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REVIEW ARTICLE

Comparison of Energy and Food Intake Between Gastric Bypass and Sleeve Gastrectomy: a Meta-analysis and Systematic Review

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Abstract

Obesity is a developed nutritional problem, and today, surgery is one of the approaches to cure it. A good understanding of the variations in food intake will be beneficial for sustaining long-term weight loss post-surgery and for improving nutrition care strategies. The purpose of this review was the comparison of the impact of two methods of gastric bypass (GBP) and sleeve gastrectomy (SG) on dietary intake. Databases of PubMed, Embase, Scopus, Google Scholar, and Web of science were used for the literature search up to June 2018. We concluded the studies that measured mean daily energy intake and the percent of macronutrients from total calorie intake of before and after GBP and SG. A total of 18 studies were finally included in the meta-analysis for the effect of bariatric surgery on food intake. Bariatric surgery significantly decreased energy intake by 1050.04 kcal/day ($p < 0.001$) compared with the baseline values of energy intake. The pooled effect of bariatric surgery on protein intake was 0.82 g/day ($p = 0.004$) compared with the baseline values. The pooled analysis found no significant impact of bariatric surgery on carbohydrate intake (WMD = 0.56 g/day; $p = 0.40$) compared with the baseline values. The pooled estimate of effect for bariatric surgery on fat intake was − 1.34 g/day ($p = 0.006$). This study demonstrates that bariatric surgery might be effective on energy and fat intake; however, there was no effect on carbohydrate intake.

Keywords Body mass index · Bariatric surgery · Roux-en-Y gastric bypass · Meta-analysis

Introduction

Obesity is a multifactorial situation that is developing rapidly in the world and is now considered as a worldwide epidemic [1]. Morbid obesity defined as body mass index (BMI) more than 40 kg/m^2 is associated with low quality of life, higher risk of morbidity, and premature death [1, 2]. Severe obesity is contributed to the higher incidence of dyslipidemia, cardiovascular diseases, type 2 diabetes, and some kinds of cancer [1, 3]. Change in lifestyle, eating patterns, and available pharmacotherapy do not sufficiently resolve obesity-related comorbidities to proffer a benefit in morbidity or mortality [4, 5]. So, whether a clinical treatment failure or not, bariatric surgery (BS) appears to be the best choice [5].

Bariatric surgery is a useful technique in the treatment of obesity when exercise and dieting do not produce the anticipated weight loss [6, 7]. This method yielded significant weight loss (nearby 60–70% of surplus weight at 12 months after surgery) as well as a meaningful improvement in the metabolic and social complications correlated with obesity [6]. Sleeve gastrectomy (SG) and Roux-en-Y gastric bypass (RYGBP) are the most frequently performed bariatric surgery types in the world [7, 8]. Many gastrointestinal signs have been documented following BS, especially nausea and vomiting following the two abovementioned methods, changes in fecal consistency and dumping syndrome post-RYGB, and gastroesophageal acid reflux disease after SG [7, 9]. Further, changes in food preference have been confirmed after different sorts of BS [5, 10, 11].

Among potential complications of obesity surgery, nutritional deficiencies are of note [6]. BS leads to a reduction in food intake and energy [12, 13], with reported decreases of around 40–50% of energy intake 6 months post-surgery [12].

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Mechanisms and causes of nutrimental deficiencies subsequent to BS are also multifactorial and are affected by the type of surgery, pre-operative deficiencies, sustained post-operative vomiting, modified eating behavior, food intolerance, and non-adherence to dietary and supplement recommendations [14]. Hence, SG, compared to GBP, might be observed as less likely to increase the risk of micronutrient deficiencies in obese subjects who are already prone to such deficiencies before surgery [8]. Although, some investigations have shown a considerably greater prevalence of nutrient deficiencies after SG [15, 16]. The other studies, comparing GBP and SG, discovered an entirely similar prevalence after both methods [8, 10, 17]. The lower food consumption and malabsorption after the surgical procedure may induce chronic or acute nutritional deficiencies in the postoperative phase [11].

A good understanding of the variations in food intake will be beneficial for sustaining long-term weight loss post-surgery and for improving nutrition care strategies. The purpose of the recent study was the comparison of the impact of two methods of GBP and SG on dietary intake, considering that no previous study has summarized these findings in a review.

Method

We used Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines for this study.

Eligibility and Inclusion Criteria

This study included interventional studies that measured mean daily energy intake and the percent of macronutrients (carbohydrate, protein, and fat) from total calorie intake before and after GB and SG.

The Exclusion Criteria

Animal papers, papers published before 1990, papers which did not report dietary intake data or baseline dietary intake data, other bariatric surgery techniques than GB or SG, and studies which supplemented protein, lipid, or carbohydrate were excluded.

Information Sources and Search

PubMed, Embase, Scopus, Google Scholar, and Web of science databases were used for the literature search up to June 2018. The search included all published articles from 1990 up to June 2018 by using the following MeSH and text words: (((Roux-en-Y Gastric Bypass) AND Title/Abstract) OR ((Bypass, Gastric) AND Title/Abstract) OR ((Bypass, Roux-en-Y Gastric) AND Title/Abstract) OR ((Roux en Y Gastric Bypass) AND Title/Abstract) OR ((Greenville Gastric Bypass) AND Title/Abstract) OR ((Gastrojejunostomy) AND Title/Abstract) OR ((Gastric Bypass) AND Title/Abstract) OR ("sleeve gastrectomy"[Title/Abstract]) OR ("mini bypass"[Title/Abstract]) OR ("Bariatric Surgery"[Title/Abstract])) AND (((Preference, Food) AND Title/Abstract) OR ((Preferences, Food) AND Title/Abstract) OR ((Food Selection) AND Title/Abstract) OR ((Food Selections) AND Title/Abstract) OR ((Selection, Food) AND Title/Abstract) OR ((taste) AND Title/Abstract) OR ((appetite) AND Title/Abstract) OR ((Food Intake) AND Title/Abstract) OR (Food Choice) AND Title/Abstract) OR ("Food Preferences"[Title/Abstract]). Additionally, the reference lists of relevant articles were hand-searched for more studies.

Study Selection

Two researchers conducted study selection in two steps:

1. Independently reviewed the titles and abstracts of all electronic database citations. Articles that did not appear to meet the inclusion criteria were discarded.
2. The same reviewers independently used the inclusion criteria on the full text of the articles.

Finally, any indecision was resolved by a third investigator.

Data Collection

Results from the included studies were abstracted into data tables. Data items extracted from each study were as follows: author, publication year, country, sample size, the gender of patients, mean age of participants, preoperative BMI, follow-up duration, dietary assessment method, total calorie intake, and macronutrient intake.

Synthesis of Results

In this research, we used mean and SD for the determination of side effects; otherwise, standard errors were converted to standard deviations according to the formula of $SE*\sqrt{n}$ and macronutrient intake reported as grams/day were converted to percent of total calorie intake. This meta-analysis was conducted to compare the pooled estimates of total calorie and macronutrient intake before GB and SG surgeries and also their changes after the surgery. Based on high heterogeneity between studies, a random effects model was used to pool the effect sizes. The analysis was performed using STATA (version: 14) software.

Results

Study Characteristics

A total of 1561 studies were identified by the initial literature search. The flow diagram describing the detailed process of screening and excluded studies with specific reasons is displayed in Fig. 1. A total of 23 data sets from 18 studies, comprising 1330 obese patients, were finally included in the meta-analysis based on the inclusion criteria for the effect of bariatric surgery on food intake.

Characteristics of the included studies are summarized in Table 1. Mean BMI of subjects in the included studies ranged from 35.8 to 60, and the follow-up duration was between 3 months and 8 years. Individuals, aged from 16 to 47 years. The sample size of the included studies ranged from 8 to 294 individuals. Energy and dietary intake had been assessed by different tools such as food frequency questionnaire (FFQ) in two studies [3, 21] 24 h daily recall questionnaire in nine studies [1, 8, 11, 18, 19, 22–24, 28, 29], 3, 4, or 7 day food intake record in six studies [2, 9, 19, 22, 26, 27, 30], and one other study used a questionnaire that had been designed and validated for the Swedish obese patients [25] and also dietary intakes of participants were collected by interviewing participants in one study [20].

The articles have been published between 1994 and 2016. Of the 18 included studies, 3 were conducted in the USA [18, 21, 26], 13 in Europe [2, 3, 8, 9, 19, 20, 22–25, 28–30], and 2 in South America [1, 11]. Six studies were done on women [2, 3, 11, 20, 27, 28], and the rest of the included studies were conducted on both genders. However, in one study, statistical analyses were separately done for men and women [19].

Bariatric Surgery and Energy Intake

The effect of bariatric surgery on energy intake was investigated in 23 data sets, involving a total of 1330 patients. Overall, when all eligible studies were pooled, it was found that bariatric surgery significantly decreases energy intake by 1050.04 kcal/day (95% CI − 1189.23 to 910.86; $p < 0.001$) compared with the baseline values of energy intake. However, a significant heterogeneity was observed among the studies ($I^2 = 97.1$, $p < 0.001$). In the subgroup analysis, all surgery types including RYGB (weighted mean difference; WMD = − 1215.16 kcal/day, 95% CI − 1542.67 to − 887.66; $p < 0.001$), GBP (WMD = − 823.10 kcal/day, 95% CI − 1111.49 to − 534.70; $p < 0.001$), and SG (WMD = − 939.38 kcal/day, 95% CI − 1231.10 to − 647.66; $p < 0.001$) were significantly associated with the reduction in energy intake (Fig. 2). In the meta-regression analysis, the pooled effect was not modified by the duration of follow-up ($B = 5.95$, $p = 0.48$; supplemental file 1). The results of Egger's test ($t = - 3.22$, $p = 0.004$) yielded a significant evidence for publication bias.

In the sensitivity analysis, the study by Judith Aron-Wisnewsky [28], which had a 3-month follow-up period, was removed and the pooled effect size did not change remarkably (WMD = − 984.39 kcal/day, 95% CI − 1149.77 to − 819.02; $p < 0.0001$). After removing studies with sample size ≤ 8 [19], the pooled effect (WMD = − 890.87 kcal/day, 95% CI − 1042.15 to − 739.60; $p < 0.0001$) was almost unchanged. Notably, the mean BMI of participants in all included studies was higher than 35; thus, a sensitivity analysis was not performed based on initial BMI.

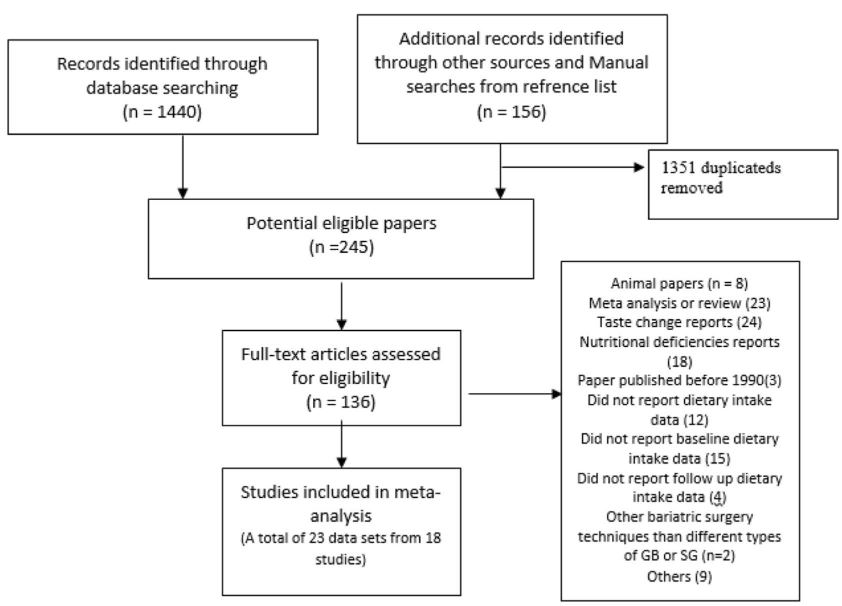


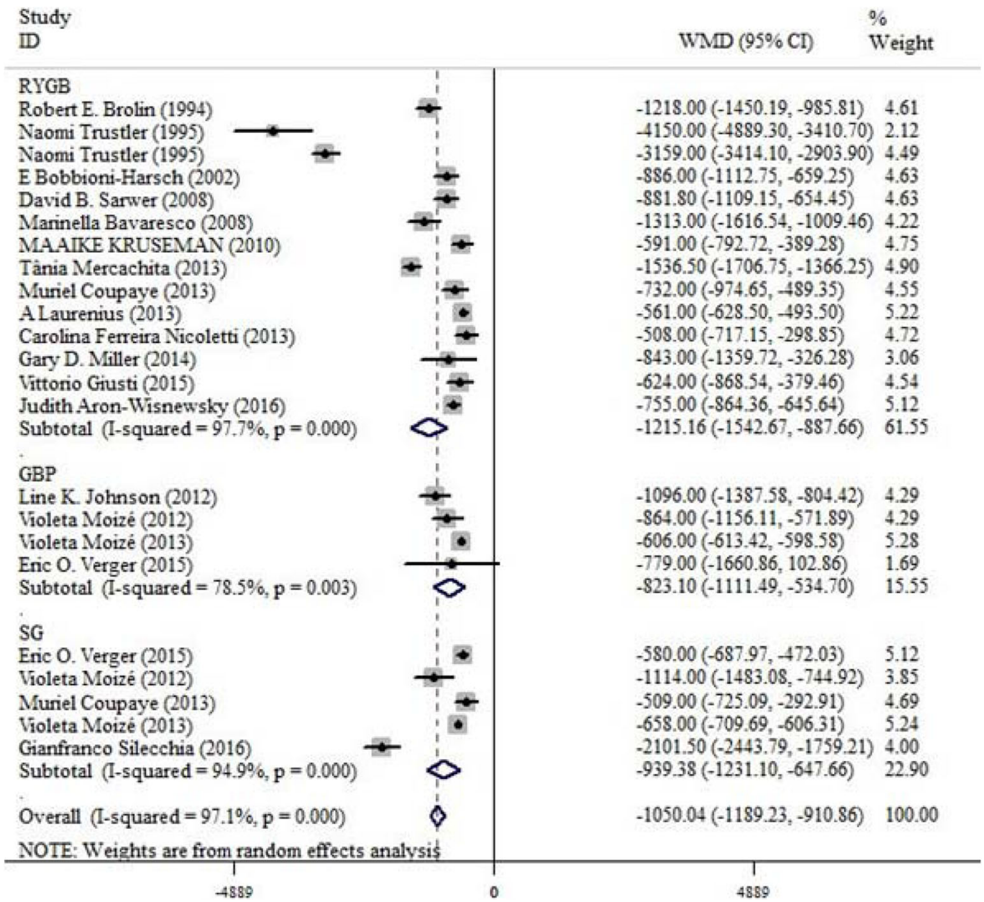
Fig. 1 Flow chart of the study

Table 1 Characteristics of the included studies

Study first author (year)	Country	Intervention-type	Gender	Mean BMI	Sample size (baseline)	Sample size (after surgery)	Mean age	Food intake assessment method	Duration (months)
Robert E. Brolin [18]	New Jersey	RYGB	M, 15 F, 93	43	108	108	38	24-h recall	36
Naomi Trustler [19]	Israel	RYGB	M	43	8	7	41	7-day food intake and 24-h recall	18
Naomi Trustler [19]	Israel	RYGB	F	43	11	4	32	7-day food intake and 24-h recall	18
E Bobbioni-Harsch[20]	Switzerland	RYGB	F	45.2	50	50	38.4	Interview and 3-day record	12
David B. Sarwer [21]	USA	RYGB	M, 36 F, 164	52.1	200	200	42–45	Block 98 FFQ	23
Marinella Bavaresco [1]	Brazil	RYGB	M, 7 F, 41	51.9	48	48	41.9	24-h recall	12
MAAIKE KRUSEMAN [2]	Switzerland	RYGB	F	45.9 7.6	80	80	40	dietary intake over a 4-day period record	96
Line K. Johnson [3]	Norway	GBP[6]	F	46.2 ± 5.2	72	72	42/6	FFQ	12
Violeta Moizé [22]	spain	GBP	M, 2 F, 23	45.5	25	25	44	3-day food record and 24-h recall	12
Tânia Mercachita [23]	Portugal	LRYGB[7]	M, 21 F, 39	42.3	60	17	41.9	24-h recall	24
Muriel Coupaye [9]	France	RYGB	M, 12 F, 31	48.6 ± 7.8	43	43	44	4-day record	12
Violeta Moizé [24]	Spain	GBP	M and F	47.4	294	294	45–46	24-h dietary recall	60
A Laurenius [25]	Sweden	LRYGB	M, 12 F, 31	44.5	43	42	43	a dietary questionnaire, designed and validated questionnaire for the Swedish obese	24
Carolina Ferreira Nicoletti [11]	Brazil	RYGB	F	47	30	30	36	24-h recall	12
Gary D. Miller [26]	USA	RYGB	M, 1 F, 16	53.6	17	17	47.3	4-day food record	12
Vittorio Giusti [27]	Switzerland	RYGB	F	44.1	16	8	39.4	7-day food record	36
Eric O. Verger [8]	France	GBP	M and F	45.5	22	14	43.5	24-h recall	12
Judith Aron-Wisnewsky [28]	France	RYGB	F, 22	46.3	14	14	40.5	24-h recall	3
Violeta Moizé 2012 [22]	Spain	SG	M, 7 F, 18	47.2	25	25	44	3-day food record and 24-h recall	12
Violeta Moizé [24]	Spain	SG	M and F	51.6	61	61	45–46	24-h dietary recall	60
Muriel Coupaye [9]	France	SG	M, 12 F, 31	48.6 ± 7.8	43	30	45	4-day record	12
Eric O. Verger [8]	France	SG	M and F	43.2	30	19	43.5	24-h recall	12
Gianfranco Silecchia [29]	Italy	LSG	M, 8 F, 22	43.9	30	30	35	24-h recall	24

BMI body mass index, *SG* sleeve gastrectomy, *M* male, *F* female, *LSG* laparoscopic sleeve gastrectomy, *RYGB* Roux-en-Y gastric bypass, *LRYGB* laparoscopic Roux-en-Y gastric bypass, *FFQ* food frequency questionnaire, *GB* gastric bypass

Fig. 2 Forest plot showing overall and subgroup analyses by surgery type on the effect of bariatric surgery on energy intake



Bariatric Surgery and Protein Intake

There were 16 data sets with 1140 cases concerning the effect of bariatric surgery on protein intake. The pooled effect of bariatric surgery on protein intake was 0.82 g/day (95% CI 0.25 to 1.38; $p = 0.004$) compared with the baseline values. Since there was a high heterogeneity among the studies ($I^2 = 76.6$, $p < 0.001$), a random effects model was applied. Nevertheless, in the subgroup analysis by surgery type, RYGB, GBP, and SG methods had no significant effect on protein intake (Fig. 3). In the meta-regression analysis, the duration of follow-up had no significant influence on the pooled effect ($B = -0.0.3$, $p = 0.19$; supplemental file 2). No evidence of publication bias was detected in the visual inspection of the funnel plot and by Egger's test ($t = 0.94$, $p = 0.36$).

In the sensitivity analysis, the study by Judith Aron-Wisnewsky [28], which had a 3-month follow-up period, was removed and the pooled effect size did not change remarkably (WMD = − 74 kcal/day, 95% CI 16 to 1.32; $p = 0.01$). Notably, the mean BMI of participants in all included studies was higher than 35 and all analyzed studies for protein intake had more than eight participants as sample size; thus, a sensitivity analysis was not performed based on initial BMI and sample size.

Bariatric Surgery and Carbohydrate Intake

There were 17 data sets with 1177 patients addressing this issue. The pooled analysis found no significant impact of bariatric surgery on carbohydrate intake (WMD = 0.56 g/day, 95% CI − 0.77 to 1.90; $p = 0.40$) compared with the baseline values. Because of the high heterogeneity among the studies ($I^2 = 87.2$, $p < 0.001$), a random effects model was used. Moreover, in the subgroup analysis by surgery type, none of the surgery methods, including RYGB, GBP, and SG, resulted in a significant decrease in carbohydrate intake (Fig. 4). In the meta-regression analysis, the pooled effect was not modified by the duration of follow-up ($B = 0.0.3$, $p = 0.32$; supplemental file 3). The results of Egger's test ($t = 0.07$, $p = 0.94$) did not also show the evidence of publication bias.

In the sensitivity analysis, the study by Judith Aron-Wisnewsky [28], which had a 3-month follow-up period, was removed and the pooled effect size did not change remarkably (WMD = 87 kcal/day, 95% CI − 0.49 to 2.24; $p = 0.20$). Notably, the mean BMI of participants in all included studies was higher than 35 and all analyzed studies for carbohydrate intake had more than eight participants as sample size; thus, a sensitivity analysis was not performed based on initial BMI and sample size.

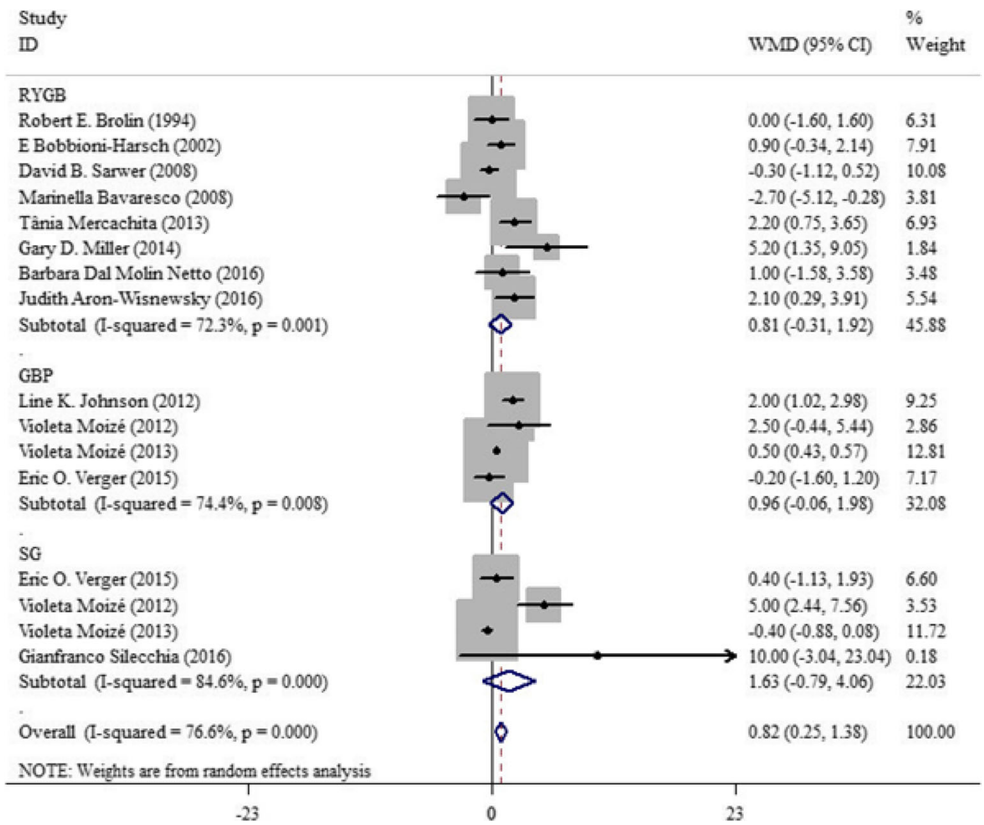


Fig. 3 Forest plot showing overall and subgroup analyses by surgery type on the effect of bariatric surgery on protein intake

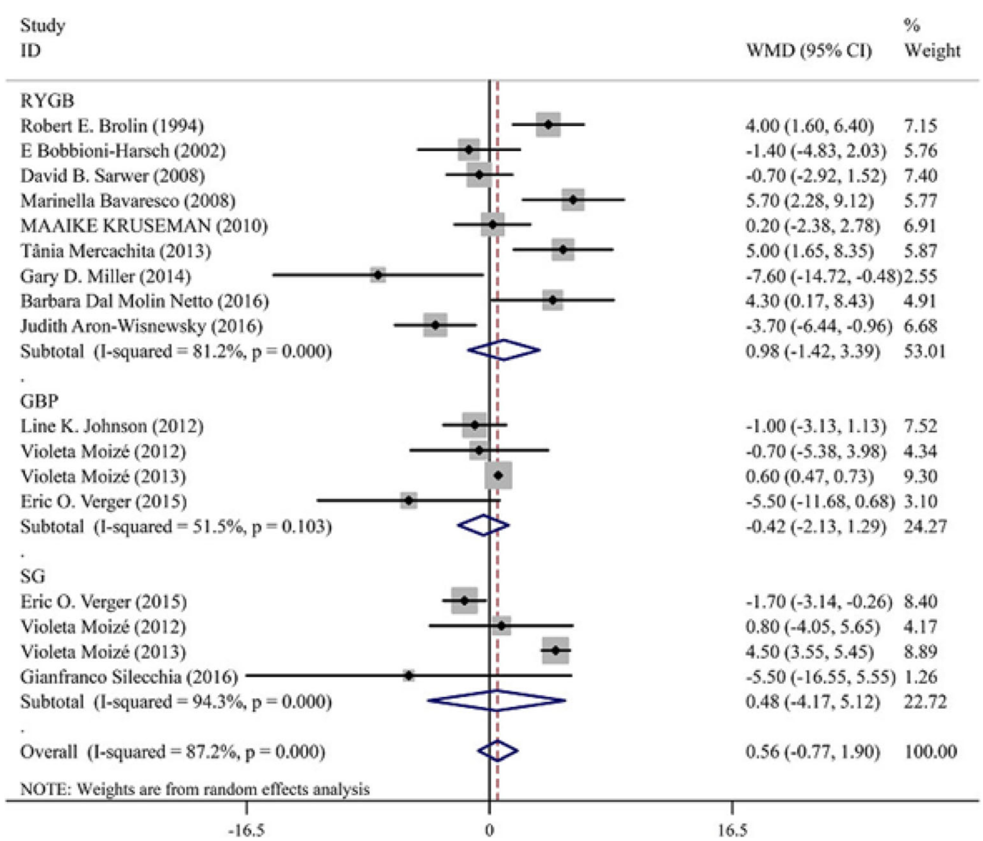


Fig. 4 Forest plot showing overall and subgroup analyses by surgery type on the effect of bariatric surgery on carbohydrate intake

Bariatric Surgery and Fat Intake

The effect of bariatric surgery on fat intake was explored in 18 data sets, involving a total of 1220 obese individuals. The pooled estimate of effect for bariatric surgery on fat intake was − 1.34 g/day (95% CI − 2.30 to − 0.38, $p = 0.006$), with evidence of high heterogeneity ($I^2 = 91.3$, $p < 0.001$). Subgroup analysis by surgery type revealed that RYGB significantly reduces fat intake by − 1.91 g/day (95%CI − 3.37 to − 0.44, $p = 0.78$), while GBP (WMD = 0.55 g/day, 95%CI − 3.38 to 4.47, $p = 0.01$), and SG (WMD = − 2.83 g/day, 95%CI − 7.07 to 1.42, $p = 0.19$) had no remarkable impacts on fat intake (Fig. 5). In the meta-regression analysis, the pooled effect of bariatric surgery on fat intake was not modified by the duration of follow-up ($B = -0.2$, $p = 0.49$; supplemental file 4). The Egger test ($t = -0.12$, $p = 0.90$) did not detect an evidence for publication bias.

In the sensitivity analysis, the study by Judith Aron-Wisnewsky [28], which had a 3-month follow-up period, was removed and the pooled effect size did not change remarkably (WMD = − 1.59 kcal/day, 95% CI − 2.56 to − 0.61; $p = 0.001$). Notably, the mean BMI of participants in all included studies was higher than 35 and all analyzed studies for fat intake had more than eight participants as sample size; thus, a sensitivity analysis was not performed based on initial BMI and sample size.

Discussion

To the best of our knowledge, the current study is the first meta-analysis that investigated the comparison of the impact of GBP and SG on dietary intake. The results of the present study showed that energy and fat intake decreases after BS. Also, there was a significant positive effect of BS on protein intake. However, there was no significant relationship between BS and CHO. Based on meta-regression analysis, follow-up after surgery did not impact on the effect of BS on energy and macronutrient intake.

Gastrointestinal symptoms including nausea and vomiting, dumping syndrome [31], changes in food preferences, food aversion [32], and heartburn which involved patients after the surgery may be several causative associations between certain bariatric procedure and nutrient intake. Based on the evidence, patients change their dietary intakes to lower caloric-fatty foods and sweets [33]. The brain reward center activation decreases after obesity surgeries [33, 34]. Some other mechanisms including increased energy expenditure, change in vagal nerve signaling, increase in gut hormones, and their effect on appetite centers are involved in nutritional status and weight loss after surgery [34]. Dietitians should be aware of complications after the surgery which impact on dietary changes. Coluzzi et al. revealed that patients reduced their

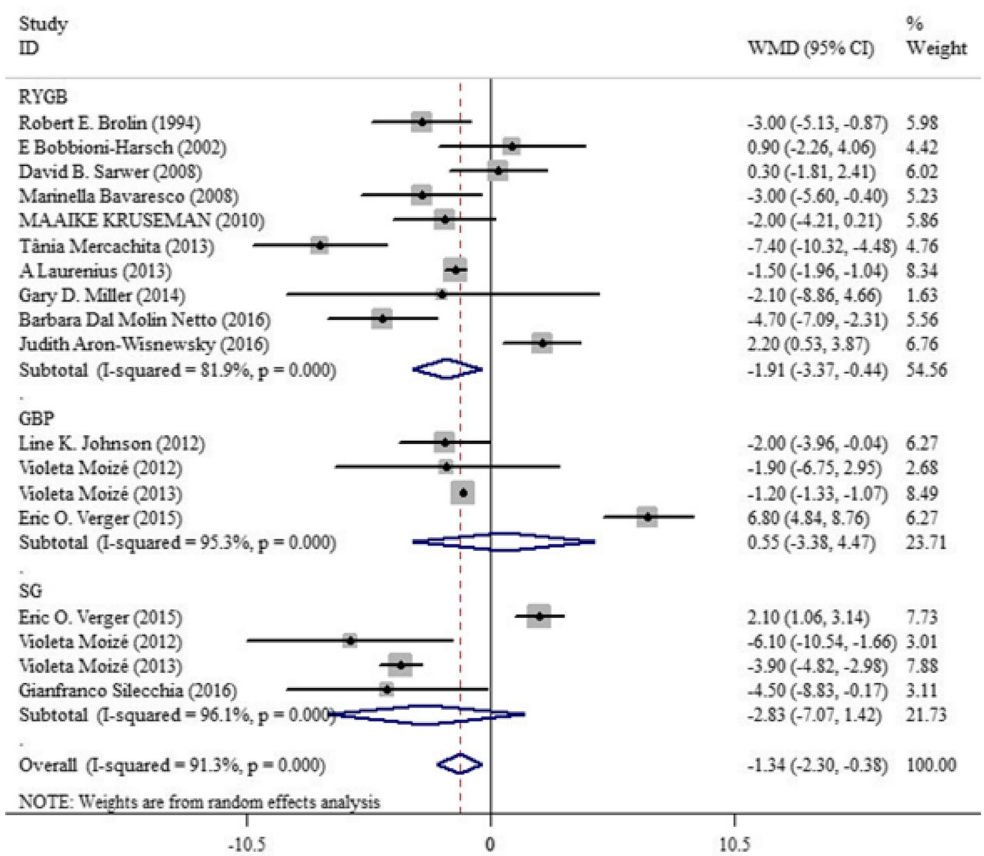


Fig. 5 Forest plot showing overall and subgroup analyses by surgery type on the effect of bariatric surgery on fat intake

energy intake 6 to 24 months after the surgery [29]. Also, another study found that there was a 50% reduction in energy intake which sustains for 5 years after the surgery [13]. Similarly, our results have shown that energy intake reduces after the surgery. This is maybe for achieving optimal weight loss or weight maintenance [35, 36]. Awareness of patients about food choices and selecting a low-fat and low-calorie food help to maintain weight reduction [29].

Similar to our result, several studies have indicated that subjects who undergo gastric bypass reported a significant decrease in fat intake [3, 29, 37]. In contrast, a study has demonstrated no significant changes in intake of fat after the gastric bypass surgery [38]. Patients who undergo BS may experience food intolerance and its symptoms such as nausea and dumping syndrome. This is effective in limiting the foods especially fats which can delay the foods transition in the gastrointestinal tract [39–41]. Patients are recommended to choose the foods that they reduce gastrointestinal symptoms. In addition, these patients will be more aware of the importance of healthy foods after surgery which can have an effect on fat reduction and a decrease in energy intake [29].

Based on our results, BS had no significant effect on CHO. In addition, BS had an increasing effect on the consumption of proteins. However, subgroup analysis demonstrated no significant effect of all types of BS on protein intake. These inconsistent results probably are due to this fact that the majority of proteins are absorbed in the duodenum which is excluded during bypass surgery [42]; therefore, it results in decreasing absorption of protein. On the other hand, surgically treated patients are recommended to consume nutritious foods such as fish and yogurt which contain protein and result in increasing protein intake [3]. Coluzzi et al. have suggested the importance of proteins in order to meet daily needs and prevention of lean body mass loss [29]. Insufficient protein intake can lead to increasing the loss of muscle mass which is possibly a risk factor for weight regain [43, 44]. Although, Kruseman et al. revealed that after gastric bypass surgery, women had a similar distribution of carbohydrates and protein at baseline and the end of follow-up [2].

Although the current study was the first meta-analysis of the effect of BS on macronutrients intake, it has some limitations. First, most analyses had a high level of heterogeneity; however, this is expectable because of included studies conducted on the various populations with different sample sizes. In addition, included studies did not report about physical activity and few of them reported about lifestyle or dietary intervention programs after the surgery; therefore, we could not adjust the effect of these variables. Also, there is limited available information about dietary intakes and nutrients resources in the body before the surgeries. Moreover, these interventional studies were conducted in the frame of quasi-experimental studies which have no control group and categories in low-quality studies. This study demonstrates that BS might be effective on energy, fat, and protein intake; however, there was no effect on CHO intake. Most obesity surgeries are a restrictive operation which may lead to restrict calorie and dietary intake and reveal different eating behaviors. Therefore, a good understanding of dietary assessment and determining changes in food preferences will be useful for maintaining weight loss as well as prevention of nutrients deficiency and prescribe of supplements after the surgery. It is suggested to perform well-designed randomized or cohort studies by considering confounding variables in the future.

Transparency Declaration

The lead author affirms that this manuscript is an honest, accurate, and transparent account of the study being reported, that no important aspects of the study have been omitted, and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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Authorship PJ and FS searched and wrote the paper; both of them separately did the exclusion and inclusion processes of articles, data extraction, and quality assessment. Any problem solved by ED. Sha analyzed data. ED commented on and edit the paper, also supervised the whole study.

Compliance with Ethical Standards

The present study is a systematic review and meta-analysis; therefore, informed consent was not needed.

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical Approval The present study was approved and supported by Exceptional Talent Development Center (ETDC), Tehran University of Medical Sciences (grant no.: 97-03-61-39369).

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