden. The WHO released a report on obesity pandemic in Europe in May 2022, stating that 60% of citizens in Europe are with obesity [36]. The prevalence of obesity may be even higher in the future. A study from Wald et al. shows that the national prevalence of adult obesity and severe obesity will rise to 48.9% by 2030 in United States [37]. Bariatric surgery is an excellent strategy to treat obesity, as it results in long-term weight loss in people with severe obesity, improves metabolic syndrome and alleviates obesity-related diseases, and decreases future overall cancer incidence and mortality [38].

LRYGB and LSG are both commonly adopted bariatric surgery methods. Compared with LRYGB, LSG is much simpler in terms of technical complexity, with a significantly shorter operative time, and a notable reduction in major complications within 30 days postoperatively [39]. However, LSG may entail more risks compared to LRYGB, such as gastroesophageal reflux [40]and gastric stenosis [41]. While LRYGB is technically demanding [13], some studies have suggested that LRYGB is more effective for weight loss than LSG [10, 42].

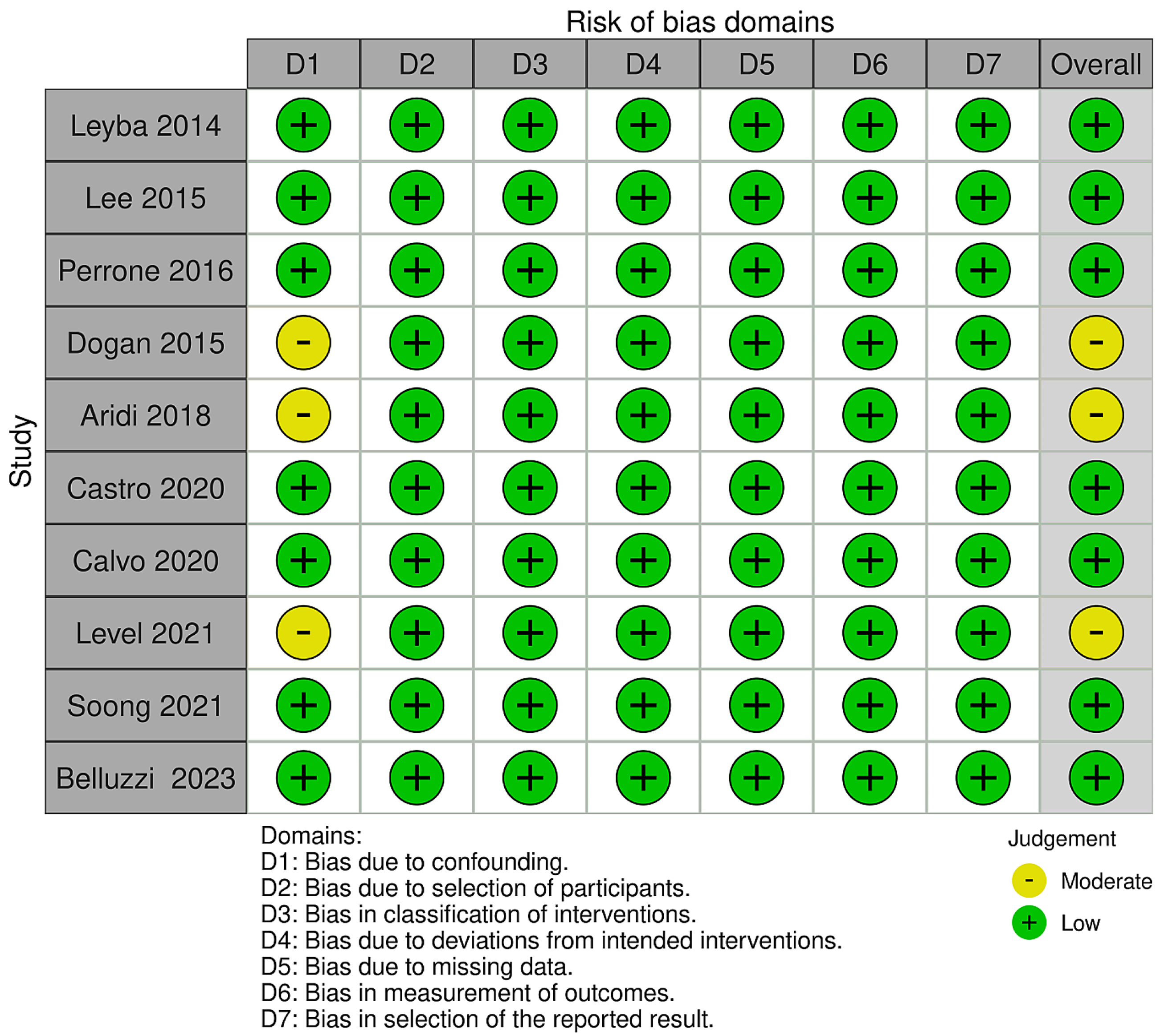


Fig. 3 Risk of bias summary of non-RCT studies

In this study, we found that LRYGB exhibited better weight loss outcomes than LSG at 5 years after surgery. Some studies have explored the effects of LRYGB compared with LSG using %EWL, indicating that LRYGB tends to result in more substantial weight loss outcomes after 5 years during their follow-up [42, 43]. Our results are consistent with these findings. However, another meta-analysis by Zhao et al. indicated that both LRYGB and LSG are equivalent for excess weight loss, possibly due to the limited availability of long-term follow-up data, with only 3 studies providing data at 5 years [44]. In our analysis, we included a total of 15 studies with 1890 patients, which provided 5 years of follow-up data on percentage excess weight loss for patients who underwent LRYGB and LSG. Notably, our study included more patients with follow-up after 5 years than Zhao's study. Furthermore, the results from 5 RCTs support our findings. We observed that the results exhibit high heterogeneity with I^2=84%. The variation in baseline patient weights among the included studies may contribute to this heterogeneity. After conducting a subgroup analysis, we still find high heterogeneity with I^2=84%. Therefore, we performed a sensitivity analysis and excluded the studies which lead to the most heterogeneity. The result still supports the primary result that LRYGB resulted in greater weight loss compared with LSG at 5 years. Nevertheless, it's important to note that the long-term superiority of LRYGB over LSG remains uncertain. Some studies have suggested comparable weight loss outcomes between the two procedures at longer follow-up intervals, such as 7 or 10 years post-surgery [10, 11]. Therefore, while LRYGB may offer advantages in weight

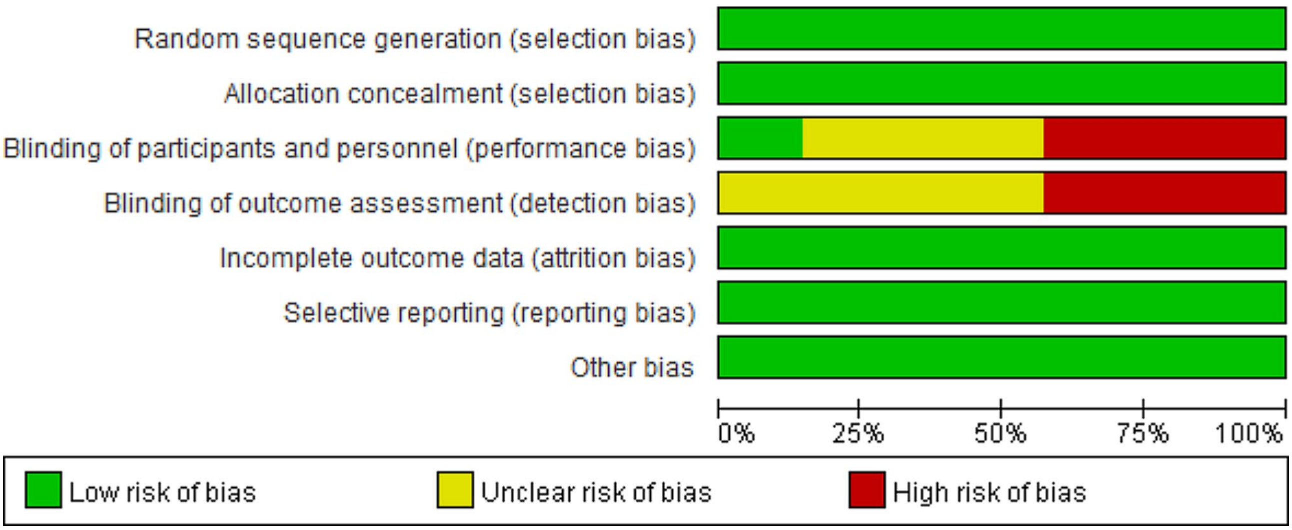


Fig. 4 Risk of bias assessment using Cochrane Collaboration's tool

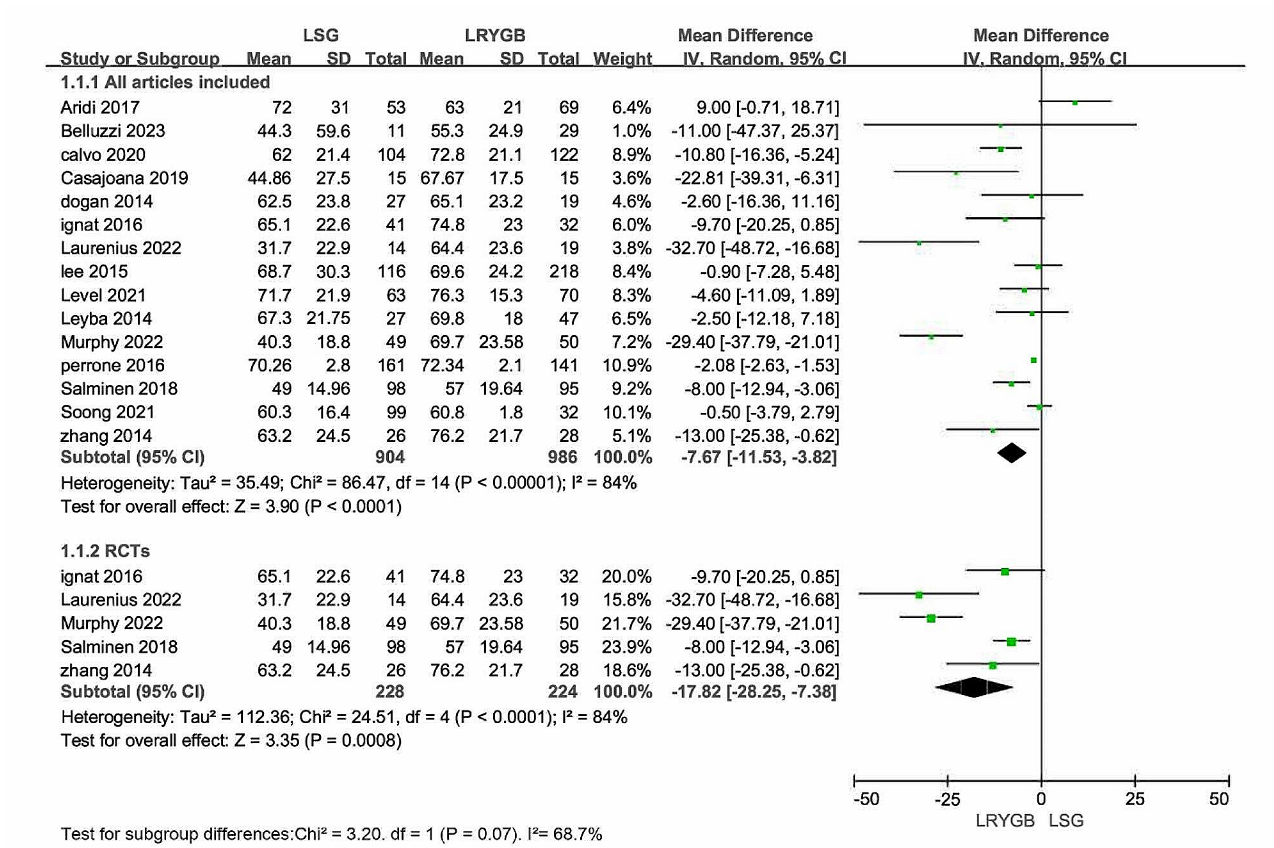


Fig. 5 Forest plot of % EWL at 5 years

loss at 5 years, further research is needed to confirm its sustained efficacy beyond this timeframe. Additionally, we performed another subgroup analysis by separating BMI into the 30–39 subgroup and the 40–49 subgroup, which showed no significant difference between LRYGB and LSG in the two subgroups. However, the number of included articles in this subgroup is limited. Therefore, further research is needed to confirm which procedure is better according to different BMI.

In this study, we found that LRYGB is superior in T2D remission at 5 years after surgery. Our findings are consistent with recent studies, which indicate that LRYGB

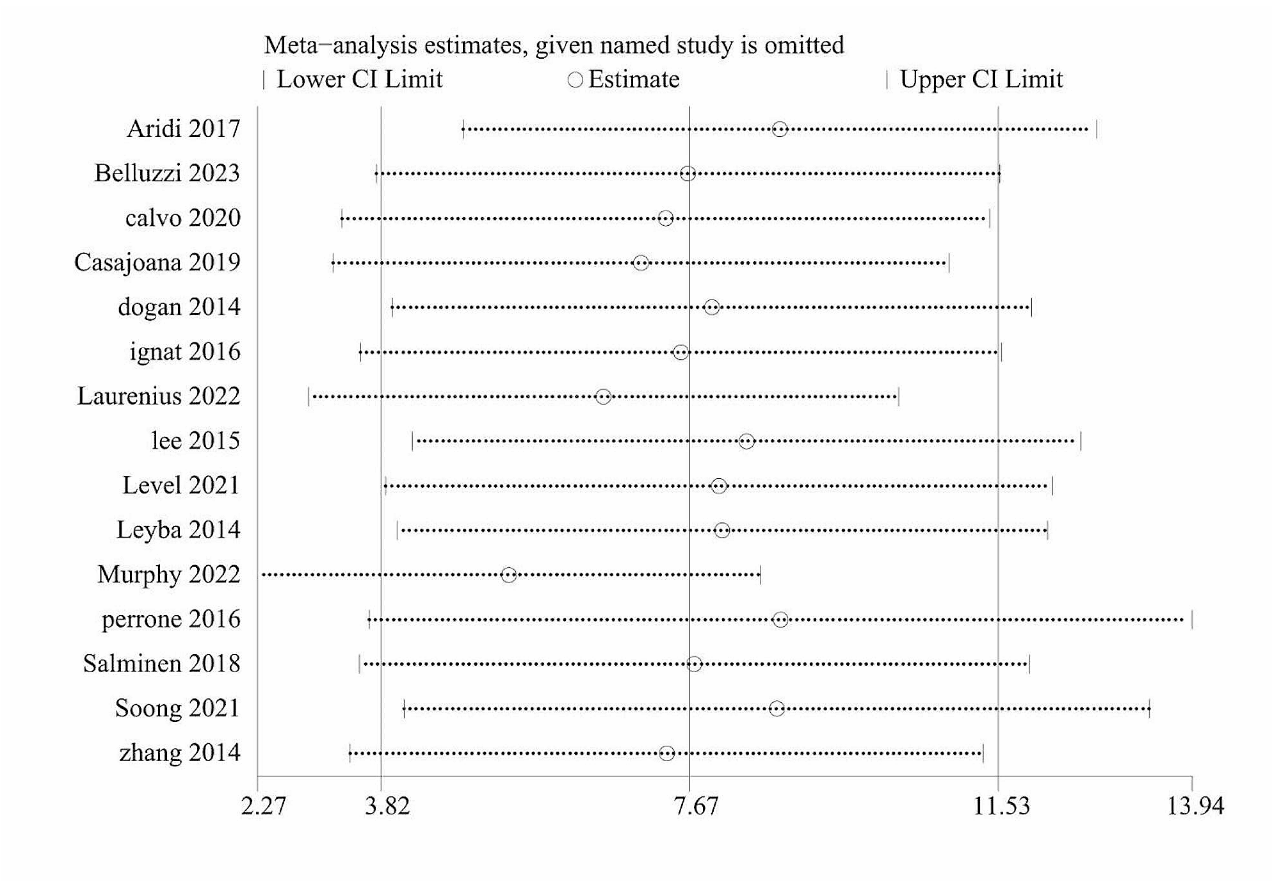


Fig. 6 Sensitivity analysis of %EWL

has better efficiency in T2D remission [42]. Our study increased sample size, which may reduce potential bias. Both procedures restrict caloric intake by reducing the size of the stomach, but LRYGB -by bypassing the duodenum - also causes changes in gastrointestinal hormones [45] and gut microbiota [46] that may enhance diabetes remission. Lee et al. conducted a meta-analysis which showed that there was no significant difference between LRYGB and LSG in T2D remission [47], However, only four studies and 351 patients were included in Lee's study. In our study, we included a total of 793 patients and 9 studies - including 5 RCTs - when comparing LRYGB with LSG in T2D remission. Our results provide updated information on the impact of LRYGB and LSG on T2D remission. Further studies are still needed to explore the efficiency and long-term results of LRYGB and LSG.

We have found that the remission rate of dyslipidemia was significantly higher in LRYGB at 5 years after surgery. Our findings are consistent with recent studies, which indicated that LRYGB may be superior to LSG in dyslipidemia remission [48, 49]. Han's study provided evidence that LRYGB was superior to LSG in dyslipidemia remission 3 years after bariatric surgery [48]. Li's study showed that dyslipidemia was significantly more resolved in the LRYGB group than in the LSG group postoperatively, but they did not specify a particular time frame [49]. This could lead to potential bias, as the remission rate of dyslipidemia varies at different time points [48]. Our findings provide a long-term evaluation of the effectiveness of LRYGB and LSG in the treatment of dyslipidemia. Therefore, LRYGB is a reasonable choice for patients with dyslipidemia undergoing bariatric surgery.

We also found that there was no significant difference in hypertension at 5 years after surgery. Our result is consistent with an RCT conducted by Zhang [24]. However, a meta-analysis by Hu et al. showed that LRYGB exhibited a significantly superior long-term (>5 years) prognosis for hypertension after surgery compared to LSG, including 4 studies with 322 patients [42]. The result is not consistent with our findings in this study. One possible explanation is that our study included 9 studies (4 cohort studies and 5 RCTs) with 755 patients, which is a larger sample size than previous studies. Further research is still needed on the alleviating effects of weight loss surgery on hypertension.

The findings showed that LRYGB is better than LSG in obstructive sleep apnea remission. One study indicated a trend towards improved resolution of obstructive sleep

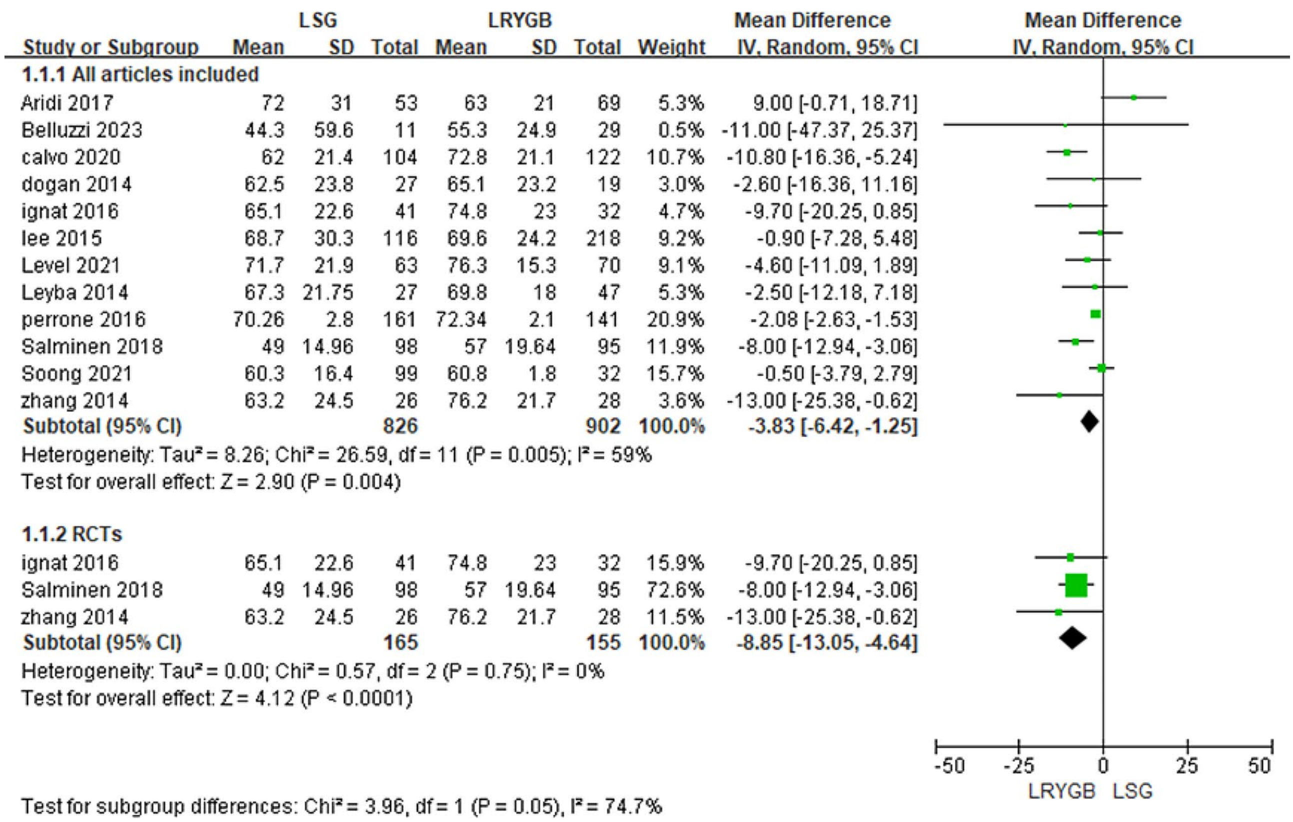


Fig. 7 After excluding the three studies

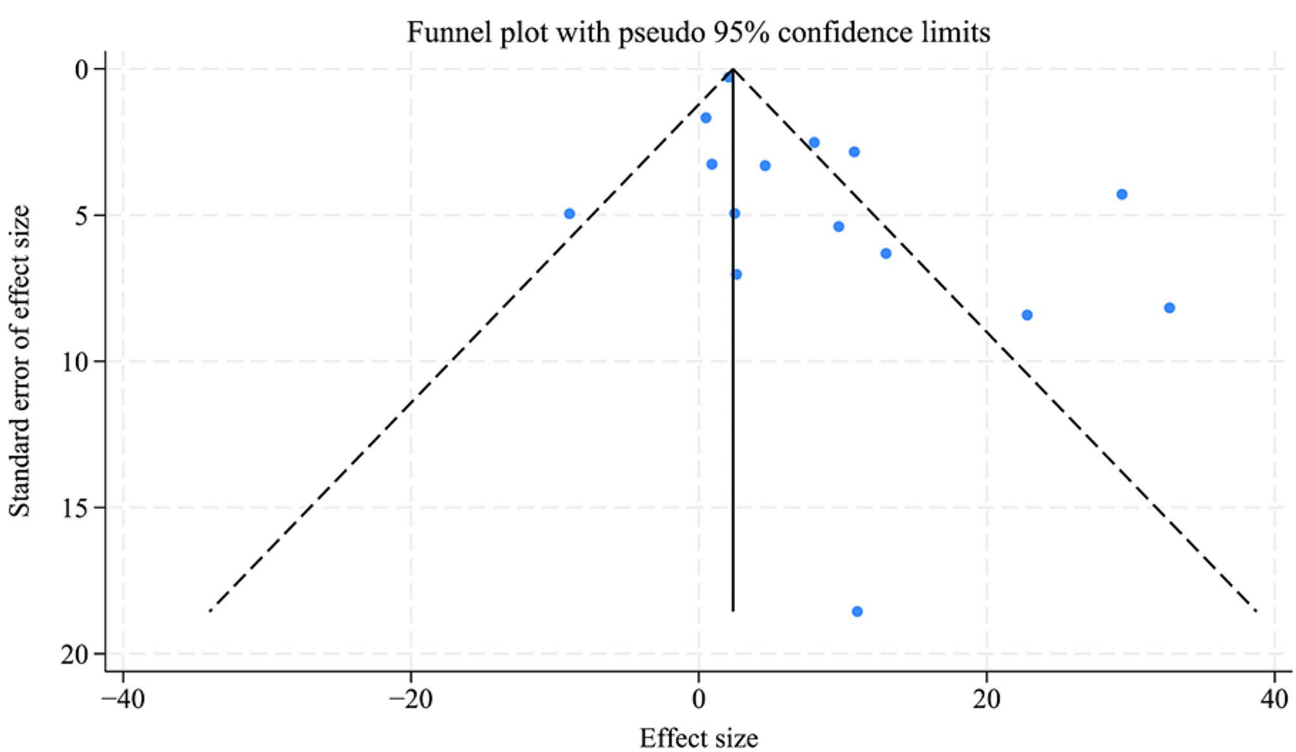


Fig. 8 Funnel plot of %EWL at 5 years

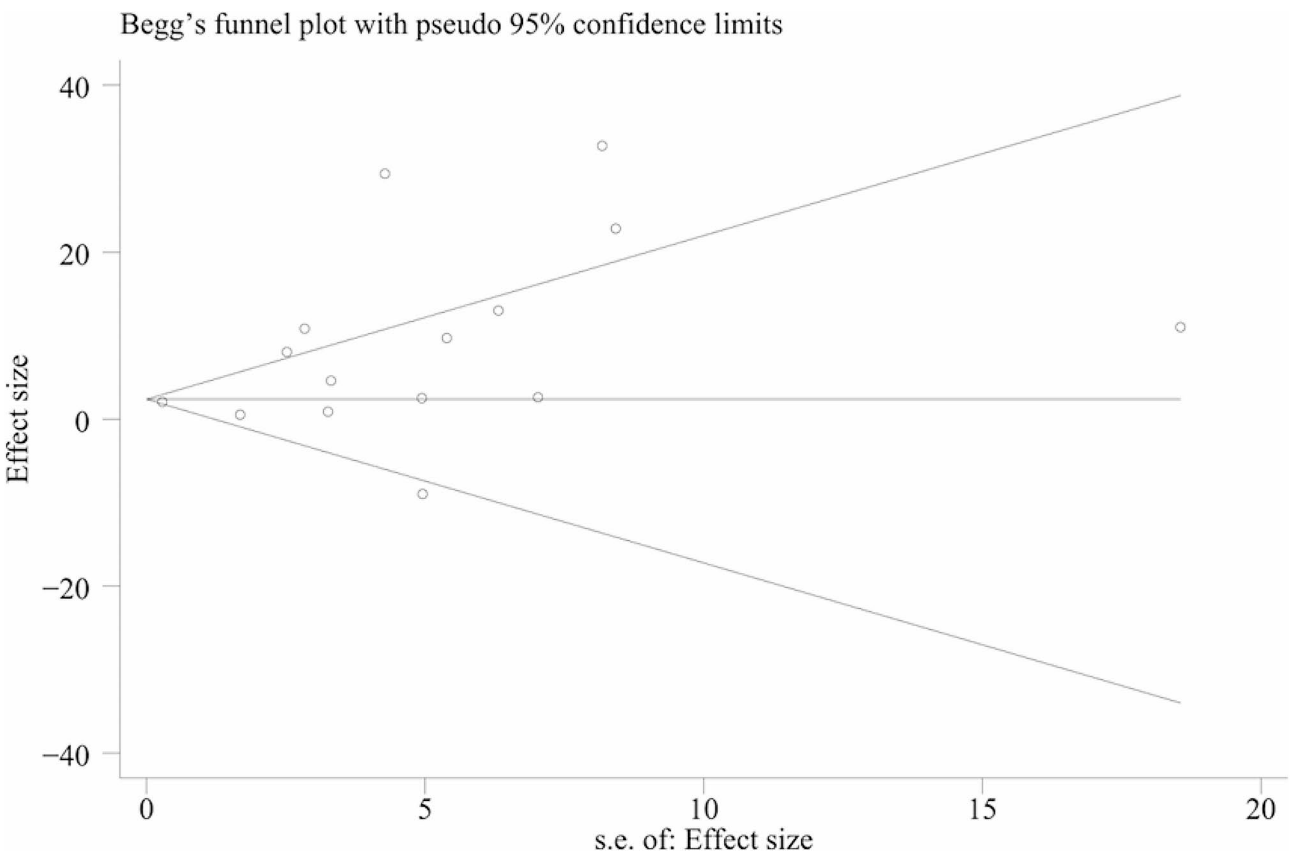


Fig. 9 Begg's test of %EWL at 5 years

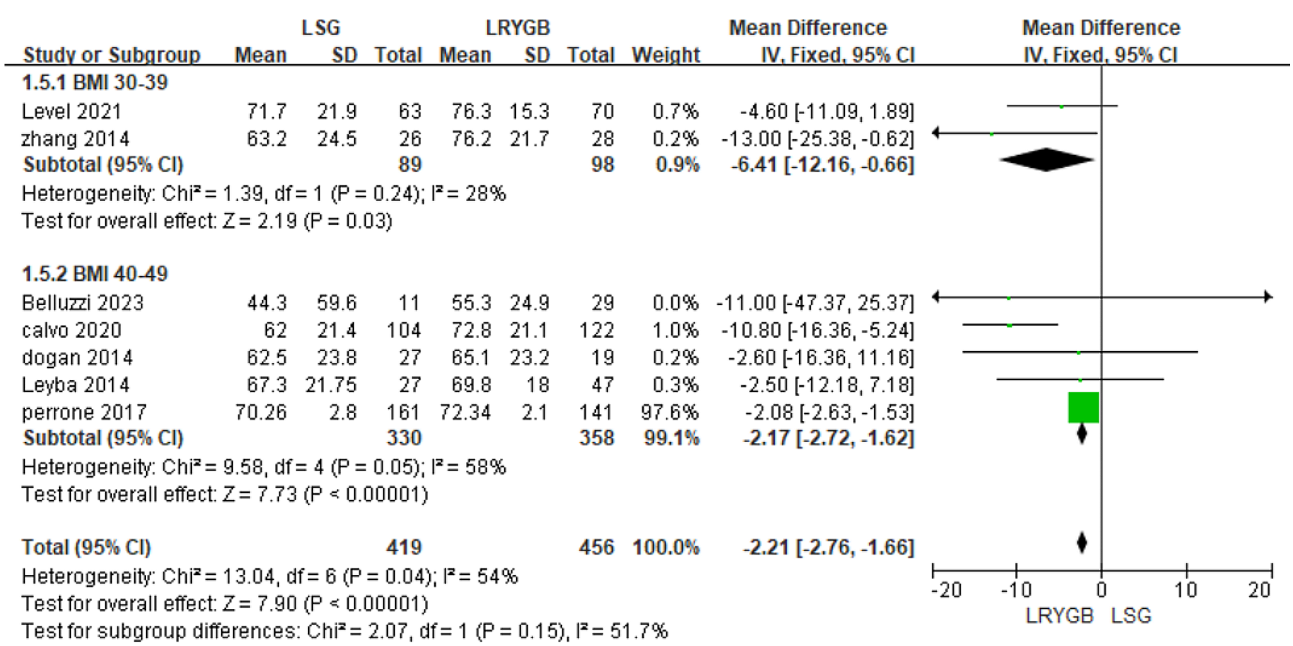


Fig. 10 A subgroup by separating BMI into 30–39 subgroup and 40–49 subgroup

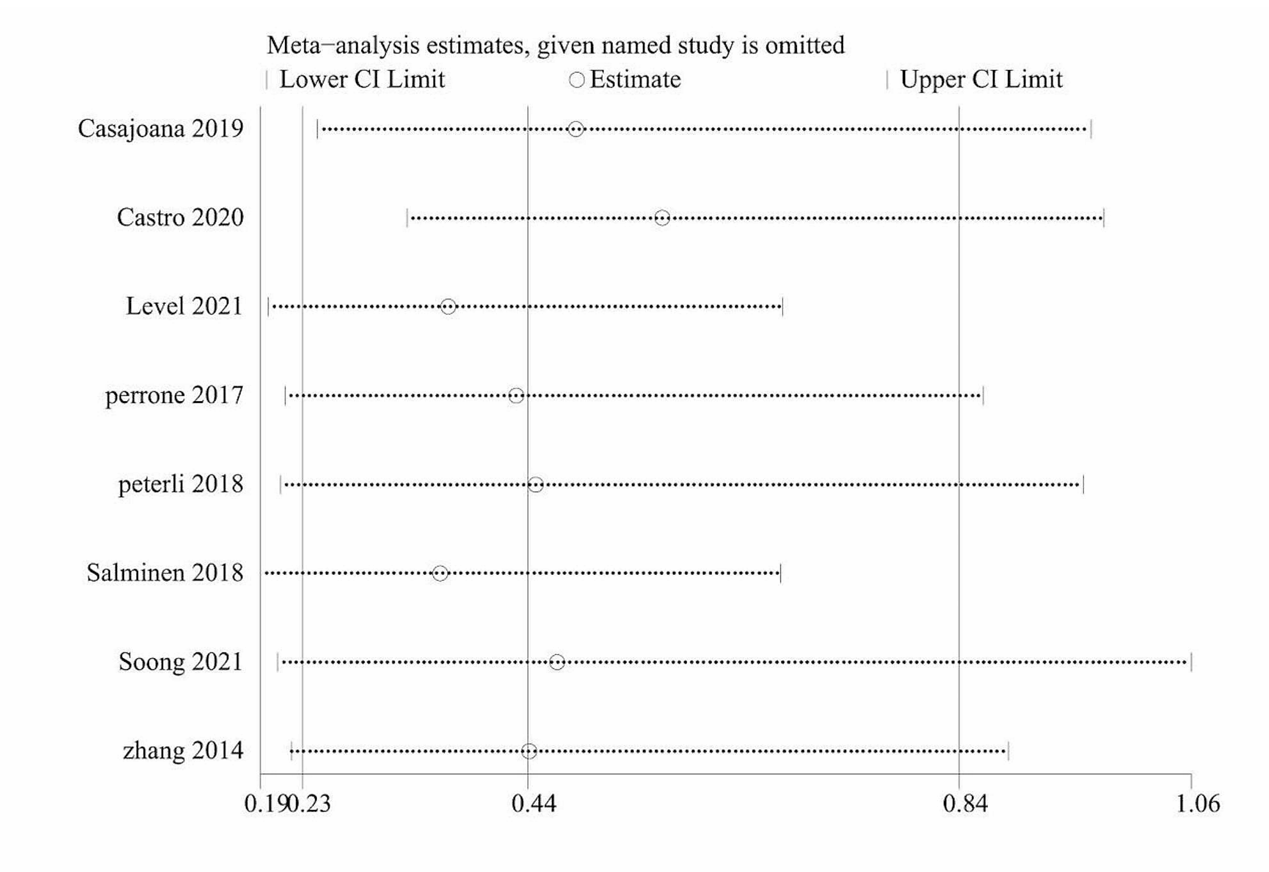
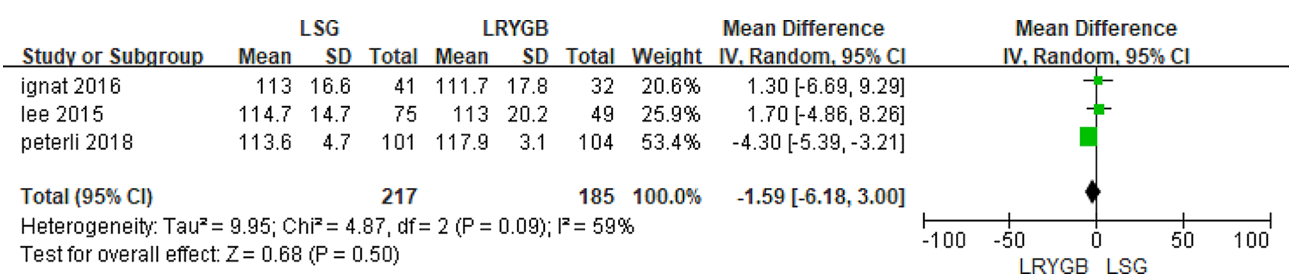


Fig. 11 Sensitivity analysis of dyslipidemia



	LSG			LRYGB				Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
ignat 2016	113	16.6	41	111.7	17.8	32	20.6%	1.30 [-6.69, 9.29]
lee 2015	114.7	14.7	75	113	20.2	49	25.9%	1.70 [-4.86, 8.26]
peterli 2018	113.6	4.7	101	117.9	3.1	104	53.4%	-4.30 [-5.39, -3.21]
Total (95% CI)			**217**			**185**	**100.0%**	**-1.59 [-6.18, 3.00]**

Heterogeneity: Tau² = 9.95; Chi² = 4.87, df = 2 (P = 0.09); I² = 59%
Test for overall effect: Z = 0.68 (P = 0.50)

Fig. 12 Quality of life at 5 years

apnea with LSG at 12 months follow-up [50]. However, some studies showed that the two procedures have equal remission rates regarding obstructive sleep apnea, which is inconsistent with our study [51, 52]. Further research is needed to confirm the efficacy and long-term outcomes between the two procedures in obstructive sleep apnea.

Our research results show that there is no significant difference in the quality of life 5 years after surgery between LRYGB and LSG. These results are based on evaluations using the GIQLI questionnaire. Our findings are consistent with previous studies [42, 52], which also utilized the GIQLI and M-A-Q II (The Moorehead-Ardelt quality of life questionnaire II) for the evaluation of quality of life. However, Nickel's research found that the total GIQLI score of LSG was significantly higher than that of LRYGB within six months after surgery [53]. Further analysis is still needed to explore the impact of different bariatric surgeries on quality of life.

In this study, the findings showed that LSG has a lower risk of morbidity than LRYGB. Our results were in accordance with other studies [11, 54]. In Fridman's study, the morbidity rate was 24.0% in the LSG group, compared to 28.6% in the LRYGB group [11]. However, Zellmer's study showed that LRYGB has a lower leak rate than LSG [55]. In Hutter's study, it was shown that LSG has higher rates of organ space infection, renal insufficiency

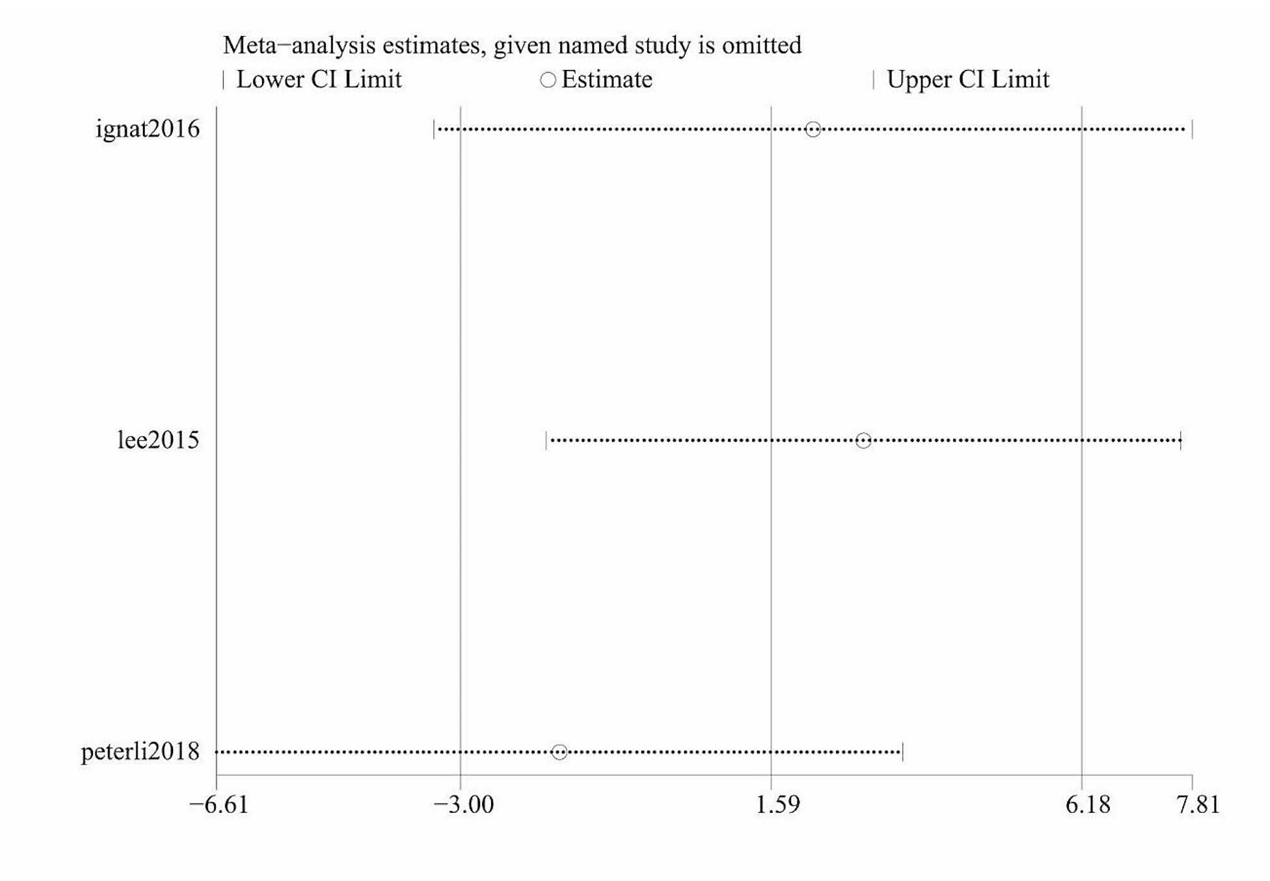


Fig. 13 Sensitivity analysis of quality of life

Study or Subgroup	LSG Events	LSG Total	LRYGB Events	LRYGB Total	Weight	Risk Difference M-H, Random, 95% CI
aridi 2017	105	400	57	400	9.7%	0.12 [0.06, 0.18]
Bellizzi 2023	1	62	11	62	8.1%	-0.16 [-0.26, -0.06]
castro 2020	3	83	1	83	10.0%	0.02 [-0.02, 0.07]
dogan 2014	31	104	37	104	7.1%	-0.06 [-0.18, 0.07]
ignat 2016	10	55	21	55	5.8%	-0.20 [-0.36, -0.04]
Lee 2015	38	116	48	116	7.2%	-0.09 [-0.21, 0.04]
level 2021	1	63	5	63	9.1%	-0.06 [-0.14, 0.01]
murphy 2022	17	58	27	58	5.5%	-0.17 [-0.35, 0.00]
Peterli 2018	16	107	23	110	8.0%	-0.06 [-0.16, 0.04]
Salminen 2018	39	121	62	119	7.2%	-0.20 [-0.32, -0.08]
Schauer 2017	1	47	4	47	8.5%	-0.06 [-0.15, 0.03]
Sonng 2021	6	99	11	99	9.0%	-0.05 [-0.13, 0.03]
Zhang 2014	4	32	10	32	4.8%	-0.19 [-0.38, 0.01]
Total (95% CI)		**1347**		**1348**	**100.0%**	**-0.07 [-0.13, -0.02]**
Total events	272		317			

Heterogeneity: Tau² = 0.01; Chi² = 60.11, df = 12 (P < 0.00001); I² = 80%
Test for overall effect: Z = 2.49 (P = 0.01)

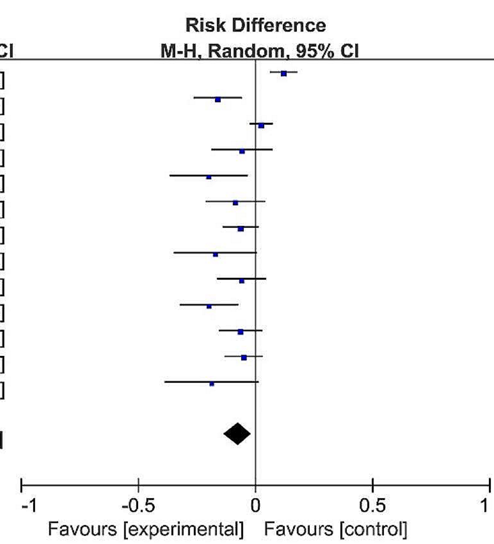


Fig. 14 Forest plot of morbidity

and sepsis than LRYGB [56]. In terms of mortality, our result showed no significant difference between the two procedures. Kumar's study showed that LSG resulted in lower mortality than LRYGB [12]. However, Thereaux's study showed that LRYGB has lower mortality than LSG [57] Further studies are still needed to explore the differences in morbidity and mortality rates between the two procedures (Fig. 15).

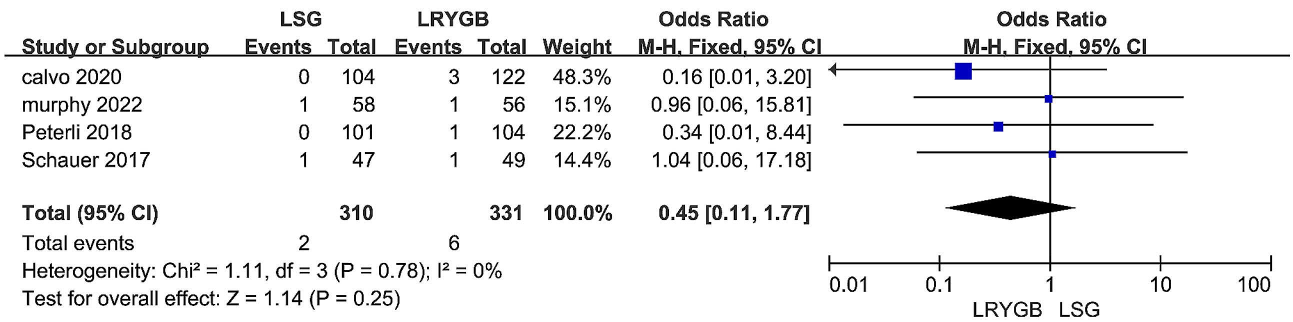


Fig. 15 Forest plot of mortality

Two included studies reported the revision rates after LSG and LRYGB with varying results when compared to each other [29, 33]. In Soong's study [33], 190 patients underwent LSG and 62 underwent LRYGB. Five patients (2.6%) required revisional surgery after LSG, while five patients (8.1%) required revisional surgery after LRYGB. In Calvo's study [28], 165 patients underwent LSG and 164 underwent LRYGB, with 13 patients (8.0%) requiring revisional surgery after LSG and 6 patients (3.6%) after LRYGB. A large retrospective database study including 349,411 bariatric procedures reported a revision rate of 0.8% in 136,483 primary LSG patients and 0.21% in 111,595 primary LRYGB patients [56]. Benjamin Clapp conducted a retrospective study using the MBSAQIP database, reporting a revision rate of 4.63% in 330,437 LSG procedures and 8.21% in 132,759 LRYGB procedures [58]. Further studies are needed to compare the revision rates of LSG with those of LRYGB.

Our study had several limitations. First, although 18 studies were included in our study, only three studies compared the impact of LRYGB with LSG on obstructive sleep apnea remission and quality of life. The small sample size may have impacted the results. Second, the included studies varied in methodologies, patient populations, and follow-up rates. Particularly, the follow-up rates at 5 years and beyond varied significantly. This variation might increase the heterogeneity of this study. Third, the meta-analysis incorporated studies with varying methodologies, varying patient populations and different follow-up rates after 5 years, which may have contributed to substantial heterogeneity in the results. Differences in preoperative patient characteristics and postoperative management protocols across studies could have influenced the assessed outcomes, posing challenges in data synthesis and interpretation. Fourth, variations in patient demographics, such as age, gender distribution, baseline BMI, and presence of comorbidities, among the included studies, may have introduced bias. Additionally, the meta-analysis included both randomized controlled trials (RCTs) and non-randomized interventional studies, which may have introduced selection bias and confounded the results. Non-randomized studies are prone to inherent methodological limitations, such as allocation bias and lack of control for potential confounders, which could compromise the validity and reliability of the findings. Fifth, dichotomous data used to evaluate resolution of T2D may influence the results. Additionally, some studies use the criteria of medication requirement to evaluate T2D remission, while others use values of HbA1c with different cutoffs. The different definition of T2D remission in studies may lead to potential bias.

Conclusions

LRYGB resulted in greater weight loss and achieved better remission in T2D and dyslipidemia when compared with LSG at 5 years after surgery, while LSG has a lower morbidity rate than that of LRYGB. However, more rigorous studies are needed to determine the relative long-term efficacy of different types of bariatric surgeries.

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

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Author contributions

YT, YL, and XL have made substantial contributions to the design of the work. ZW, HS and GC interpreted the patients' data. YL, ZW, XF and YW were major contributors in writing the manuscript. VJ, YT, and JH have drafted the work or substantively revised it. All authors read and approved the final manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
For this type of review, institutional ethical approval was not required.

Consent for publication
The manuscript has been reviewed and approved for publication by all the co-authors. As this article is a systematic review, the statement of consent and the statement for human and animal rights are not applicable.

Competing interests
The authors declare no competing interests.

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