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ORIGINAL CONTRIBUTIONS

The Relationship Between Bariatric Surgery and Diet Quality: a Systematic Review

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Abstract

Background Bariatric surgery is currently the most effective treatment for morbid obesity. These procedures change the gastrointestinal system with the aim of reducing dietary intake. Improving diet quality is essential in maintaining nutritional health and achieving long-term benefits from the surgery. The aim of this systematic review was to examine the relationship between bariatric surgery and diet quality at least 1 year after surgery.

Methods A systematic search of five databases was conducted. Studies were included that reported diet quality, eating pattern, or quality of eating in adult patients who had undergone laparoscopic-adjusted gastric banding (LAGB), Roux-en-Y gastric bypass (RYGB), and sleeve gastrectomy (SG) procedures. Data was extracted to determine the relationship between having had bariatric surgery and subsequent diet quality.

Results A total of 34 study articles (described in 36 articles) met the inclusion criteria. The majority of studies were observational in nature and showed a reduction in energy intake following surgery, as well as inadequate intakes of micronutrients and protein, and an excessive intake of fats. There was evidence of nutrient imbalances, suboptimal compliance with multivitamin and mineral supplementation, and limited follow-up of patients.

Conclusion The current evidence base suggests that despite being effective in reducing energy intake, bariatric surgery can result in unbalanced diets, inadequate micronutrient and protein intakes, and excessive intakes of fats. In combination with suboptimal adherence to multivitamin and mineral supplementation, this may contribute to nutritional deficiencies and weight regain. There is a need for high-quality nutrition studies, to identify optimal dietary compositions following bariatric surgery.

Keywords Bariatric surgery · Gastric banding · Sleeve gastrectomy · Gastric bypass · Diet quality · Food groups · Nutrition

Introduction

Bariatric surgery is currently the most effective treatment for the chronic condition of obesity. It results in a substantial weight loss, reduces the risk of comorbidities associated with excess weight, and improves quality of life [1]. Bariatric procedures change the anatomy and physiology of the gastrointestinal system and hence have an impact on diet quality, digestion, and absorption of food and nutritional status [2, 3]. Following surgery, the volume of food consumed and hence energy intake is significantly reduced [2]. However, diet quality can be compromised, particularly if gastrointestinal

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symptoms are experienced from ingesting certain foods. While the gastrointestinal system adapts over time and increased food intake has been reported [4, 5], malabsorption of nutrients may persist due to the anatomical changes. In general, the restrictions in diet quality and food intolerances are a problem in the first year following surgery. A balanced diet is expected to be tolerated by most patients, after this period of adjustment. Some foods may continue to present as challenges, even in the longer term. These food intolerances may contribute to avoidance of food groups and this in turn may impact diet quality [6, 7]. The extent of dietary change and associated nutritional consequences varies between procedures. The lap-adjusted gastric banding (LAGB) procedure appears to induce more gastrointestinal symptoms and hence food intolerances than sleeve gastrectomy (SG) and the Roux-en-Y gastric bypass (RYGB) procedure [6, 8]. This can affect the quality of the long-term diet consumed by patients.

Studies on dietary tolerance post bariatric surgery have been inconsistent, despite reports that the majority of patients tolerated most food groups [9]. A trend towards healthier food consumption and significantly better food tolerance over time has been shown in patients following SG [10]. Other studies have shown the opposite, with some patients continuing to experience problems with tolerance of basic (core) foods, due to adverse gastrointestinal symptoms, whereas others might choose to return to pre-operative suboptimal eating habits [11, 12]. Understanding what is happening in this clinical population is important, as adequate intake of protein, maintaining optimal nutritional status, and improving diet quality and lifestyle is essential in maintaining weight loss and improving long-term health [11].

Given that obesity is recognized as a chronic and relapsing condition, a long-term treatment plan for all contributing factors including diet and lifestyle is needed. The current bariatric guidelines focus on the dietary and nutritional recommendations in the first post-operative year, but there is very little evidence supporting the diet quality of patients in the long term [13]. Few studies have reported on the optimal long-term diet composition following bariatric surgery [14, 15] and there is a lack of high-quality evidence describing the optimal diet. In order to develop dietary guidelines for the long-term, an evaluation of the current evidence base is required. Hence, the aim of this systematic review was to examine the relationship between bariatric surgery and diet quality at least 1 year after surgery.

Method

Search Strategy

A systematic search of the databases Medline (EBSCO), PubMed, Scopus, Cochrane Central Registry of Controlled Trials, and CINAHL (EBSCO) (all years to October 2018) was conducted. The search terms used in Medline were as follows: ((MH "Bariatric Surgery+") OR bariatric surgery OR Sleeve Gastrectomy OR Roux-en-Y Gastric Bypass OR gastric bypass) AND ("diet quality" OR "food groups" OR (MH"Diet+") OR "nutrition") (see Appendix for search team for Scopus).

The review protocol was pre-registered in PROSPERO in September 2018. The protocol can be accessed at: http://www.crd.york.ac.uk/PROSPERO/display_record.php?ID=CRD42018106564. This systematic review was reported according to The Preferred Reporting Items for Systematic Reviews and Meta- Analysis (PRISMA) statement [16].

Selection Criteria

Included studies were those conducted in human adults aged 18 years and older, who had undergone LAGB, gastric bypass and SG (Reviewer #2 Comment #2), and reported on diet quality: nutritional outcomes, macro- and micronutrient intake, and quality of eating beyond 1-year post-operative. This post-operative period was selected, as at this stage, the gastrointestinal system should have adjusted well enough for the patients to be able to tolerate a full consistency bariatric diet [17].

Initially, titles and abstracts were screened, with potentially eligible articles retrieved for full-text review. Article selection was conducted by the same researcher (NZ) and a second reviewer (EN) consulted in the case of ambiguity.

Critical Appraisal/Quality Assessment

The main researcher (NZ) assessed the methodological quality of all the included papers using the American Dietetic Association evidence appraisal tool checklist [18]. A second reviewer with expertise in systematic reviews (EN) independently reviewed the included papers, and in case of any ambiguities, a third expert reviewer (LT) was consulted. Studies were also categorized according to Australia's National Health and Medical Research Council (NHMRC) level of evidence guidelines: level I reflecting the highest level of evidence and level IV the lowest [19].

Data Extraction

Data was extracted by the principle investigator (NZ) and checked for accuracy by a second reviewer (EN). A standardized table was used to extract data and included details on study design, methodology, and study characteristics (patient demographics, surgical procedures, length post-operative of time, anthropometric measures, and dietary methodology). Dietary intake results were extracted for both the pre- and post-operative stage and these included energy intake, macro- and micronutrient intake, food intolerances, and adherence to multivitamin and mineral supplementation. Where additional details were required, authors were contacted to clarify details and provide further information. Due to the nature of studies and their variability in methodology, it was not considered appropriate to conduct a meta-analysis.

Results

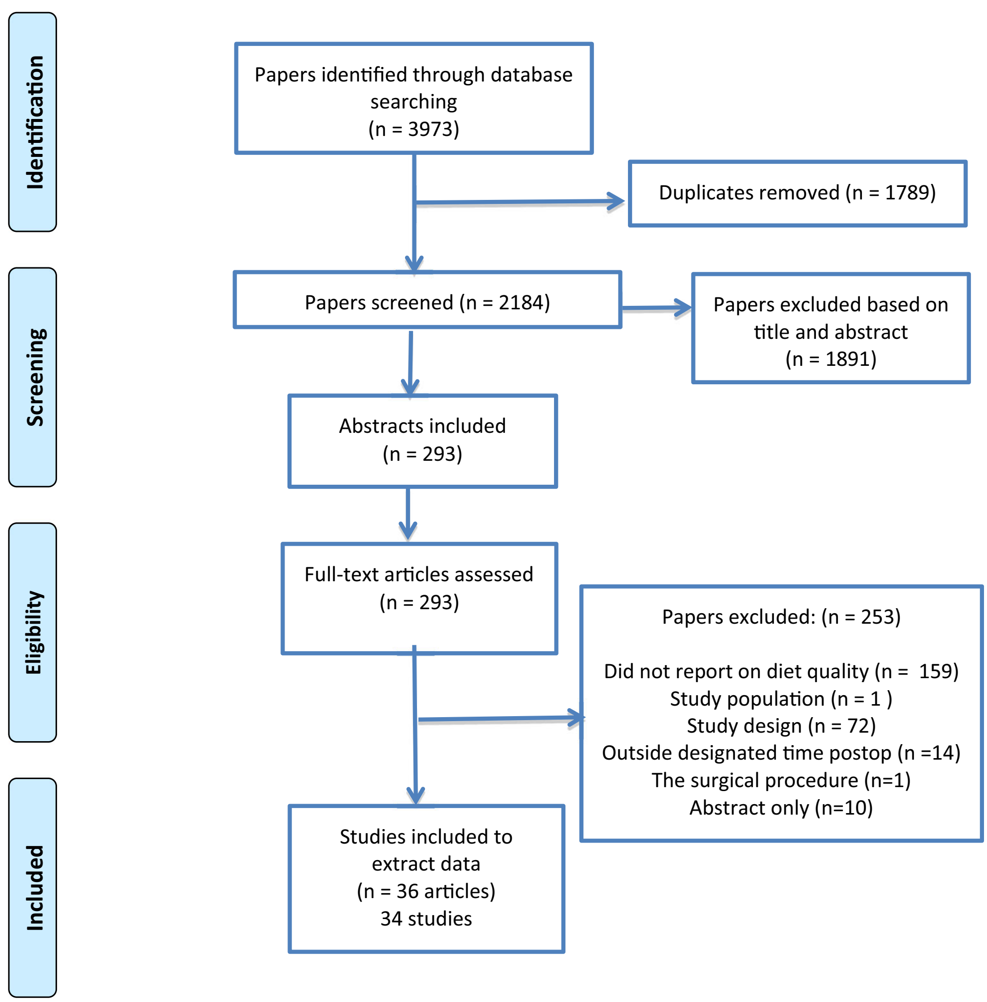
The initial search retrieved 3972 papers and 2184 papers were screened after removing 1789 duplicates. Full texts of 293 articles were reviewed, and subsequently 36 articles (describing 34 separate studies) met the inclusion criteria (Fig. 1).

Description of Studies

The studies were generally observational and classified as level IV evidence according to the NHMRC level of evidence criteria [19]. One prospective cohort study was part of a randomized controlled trial [20]. In one study [14], the participants were recruited from the Swedish Obese Subjects Study, which was a matched prospective trial (nonrandomized) that compared bariatric surgery with usual care for obese patients (Table 1). The studies were conducted across the world, including Asia, Australia, the Middle East, Europe, and North and South America. The sample size ranged from 17 to 1610 [14]. However, the majority of studies ($n = 25$) had a sample size of < 100. The majority of participants were female, with several papers reporting only on females [5, 17, 21–25]. The participants' age ranged from 33 to 52 years.

The surgical intervention in the majority of studies ($n = 20$) was a standard RYGB, mostly performed laparoscopically. Few studies reported on banded RYGB [21–23], and in two studies, the RYGB was performed as an open procedure [11, 26]. There were only two articles (one study) presenting data following LAGB [3, 27] and four studies on SG [10, 20, 28, 29]. Two studies reported on both SG and RYGB [30–32] and others reported on a mixture of procedures [4, 6, 9, 14, 30–34]. Two studies also reported on historical techniques or procedures [4, 9].

Fig. 1 PRISMA flow diagram of literature search process



The follow-up period of the studies as per our inclusion criteria was a minimum of 1-year post-operative and the majority of study follow-ups were < 3 years. Only three studies ($n = 11$) reported data on 5, 8, and 10 years post-operative [5, 14, 29]. Only a third of studies reported follow-up rates and these were found to decrease as time lengthened post surgery. The values were varied with follow-up at 1 year found to be in the range of 32–96%, at 18 months 15–38%, at 2 years 69.7–86%, at 3 years 10–64%, and at 5 years and beyond 3–59%.

Anthropometry

The pre-operative weight ranged from 115.8 ± 13.7 to 145.7 ± 40 kg, with BMI ranging from 30 ± 5.5 to 54.9 ± 8.9 kg/m^2 (Table 1). Anthropometric changes were reported by almost all studies. Studies presenting data at 1-year post-operative showed a weight loss in the range of 26–32 kg and an excess weight loss (EWL) range of 58–77%. Those with data from 2–5 years post-operative showed 32–34% weight loss or 58% EWL. Only a small number of studies had over 5 years of data, with Kanerva et al. reporting a 14.9% weight loss in men and 16.9% weight loss in woman at 10 years post-operative [14].

Assessment of Dietary Intake

Dietary assessment methods utilized in the studies are summarized in Table 2. These methods were mostly retrospective in nature and included 24-h food recall, food frequency questionnaire, and other invalidated questionnaires. Studies generally used a self-administered questionnaire; however, assistance in person or via the phone in completing these was reported in 15 studies (44%) [3, 5, 7, 9, 11, 17, 24, 26, 27, 32, 35–37].

Energy Intake

A total of fourteen studies reported nutritional intake pre-operatively, with some only reporting energy intake, whereas others explored food groups or the macronutrient intake and diet composition. The range of pre-operative energy intake in these studies was 2005 to 3312 kcal/day (RYGB). One study reported pre-operative energy intake of SG patients to be 1658 kcal/day [30].

Energy intake following surgery was reported by twenty-five studies [2–5, 7, 11, 17, 20, 21, 24–26, 28–32, 35–42]. They collectively showed a substantial reduction in energy intake, up to a 50 to 68% reduction in some studies [28, 29], with a large range in values. The total reported energy intake less than 2 years pre-operatively ranged from 1006 kcal/day [28] to 2131 kcal/day [40]. These changes in all studies were reported to be statistically significant where compared to the pre-operative energy intake. Only one article reported energy intake following LAGB [3] with an estimated intake of 4894 ± 2360 kJ and a range of 1137 to 13,176 kJ (270–3137 kcal).

A total of eight studies [4, 5, 11, 28, 29, 31, 39, 40] reported energy intake beyond 1 year following surgery, showing an increase over time. Once again, a large range was observed with a caloric intake per day of 900 [28] to 2425 [40] at 2 years post-operative, 1386 at 3 years post-operative [4], 1221 to 1625 for up to 5 years post-operative [11, 29, 31], and 1680 kcal at 8 years following surgery [5]. Studies that compared the energy intake following RYGB vs. SG [30–32] did not find a statically significant difference between these surgical groups.

Macronutrient and Food Group Intake

A total of eleven studies reported the percentage of energy intake from macronutrients pre-operatively (Table 2) [2, 4, 5, 14, 20, 28, 30, 31, 36, 40, 41], with generally an adequate protein, suboptimal carbohydrate, however excessive fat intake compared to dietary recommendations [43]. Only two studies looked at food groups pre-operatively and compared this to recommendations [30, 41]. The post-operative macronutrient intake is summarized in Table 2, with protein intake ranging from 95 ± 35.9 to 163.9 ± 123.8 g, carbohydrates from 224.7 ± 128.6 to 432.6 ± 51 g, and fat intake from 89 ± 7 to 177 ± 25.3 g. Fiber intake was only reported by three studies [2, 28, 41]. Percentage of macronutrient contribution to energy compared to dietary recommendations is summarized in Table 3. The comparison was made based on recommendations by Moize et al. and Kanerva et al. [14, 15] and based upon data which show that such diet composition was found to be most adequate in promoting weight loss and weight maintenance long term, following bariatric surgery.

Micronutrient Intake

The dietary intake of several micronutrients was shown to be inadequate compared to published recommendations (see Table 2 for recommendations used as references for individual studies) in several studies. These included vitamins D, E, C, folate, B12, B1, copper, zinc, calcium, and iron [2, 7, 17, 21, 23, 24, 27, 31, 41].

Food Intolerances and Changes in Preferences

Tolerance of food and satisfaction with diet quality was assessed and reported by 12 studies [6, 9, 10, 20, 22, 23, 26, 28, 33, 35–37]. Six studies (Kafri et al. 2011, Freeman et al. 2014, Coluzzi et al. 2016, Cano-Valderrama et al. 2017, Dagan et al. 2017) used a validated questionnaire to assess food tolerance following bariatric procedures. Coluzzi et al., Dragan et al., and Kari et al. showed an improvement in the eating questionnaire score over time, following SG,

Table 1 Summary of study characteristics

Author	Study design/ NHMRC grading	Study quality criteria[a]	Country	Surgery types	Participants *n* (response rate %)	Age (years), mean ± SD (range)	Female (%): male (%)	Pre-operative anthropometry Wt kg mean ± SD BMI kg/m^2 mean ± SD	Post-operative anthropometry Wt kg mean ± SD BMI kg/m^2 mean ± SD	Time postop (months, years), mean ± SD	Follow-up % of patients
Bavaresco at al. (2010)	Cohort Level IV	N	Brazil	RYGB	48	41.9 ± 8.8	41 (85): 7 (15)	Wt: 139.7 ± 23.9 BMI: 51.9 ± 7.8	Weight: 90.7 ± 18.4* BMI: 33.6 ± 5.9*	1, 3, 6, 8, and 12 (months)	n/a
Benson-Davies et al. (2013)	Cross-sectional pilot study/ level IV	P	USA	RYGB	24 (92)	51.8 ± 10.5 (30–70)	24 (100): 0	Wt: 137.4 ± 32.3 BMI: 49.9 ± 12.0	Weight: 93.3 ± 22.4 BMI: 33.7 ± 7.5 Wt loss: 60.3 ± 24.4 24 sustained weight loss of 44.1 ± 25.3% Weight regain kg: 27 (16.2 ± 12.7 @ ~ 6 years: 88% (21/24): regained more than 5 kg, 18 of 24 (75%): sustaining ≥ 50% excess weight loss)	6.25 ± 2.7 (years)	n/a
Brolin et al. (1994)	Prospective, observational/ level IV	N	USA	VBG, RYGB—old version	VBG 30 RYGB 108	VBG: 39 ± 9 RYGB: 38 ± 10	VBG 24: 6 RYGB 93: 15	VBG: Wt: 252 ± 39 BMI: 42 ± 4 RYGB: Wt: 266 ± 48 BMI: 43 ± 4	RYGB: at 16 months WL: 99 ± 24 lb*** (%EWL: 72% (in 92% of RYGB group))	14 (months)	n/a
Cano-Valderrama et al. (2017)	Cross-sectional/ level IV	P	Spain	RYGB, MBPD, MDS	GBP: 99 (50.5) MBPD: 54 (26.6) MDS: 43 (21.9)	44.2 (CI 42.4–46.1)	150 (76.5%)	BMI: 48.8 (CI 47.8–49.8)	NR	87.9(months)	35 (17.9%) patients were lost during the follow-up.
Chou et al. (2017)	Cross-sectional, retrospective/ level IV	N	Taiwan	SG	40 (33% completed questionnaire, 85% completed blood test)	33.5 ± 9.7	30 (75): 10 (25)	Wt: 102.3 ± 22.4 BMI: 37.9 ± 6.6	Wt: 72.9 ± 12.2 WL: 29.6 (%TWL of 27.5%) %EWL: 95.5% BMI: 27.3 ± 3.9 BMI loss (BMIL): 10.6 kg/m^2 % TWL @1 year: 30 ± 9.72 @3 years: 9.2 ± 12.4 @5 years: 27.5 ± 11.7	5 (years)	n/a
Coluzzi et al. (2016)	Prospective, longitudinal/ level IV	P	Italy	SG	30	35 (25–66)[+]	22: 8	Wt: 131 (102–160) BMI: 43.9 (39.5–57.3) median	Wt @1 year: 79.7 (70–127) @ 2 years: 74.8 (65–115) BMI @1 year: 29.3 (23.9–45.5) @ 2 years: 28.1 (22.2–41.2)	n/a	n/a

Table 1 (continued)

Author	Study design/ NHMRC grading	Study quality criteria[a]	Country	Surgery types	Participants *n* (response rate %)	Age (years), mean ± SD (range)	Female (%): male (%)	Pre-operative anthropometry Wt kg mean ± SD BMI kg/m^2 mean ± SD	Post-operative anthropometry Wt kg mean ± SD BMI kg/m^2 mean ± SD	Time postop (months, years), mean ± SD	Follow-up % of patients
Coughlin et al. (1983)	Cross sectional, prospective/ level IV	N	USA	RYGB	25	32.9 ± 1.66 (± SEM)	21: 4	Wt: (± SEM) 132.5 ± 7.39 Excess weight: 72.3 ± 4.89	%WL: @ 1 year: 27.3 (14.2–45.5) @ 2 years: 31 (19.1–50.3) @ 1 year: Wt: 82.9 ± 5.86***	1, 3, 6, and 12 (months)	n/a
Dagan et al. (2017)	Prospective cohort study/ level IV	0	Israel	SG	77 (77)	43.1 ± 9.3	(57.1): (42.9)	Wt: 121.0 ± 18.5 BMI: 42.1 ± 4.8	Wt: 83.5 ± 13 BMI: 29.1 ± 3.4 %EWL: 77.2 ± 18 *n* = 66, 85.7% had an EWL of ≥ 60%	12 (months)	80% @ 3/6 months 77% @ 12 months
da Silva et al. (2016)	Retrospective, cohort study/ level IV	P	Brazil	RYGB	Total: 80 WR: 19 SW: 61 regained < 10% weight regain	Total: 46.0 (16.0)[+] WR: 43.0 (20.0)[+] SW: 46.0 (16.0)[+]	Total: 71 (88.8): 9 (11.2)	BMI total: 49.8 ± 9.3	BMI: Total: 33.6 ± 7.2 %EWL: Total: 74.5 (27.3) WR group: 73.0 (15.4) SW group: 76.0 (29.3) *p*: 0.85	Mean total: 47 ± 18.0 (months)	Nutrition counseling attendance—min 7 visits in 2 years—% Total: 31.6 WR: 27.7 WS: 32.8 *p*: 0.69
de Torres et al. (2012)	Cross-sectional, controlled study/level IV	0	Brazil	RYGB	OG *n* = 44 (31) NOG *n* = 38 (72)	OG: 45.4 ± 9.5 NOG: 46.0 ± 9.4	44 (100)	BMI: OG: 50.2 ± 16.2	BMI: 28.9 %EWL: 77.8%	3.4 (years)	n/a
Dias et al. (2006)	Prospective, observational/ level IV	N	Brazil	RYGB	40	42.5 ± 10.8	40 (100)	BMI: 51.9 ± 11.8	End of 1 year % EWL 67%	3 monthly until 12 (months)	32.5% (13 subjects) at 1 year
El Labban et al. (2015)	Retrospective, cross-sectional/level IV	N	Lebanon	RYGB and SG	60 RYGB: 30 SG: 30	RYGB: 39.6 ± 11.3 SG: 33.0 ± 12.3	RYGB: 14 (47): 16 (53) SG: 14 (73): 8 (27)	Wt: RYGB: 124.0 ± 21.5 SG: 115.4 ± 20.7 BMI RYGB: 42.7 ± 5.2 SG: 41.2 ± 4.1	Wt: RYGB: 85.2 ± 16.1 SG: 79.3 ± 14.3 *p*: 0.138 BMIL: RYGB: 29.4 ± 4.7 SG: 28.3 ± 3.3 *NS*	RYGB: 22.4 ± 17.1 (months) SG: 23.4 ± 11.5 (months) *p*: 0.789	n/a
Ernst et al. (2009)	Cross-sectional/level IV	N	Switzerland	RYGB *n* = 48 LAGB *n* = 73	NOC: *n* = 45 OC: *n* = 45 RYGB: *n* = 48 GB: *n* = 73	NOC: 39.7 ± 2.3 OC: 42.6 ± 2.0 RYGB: 40.2 ± 1.5 GB: 44.0 ± 1.2	NOC: 34: 11 OC: 35: 10 RYGB: 37: 11 GB: 59: 14	Wt: RYGB: 46.5 ± 0.7 Wt: GB: 44.6 ± 0.5	RYGB: EBL: 81.7 ± 2.6%*** %EWL: 76.3 ± 2.4*** LAGB: EBL: 51.0 ± 2.7%*** %EWL: 48.1 ± 2.6***	GB: 78.9 ± 3.2 RYGB: 22.7 ± 2.3 (months) *p* < 0.001	n/a
Freeman et al. (2014)	Prospective, cross-sectional/ level IV	0	Australia	LAGB, SG, RYGBP	116 (34)	C: 47 (28) AGB: 46 (21) RYGB: 58 (15) SG: 50 (18) Median (IR)	Total: women (67.7)	BMI: C: 43.2 (15.9) AGB: 45.5 (10.4) RYGBP: 42.4 (9.1) SG: 43.2 (8.1) Median (IR)	BMI: AGB: 36.4 (6.9)[b] RYGB: 29.0 (6.4)[c] SG: 30.0 (8.9)[d] EWL (%): AGB: 38.2 (35.9)*** RYGB: 76.5 (27.6)	AGB and RYGB: 12 (months) SG: 10 (months)* **p* = 0.003	n/a

Table 1 (continued)

Author	Study design/ NHMRC grading	Study quality criteria[a]	Country	Surgery types	Participants *n* (response rate %)	Age (years), mean ± SD (range)	Female (%): male (%)	Pre-operative anthropometry Wt kg mean ± SD BMI kg/m² mean ± SD	Post-operative anthropometry Wt kg mean ± SD BMI kg/m² mean ± SD	Time postop (months, years), mean ± SD	Follow-up % of patients
									SG: 76.3 (43.3)	vs. RYGBP	
Freire et al. (2012)	Cross-sectional, prospective/level IV	N	Brazil	RYGB, open—Fobi-Capella	100 (42)	Total ($n = 100$): 45.1 ± 9.9	Total ($n = 100$): 84: 16	BMI: 54.9 ± 8.9	BMI: G1 up to 2 years: 37.4 ± 8.3 kg/m^2, G2 2–5 years: 32.6 ± 6.3 kg/m^2, and G3 > 5 years: 37.8 ± 6.3 %EWL: Total: 59.1 ± 20.3% (15.4–100.4%)	Total ($n = 100$): 45.5 (months) G1: 12.4 ± 7.1 G2: 39.9 ± 10 G3: 85.0 ± 17.8 $p < 0.01$	53% reported receiving nutritional counseling. Up to 2 years: 85.3% 2 to 5 years: 69.7% > 5 years: 3% ($p < 0.01$)
Gesquiere et al. (2017)	Prospective, observational/level IV	P	Belgium	RYGB	Pre-op: 54 Post-op: 42 (41)	48.0 (46.6–49.3)	32: 21	BMI: 40.4[95% CI 39.4; 41.4]	BMI: 27.4 (95% CI 26.5; 28.3) %EWL: 70.6% (95% CI 66.5; 74.7)	1, 3, 6, and 12 (months)	n/a
Giusti et al. (2016)	Prospective, longitudinal/level IV	N	Switzerland	RYGB	16	39.4 ± 2.4	n/a	Wt: 117.1 ± 3.7 kg BMI: 44.1 ± 1.6	WL: 39.7 ± 1.0 kg %WL: 34.2% ± 1.0%***	12 ($n = 16$) (months) 36 ($n = 8$) (months)	13 ($n = 16$) and 36 ($n = 8$) months after surgery
Harbottle (2011)	Cross-sectional/level IV	0	Channel Islands	LAGB: 22% RYGBP: 71% Other: 7%	68 (38)	44	61 (90): 7 (10)	BMI: 44.2 (33–60)	WL: 42.7 ± 15.09 Weight regain: 4.5 ± 5.71 %WL: 32.7 ± 10.42 % weight regain: 9.9% ± 13.40 Mean overall %WL: < 2 years ($n = 25$): 30.1 (14.8–55.4) 2–5 years ($n = 35$): 32.9 (23.9–50.3) > 5 years ($n = 8$): 27.4 (6.8–49)	2.4 (years)	26 (38%) received dietetic advice 12 (18%) dietetic follow-up
Kafri et al. (2011)	Cross-sectional, prospective/level IV	P	Israel	SG	60 (76) G2 > 1 year $n = 25$	Total: 41.2 ± 11.9 G2: 43.9 ± 12.6 (> 1 year post-operative group)	Total: 49: 11	Wt total: 121.6 ± 18.7 G2: 120.0 ± 20.8 BMI total: 44.5 ± 6.0 G2: 45.3 ± 6.6	Weight: Total: 86.1 ± 14.8 G2: 82.7 ± 11.6 BMI: Total: 31.5 ± 4.8 G2: 31.3 ± 4.5 %EWL Total: 68.6 ± 19.2 G2: 70.9 ± 15.3	Total ($n = 60$): 11.7 ± 7.4 (months) G2: 18.8 ± 5.8 G2 included	n/a
Kanerva et al. (2017)	Cross-sectional/level IV	P	Sweden	LAGB $n = 376$ (adjustable and non-adjustable)	1610 (80)	F: 47.3 ± 6.1 M: 47.3 ± 5.8	1130: 480	Wt: Female: 115.8 ± 13.7 Male: 132.5 ± 17.2	%WL: @ 1 year Men: 24.0 ± 9.6 Women: 25.8 ± 9.3 @ 10 years	6 (months)–10 (years)	Follow-up visits (0.5, 1, 2, 3, 4, 6, 8, and 10 years)

Table 1 (continued)

Author	Study design/ NHMRC grading	Study quality criteria[a]	Country	Surgery types	Participants *n* (response rate %)	Age (years), mean ± SD (range)	Female (%): male (%)	Pre-operative anthropometry Wt kg mean ± SD BMI kg/m^2 mean ± SD	Post-operative anthropometry Wt kg mean ± SD BMI kg/m^2 mean ± SD	Time postop (months, years), mean ± SD	Follow-up % of patients
				VBG *n* = 1369 RYGB *n* = 265					Men: 14.9% ± 10.5% Women: 16.9% ± 11.8%		
Kruseman et al. (2010)	Longitudinal, cohort study/level IV	P	Switzerland	RYGB	135 (59)	40 ± 10	F: 80 (100)	Wt: 124.3 ± 21.5 BMI: 45.9 ± 7.6	Wt: 93.7 ± 18.9*** BMI 34.5 ± 6.2*** Over 50% of patients regained at least 5 kg	8 ± 1.2 (years)	1 year: 96% 8 years: 59%
Laurenius et al. (2013)	Longitudinal, cohort study/level IV	P	Sweden	RYGB	43 (86)	43 ± 10	31: 12	BMI: 44.3 ± 4.9	1 year: Wt: 91.2 kg (16.8)*** 2 years: Wt: 89.9 kg (18.4)*** 1 year: WL: 30.7% (6.7)*** 2 years: WL: 31.8% (9.3)***	1 and 2 (years)	Number of dropouts was 4 of 203 visits
Leiro et al. (2014)	Cross-sectional/level IV	N	Brazil	RYGB—Fobi-Capella ring	36	n/a	36 (100)	BMI 30.0 ± 5.5	%EWL: 60.9% ± 23.2%	20.1 ± 3.7 (months)	n/a
McGrice et al. (2012) and McGrice (2014)	Cross-sectional/level IV	P	Australia	LAGB	52 (24)	45.0 ± 10.5	38: 14	Wt: 127.9 ± 29.9	Lowest wt post-op: 99.5 ± 23.9 Wt at 12/12: 101.8 ± 25.0 WL: 26 kg 19 (36.5%): regained weight	12 (months)	n/a
Miller et al. (2014)	Prospective, cohort/level IV	0	USA	RYGB	17 (63)	47.3 ± 2.2 (mean ± SEM*)	16: 1	Wt: 144.5 ± 5.5 BMI: 53.6 ± 1.7	Wt loss: 33.2 ± 1.6% EWL%: 58.3 ± 3.2%	12 (months)	n/a
Moize et al. (2013)	Longitudinal, prospective, observational/ level IV	0	Spain	RYGBP *n* = 297 SG *n* = 61	355 SG: 61 GBP: 294	SG: 46.4 ± 11.6 GBP: 45.2 ± 10.6	267 (75.2): 88 (24.8)	Wt: SG: 137.9 ± 19.4 GBP: 126.1 ± 20.1 BMI SG: 51.6 ± 6.7 GBP: 47.4 ± 6.0	NR	48 (months)	Dropout rates: for GBP vs. SG were @ 2 years: 12% vs. 16%, @ 3 years: 31% vs. 41%, and @ 5 years: 53% vs. 66%
Moize et al. (2003)	Prospective, longitudinal/level IV	N	USA	Open RYGB Varying afferent limb sizes	106 (88)	41.1 ± 12.1	77: 16	Wt: 145.7 ± 40 BMI: 52.0 ± 12.9	BMI: 39.4 ± 11.0 Weight: 110.8 ± 31.5 % EWL: 48.5 ± 16.7	3, 6, 12 (months)	12 months: 38% 18 months: 15% 24 months: 12%
Novais et al. (2012) and Novais et al. (2011)	Cross-sectional/level IV	0	Brazil	Banded RYGB 90% Standard RYGB 10%	141	44 ± 9	F: 141 (100)	Wt: 117.1 ± 16.4 BMI: 45.9 ± 16.4	Wt: 76.5 ± 12.2** BMI: 30.0 ± 4.5** %EWL: 68.5 (32.3–121.3)**	3.9 ± 1.4 (years)	n/a
	Cross-sectional/level IV	N	Spain	RYGB	107 (82)	41.8 ± 9.8	(79): (21)	Wt: 139.4 ± 25.3	Wt: 85.6 ± 17.1 kg		n/a

Table 1 (continued)

Author	Study design/ NHMRC grading	Study quality criteria[a]	Country	Surgery types	Participants *n* (response rate %)	Age (years), mean ± SD (range)	Female (%): male (%)	Pre-operative anthropometry Wt kg mean ± SD BMI kg/m² mean ± SD	Post-operative anthropometry Wt kg mean ± SD BMI kg/m² mean ± SD	Time postop (months, years), mean ± SD	Follow-up % of patients
Ortega et al. (2012)								BMI: 50.7 ± 11.8	BMI: 31.7 ± 5.4 %EBMIL was 77.4 ± 23.7%	3.0 ± 1.8 (years)	
Reid et al. (2016)	Cross-sectional/level IV	p	Canada	RYGB	Total = 27 (44) *n* = 10 maintainers *n* = 17 regainers	Total: 53.2 ± 8.3 Maintainers: 54.4 ± 7.6 Regainers: 51.1 ± 9.6	(89): (11)	NR	Wt: Regainers: 95.5 ± 19.5 Maintainers: 80.5 ± 18.8 Total: 86.0 ± 20.1 WL (%) R: 18.2 ± 6.3 M: 44.4 ± 5.4 Total: 34.7 ± 14.0 BMI: R: 38.5 ± 10.4 M: 31.1 ± 6.9 Total: 33.8 ± 8.1	12.15 ± 3.7 (months)	75% reported never being in contact with a dietitian
Silver et al. (2006)	Cross-sectional/level IV	P	USA	RYGB	140 (66)	45.2 ± 9.9	124 (88.6): 16 (11.4)	Wt: 138 ± 22.2 BMI: 49.8 ± 7.9	WL: 55.8 ± 15.2 90% in 1st 12/12	24.2 ± 7.9 (months)	n/a
Soares et al. (2014)	Cross-sectional/level IV	N	Brazil	RYGB	154 (89)	42.38 ± 9	159 (92.44): 13 (7.56)	Wt: NR BMI: 46.88 ± 5.97	*n* = 154 BMI: 31.36 ± 4.58 EWL: 71.81 ± 18.22	≥ 6–≥ 12 (months)	n/a
Verger et al. (2016)	Prospective, cohort study/level IV	0	France	RYGB *n* = 14 SG *n* = 19	33 (63) (RYGB: 30 SG 22)	RYGB: 43.5 (38–51) SG: 41 (36–49)	RYGBP: F: 68.2% SG: F: 66.7%	Wt: RYGBP: 127 (113–139) Wt: SG: 117 (108–137)	WL: RYGB: 38.8 (29–48.6)* SG: 27.2 (25.6–33)*	12 (months)	RYGBP 63% @ 1 year SG 63% @ 1 year
Warde-Kamar et al. (2004)	Cohort study/level IV	P	USA	RYGB	62 (17)	46 ± 11	64%: 5%	Wt: 145 ± 30	WL: 48 %EWL: 58 ± 17%	30 ± 8 (months)	54% @ 1 year 38% @ 18 months 10% @ 3 years

P positive, *N* negative, *0* neutral, *RYGB* Roux-en-Y gastric bypass, *SG* sleeve gastrectomy, *LAGB* laparoscopic-adjusted gastric banding, *MBPD* modified biliopancreatic diversion, *MDS* modified duodenal switch, *VBG* vertical banded gastroplasty, *SD* standard deviation, *SEM* standard error of mean, *IR* interquartile range, *NOC* non-operated control, *OC* operated control, *OG* operated group, *NOG* non-operated group, *WR* weight regainers, *SW* stable weight, *CI* confidence interval, *Wt* weight, *BMI* body mass index, *NS* not statistically significant between groups

*Statistically different to pre-op but not between groups; **$p < 0.05$ compared to pre-op; ***$p < 0.001$ compared to pre-op or between groups; [b] $p = 0.001$ vs. RYGB; [c] $p = 0.002$ vs. SG; [d] $p < 0.001$ vs. pre-op and control groups

[a] The methodological quality was assessed, using the American Dietetic Association critical appraisal tool

[+] Median (range)

Table 2 Summary of dietary intake findings

		Pre-operative data			Post-operative data		
Author	Assessment method	Energy intake (kcal/day)$^+$	Macronutrient intake$^+$ % of daily energy intake	Biochemical deficiencies^{++}	Energy intake (kcal/day)$^+$	Macronutrient intake$^+$ % of daily energy intake	Inadequate dietary micronutrient intake$^\#$
Bavaresco et al. (2010)	24 h-R	2347 ± 1016	Protein: 20.5 ± 6.3 Lipids: 33.2 ± 6.7 CHO: 46.1 ± 10.2	Alb: 15.6 Ca: 2.4 Fe: 12.2	1034 ± 345***	Protein: 17.8 ± 5.8******** Fat: 30.2 ± 6.3******** CHO: 51.8 ± 6.5********	Fe (mg):$^{\Phi}$ 6.5 ± 3.0 ******** Fiber (g):$^{\Phi}$ 9.7 ± 7.0********
Benson-Davies et al. (2013)	7-day FR	NR	NR	NR	T: 1429 ± 411 WR: 1630 ($n = 9$) WM: 1343 ($n = 15$)	CHO: 43 Protein: 17 Fat: 39 Sat fat: 19.0 ± 9.9 g/day Fiber: 10.5 ± 4.9 g/day	NR
Brolin et al. (1994)	DH & SAQ	2604 ± 1087	Protein: 18 ± 6 CHO: 46 ± 9 Fat: 36 ± 8 SWS: 17 ± 10 MIC: 9 ± 9 NLS: 23 ± 27 HCL: 26 ± 33	NR	12/12: 1116 ± 426**** 18/12: 1256 ± 504**** 24/12: 1319 ± 912**** 36/12: 1386 ± 578****	12/12: Protein: 19 ± 6 I CHO: 47 ± 12 Fat: 34 ± 11 18/12: Protein: 19 ± 5 CHO: 46 ± 12 Fat: 35 ± 12 24/12: Protein: 20 ± 7 CHO: 45 ± 13 Fat: 34 ± 11 36/12: Protein: 18 ± 6 CHO: 50 ± 9 Fat: 33 ± 8	NR
Cano-Valderrama et al. (2017)	FTQ	NR	NR	NR	NR	NR	NR
Chou et al. (2017)	24 h-R & FFQ	2418	NR	Fe deficiency anemia: 7.5 Secondary hyperparathyroidism: 17.5	Male: 1221 ± 635 Female: 1233 ± 504	Protein: 22.7 ± 5.2 Fat: 50 ± 25 CHO: 41.2 ± 9.2 Fiber: 11.7 ± 6.5 g/day	Calcium (mg/day):$^{\Phi}$ 536.2 ± 291.6 Iron (mg/day):$^{\Phi}$ 7.5 ± 3.9 Folate (μg/day):$^{\Phi}$ 110.1 ± 36.2 Zinc (mg/day):$^{\Phi}$ 8.2 ± 4 B1 (mg/day):$^{\Phi}$ 0.9 ± 0.42 Retinol (μg/day):$^{\Phi}$ 238.7 ± 131.2 Niacin (mg/day):$^{\Phi}$ 13 ± 6.5 Vit C (mg/day):$^{\Phi}$ 66.6 ± 42.7 Vit E (mg/day):$^{\Phi}$ 3.4 ± 1.9
Coluzzi et al. (2016)	24 h-R & FTQ	3002 (1824–5533)	Protein: 17 Fat: 36 Carbohydrate: 47 Fiber: 18 g/day	NR	1 Y: 1006 (938–1133)** 2 Y: 900.5 (693–1244)**	Protein: 1 Y: 22******* 2 Y: 27******* Fat: 1 Y: 36******* 2 Y: 31.5******* CHO: 1 Y: 42******* 2 years: 41.5******* Fiber g/day: 1 Y: 12******* 2 Y: 12*******	NR
Coughlin et al. (1983)	24 h-R	3979.4 ± 492.19	Protein: 16.6 ± 1.20 Fat: 39.2 ± 1.71 CHO: 44.2 ± 1.99	M: Hb: 17 g/dL Hematocrit: 50%	1 year: 1091.0 ± 116.12*******-*	Protein: 22.3 ± 2.67 NS Fat: 35.5 ± 1.86 NS CHO: 41.2 ± 2 NS	NR

Table 2 (continued)

				F: Hb: 14 g/dL Hematocrit: 40%			
da Silva et al. (2016)	24 h-R	NR	NR	NR	T: 1282 (453)$^{\delta\delta}$ WR: 1392 (408)$^{\delta\delta}$ WM: 1223 (491)$^{\delta\delta}$ (NS)	CHO: T: 51.0 ± 10.9$^{\delta\delta}$ WR: 49.0 ± 6.5$^{\delta\delta}$ WM: 52.1 ± 10.8$^{\delta\delta}$ NS Fats: T: 32.0 ± 10.1$^{\delta\delta}$ WR: 35.0 ± 6.9$^{\delta\delta}$ WM: 31.1 ± 11.0$^{\delta\delta}$ NS Protein g/day: T: 51.5 ± 24.5$^{\delta\delta}$ WR: 48.5 ± 29.5$^{\delta\delta}$ WM: 52.0 ± 24.5$^{\delta\delta}$ NS	NR
Dagan et al. (2017)	3-day FR & FTQ	2145.3 ± 938.6	CHO: 40.7 ± 11.1 Fats: 38.5 ± 7.7 Proteins: 18.8 ± 6.6	Fe: 6.5 Ferritin: 1.3 B12: 31.2 B1: 3.9 Folic acid: 1.3 Vit D: 83.1 Hb: 3.9	1317.0 ± 493.3**	CHO: 43.4 ± 7.9** Fats: 36.6 ± 6.2** Protein: 18.2 ± 4.6**	NR
de Torres et al. (2012)	4-day FR	NR	NR	NR	OG: 1383.0 ± 473.9 NOG: 1536.1 ± 419.0 NS	NR	OG & NOG:$^{\Phi\Phi}$ Vit A, Vit E, Vit B12, Ca, Fe OG:$^{\Phi\Phi}$ Vit C
Dias et al. (2006)	24 h-R	NR	NR	NR	866.2 ± 342.7$^{\delta\delta\delta}$	NR—contacted author but no reply. NS between protein, fats, and CHO	Zinc (mg/day):$^{\Phi}$ 4.1 ± 0.6 Iron (mg/day):$^{\Phi}$ 5.6 ± 0.9
El Labban et al. (2015)	FFQ & 24 h-R	NR	NR	NR	RYGB: 1555 ± 657 SG: 1373 ± 606 NS	CHO: 42 Protein: 14 Fat: 36 Sugar: < 10% NS	NR
Ernst et al. (2009)	FFQ	NR	NR	NR	NR	NR	NR
Freeman et al.	24 h-R and FTQ	NR	NR	NR	NR	NR	NR
Freire et al. (2012)	24 h-R & FFQ	NR	NR	NR	T: 1152 ± 462 G1 (<2 years): 949 ± 334 G2 (2–5 years): 1343 ± 530 G3 (>5 years): 1169 ± 426 WR: 1264.7 ± 435.1****** WS: 1008.8 ± 460.4******	CHO: 51.1 ± 8.9 Fats: 33.7 ± 7.5 Protein: 15.2 ± 4.1 NS	All micronutrients$^{\Phi}$ but similar among groups and sexes
Gesquiere et al. (2017)	FR	2235.7 (2053.4–2418.0)	NR	Anemia: 9.2 Iron deficiency: 49.1 B12: (< 191): 3.8 Zn: 0	12/12: 1491.9 (1387.5–1596.4)	NR	Dietary Fe: 14.3$^{\Phi\Phi\Phi}$ T Fe: 7.1$^{\Phi\Phi\Phi}$ Dietary Vit B12: 0.0$^{\Phi\Phi\Phi}$ T Vit B12: 0.0$^{\Phi\Phi\Phi}$ Dietary Zn: 2.4$^{\Phi\Phi\Phi}$ T Zn: 0.0$^{\Phi\Phi\Phi}$ Dietary Cu: 4.8$^{\Phi\Phi\Phi}$ T Cu: 2.4$^{\Phi\Phi\Phi}$ Dietary Vit C: 54.8$^{\Phi\Phi\Phi}$ T Vit C: 21.4$^{\Phi\Phi\Phi}$
Giusti et al.(2016)	7-d FR	2072 ± 108	Protein: 87 ± 4 g/day	NR	12/12: 1240 ± 87$^{\delta}$**		NR

Table 2 (continued)

			CHO: 231 ± 11 g/day Fat: 89 ± 7 g/day		36/12: 1448 ± 57$^{\delta}$**	12/12: Protein: 14.8 ± 4.6$^{\delta}$** CHO: 44.5 ± 14.3$^{\delta}$** Fat: 40.6 ± 13.1$^{\delta}$** 36/12: Protein: 15.3 ± 3.5$^{\delta}$** CHO: 38.7 ± 9.1$^{\delta}$** Fat: 46 ± 11$^{\delta}$**	
Harbottle (2011)	SAQ	NR	NR	NR	NR	NR	NR
Kafri et al. (2011) (* data from G2 reported)	FFQ & FTQ	NR	NR	NR	NR	NR	NR
Kanerva (2017)	Semi-quantitative FR	M: 3226 ± 1131 F: 2746 ± 1186	CHO: M: 43.3 ± 5.8 F: 44.4 ± 5.6 Fat: M: 36.6 ± 5.1 F: 36.6 ± 4.8 Protein: M: 16.3 ± 2.4 F: 16.5 ± 2.5 Fiber: M: 1.5 ± 0.4 F: 1.7 ± 0.5 Alcohol: M:2.4 ± 2.5 F: 0.9 ± 1.3	NR	NR	NR	NR
Kruseman et al. (2010)	4-day FR	2271 ± 769	CHO: 41.3 ± 7.2 Lipids: 41.8 ± 6.4 Protein: 15	NR	1 Y (n = 135): 1442 ± 340$^{\#}$ 8 Y (n = 80): 1680 ± 506	8 Y: Protein: 19% 1 Y: CHO: 1 Y: 41.3 ± 7.2 8 Y: 41.5 ± 9.3 NS Fats: 1 Y: 41.8 ± 6.4 8 Y: 39.8 ± 7.8*********	NR
Laurenius et al. (2013)	SAQ	2986 (2619–3354)	Fat: 37.0 (34.2–38.8) Alcohol: 2.47 (1.31–3.63)	NR	1 Y: 2131 (1873–2390)** 2 Y: 2425 (2103–2591)** Calculated RMR 2314 (2173–2455)	Fat: 1 Y: 34.3 (32.6–35.9)** 2 Y: 35.3 (32.7–36.3)** Alcohol: 1 Y: 2.39 (1.31–3.48) 2 Y: 2.42 (2.08–4.76)	NR
Leiro et al. (2014)	FFQ	NR	NR	NR	NR	NR	Fe, Ca, and Vit D$^{\Phi\Phi\Phi\Phi}$ Adequacy in: Fe: 30.5% Ca: 59.0% Vit B12: 104.2% Vit D: 3.3%
McGrice et al. (2014), McGrice (2012)	FFQ	NR	NR	NR	T: 4894 ± 2360 (kJ) M: 5089 ± 3093 (kJ) F: 4693 ± 2071 (kJ)	Protein: 22.7 Fat: 35.8 Sat fat: 14.6 CHO: 39.8 Alcohol: 2.8	M & F: Ca, folate, Mg, retinol, Vit B1, and Vit E M: Zn pre-menopausal F: Fe
Miller et al. (2014)	4-day FR	2150 (165)$^{\delta}$	Protein: 17.4 ± 1.0 Fat: 39.2 ± 1.9 CHO: 44.7 ± 2.1 Fiber: 16.0 ± 1.9 g/day	NR	1307 (129)****	Fat: 37.1 ± 2.0 CHO: 42.0 ± 2.0 Protein: 22.6 ± 1.2	Vit A: 11.8$^{\Phi\Phi\Phi}$ Vit D: 88.2$^{\Phi\Phi\Phi}$ Vit E: 88.2$^{\Phi\Phi\Phi}$ Vit C: 76.5$^{\Phi\Phi\Phi}$ Vit B1: 41.2$^{\Phi\Phi\Phi}$ Vit B2: 11.8$^{\Phi\Phi\Phi}$ Vit B3: 29.4$^{\Phi\Phi\Phi}$ Vit B6: 47.1$^{\Phi\Phi\Phi}$ Folate: 58.8$^{\Phi\Phi\Phi}$ Vit B12: 11.8$^{\Phi\Phi\Phi}$ Ca: 64.7$^{\Phi\Phi\Phi}$

Table 2 (continued)

							Mg: 76.5[ΦΦΦ] Fe: 35.3[ΦΦΦ] Zn: 29.4[ΦΦΦ] Cu: 29.4[ΦΦΦ]
Moize et al. (2003)	24 h-R	NR	NR	NR	1075 ± 378	1 Y Protein: 23.3 ± 6.5 CHO: 46.7 ± 10.6 Fat: 30.3 ± 11.2	NR
Moize et al. (2013)	FR & 24 h-R	SG: 2283 (75.1)[δ] RYGBP: 2187 (34.2)[δ]	SG and RYGB: Protein: 18.3 (17.7–19) CHO: 39.9 (38.8–41) Fat: 41.7 (40.6–42.8)	Fe: SG: 30.8 RYGB 26.5 Ferritin: SG: 8.3 RYGB: 18.6 B12: SG: 2.7 RYGB: 1.8 B1: SG: 0 RYGB: 5.5 B6: SG: 75* RYGB: 11.3 Folic acid: SG: 0 RYGB: 1.8 Vit D: SG: 90* RYGB: 60.6 PTH: SG: 62* RYGB: 44 Hb: SG: 10 RYGB: 22* Alb: SG: 5.4* RYGB: 4.5	SG: 12/12: 1319 (79.7)[δ] 24/12: 1469 (92.3)[δ] 48/12: 1409 (118.6)[δ] 60/12: 1625 (191.8)[δ] RYGB: 12/12: 1390 (35.8)[δ] 24/12: 1533 (39.9)[δ] 48/12: 1581 (50.2)[δ] 60/12: 1581 (55.2)[δ] NS between groups	Protein: SG: 12/12: 21.8 ± 0.8 24/12: 20.4 ± 0.9 48/12: 20.2 ± 1.1 60/12:17.9 ± 1.8 RYGB: 12/12: 19.7 ± 0.3 24/12: 18.9 ± 0.4 48/12: 18.3 ± 0.5 60/12: 18.9 ± 0.5 NS CHO: SG: 12/12: 35.1 ± 14********** 24/12: 42.5 ± 1.6 48/12: 43.4 ± 2.1 60/12: 44.3 ± 3.5 RYGB: 12/12: 39.7 ± 0.6********** 24/12: 39.8 ± 0.7 48/12: 40.3 ± 0.9 60/12: 40.6 ± 1.0 Fats: SG: 12/12: 42.0 ± 1.4 24/12: 38.3 ± 1.6 48/12: 37.2 ± 2.1 60/12:38.1 ± 3.48 RYGB: 12/12: 40.4 ± 0.6 24/12: 41.2 ± 0.7 48/12: 42.0 ± 0.9 60/12: 40.3 ± 1.0 NS	Ca:[Φ] SG: 75–90% RYGB: 79–92% Fe:[Φ] SG: 42–88% RYGB: 48–79 Protein:[Φ] (< 60 g/day) SG: 50% RYGB: 41.2% NS
Novais et al. (2012) and Novais et al. (2011)	DH & Short FFQ	NR	NR	NR	< 50% EWL: 1613 ± 372 50–75% EWL: 1457 ± 554*** > 75% EWL: 1449 ± 417***	CHO: < 50% EWL: 47.2 ± 7.1 50–75% EWL: 49.6 ± 8.9 > 75% EWL: 49.8 ± 9.4 NS Proteins: < 50% EWL: 15.0 ± 4.8 50–75% EWL: 15.8 ± 4.9 > 75% EWL: 16.0 ± 5.8 NS Fats: < 50% EWL: 37.7 ± 4.7 50–75% EWL: 34.5 ± 7.3 > 75% EWL: 34.1 ± 6.5 NS	Folic acid, Vit E, Vit C, Mg
Ortega et al. (2012)	3-day FR	NR	NR	NR	1364 ± 293	CHO: 47%	NR

Table 2 (continued)

Reid et al. (2016)	3-day FR & SAQ	NR	NR	NR	T: 1705 ± 573 (n = 27)	Proteins: 15% Fats: 38% Protein: T: 19.21 ± 5.87 WR: 16.81 ± 6.48 WS: 20.64 ± 5.17 CHO: T: 42.67 ± 11.15 WR: 43.42 ± 8.73 WS: 42.22 ± 12.59 Fat: T: 35.24 ± 10.73 WR: 33.71 ± 11.22 WS: 36.15 ± 10.67 Alcohol T: 8.5 ± 20.5 WR: 18.5 ± 30.9**********-* WS: 2.6 ± 6.5	NR
Silver et al. (2006)	SAQ	NR	NR	NR	NR	NR	NR
Soares et al. (2014)	DH	NR	NR	NR	NR	NR	NR
Verger et al. (2016)	SAQ & 24 h-R	RYGB: 2005 (1539–2266) SG: 1658 (1445–2395) NS Both under report by 8%	RYGB: Fats: 32 (30–40.6) CHO: 47.8 (42–49.7) SG: Lipids: 37.4 (33.2–39.9) CHO: 44.1 (40–46.7) RYGB: Protein: 83.5 g/day (70.6–105.6) SG: Protein: 78.3 g/day (64–107.2)	RYGB: Vit D: 86 PTH: 59 Fe: 18 SG: Vit D: 83 PTH: 50 Fe: 7	RYGBP 1226 (813–1559) SG 1078 (793–1354)	RYGB: Fats: 38.8 (33.6–45.6) CHO: 44.1 (40–46.7) SG: Fats: 39.5 (37.1–44.5) CHO: 42.4 (33.4–45.1)	NR
Warde-Kamar et al. (2004)	SAQ & 24 h-R	NR	NR	NR	1786 ± 827 (624–6034)	Protein: 22 ± 7 CHO: 45 ± 11 Fats: 32 ± 11	Ca: 68 ± 47 Vit D (% NR) Folic acid: 61 ± 37

	Post-operative data				
Author	Outcome—dietary quality	Foods causing digestive problems	Side effects GIT and other (% reported)	Supplement adherence (% of patients)	Biochemical deficiencies++
Bavaresco et al. (2010)	Dietary intake pre- and post-op: • Low protein intake: 46.6 ± 20.0 g/day • Low in fibers (vegetables, fruit, legumes) and Fe	NR	NR	NR	Alb: 8.9 Ca: 16.7 Fe: 14.6
Benson-Davies et al. (2013)	NR	NR	NR	NR	NR
Brolin et al. (1994)	• Maladaptive eating behavior leading to excessive calorie intake and inadequate weight loss after RYGB	Milk	76% of RYBG reported no emesis	NR	RYGB. Vit B12: n = 30 Folate: n = 2 Fe: n = 30

Table 2 (continued)

	• Excessive high-calorie liquid intake resulted in < 50% EWL in > 50% of RYGB • High intake of high-calorie salty snack foods after RYGB				With concomitant anemia: $n = 14$
Cano-Valderrama et al. (2017)	NR	Red meat	Vomiting post RYGBP Daily: 1 (1.2%) Often: 5 (6.0%) Rarely: 10 (11.9%) Never: 68 (81.0%)	NR	NR
Chou et al. (2017)	• Lower than recommended intake of protein, CHO, and fiber • Higher intake of fats than recommended	NR	NR	NR	Iron deficiency anemia: 41.2% Secondary hyperparathyroidism: 60.7% No significant changes in Alb, Ca, and cholesterol levels
Coluzzi et al. (2016)	• The absolute amount of fat intake decreased and the reductions were sustained over 24 months. The percentage intake of fat did not change • The absolute amount of CHO decreased by 2/3 at 24/12-post-op compared with pre-op intake • The quality of the CHO changed from high GI to lower GI over 24/12	Untoasted breads Tough meats Fruit with skins Fibrous vegetables	Regurgitation and vomiting At 1 year: "rarely" (in 35%), "never" (in 65%) At 2 years: "rarely" (in 30%), "never" (in 63%), "often" (in 7%)	NR	NR
Coughlin et al. (1983)	64% reported changes in eating behavior: decreases in consumption of "junk" foods, sodas, sweets, and fried food	Milk and milk products	NR	68 32 stopped at 12/12	12/12 post-op M: Hb: 18 g/dL F: Hb: 14 g/dL Hematocrit: 41 All no change to pre-op
da Silva et al. (2016)	• Only 8.8% had good-quality diet based on HEI (score > 100 points). WR had lower HEI score than WM 72.4% vs. 82.6%************ • WR: consumed significantly less fruits daily and marginally less beans and grains. WR: diet pattern may lead to low fiber intake and a high-GI diet, which may compromise weight maintenance. • Both groups consumed less protein than recommended. Protein intake has not been associated with weight regain. Low protein intake is indicator of poor diet quality.	Food intolerance—reported as the most frequent symptom in both groups (in 66.3%)	Patients with weight regain had a greater incidence of weekly vomiting (36.8 vs. 13.3%)****	NR	NR
Dagan et al. (2017)	12/12 post-op: 40.3% achieved an adequate protein intake of ≥ 60 g/day	Satisfaction with eating @ 1 Y: 71.1% reported on good or excellent eating quality	Vomiting: 5.2% Hiccups: 31.2% Heartburn: 24.7%	MV: 79.2 Ca: 64.9 Vit D: 61 Vit B12: 13 Folic acid: 1.3 Fe: 3.9	Fe: 2.6** Ferritin: 3.9 Vit B12: according to lab normal: 1.3 according to <350 pg/mL: 26.3**

Table 2 (continued)

				MVs plus Ca with D and D: @ 1 year: 57.1	B1: 0 Folic acid: 5.3** Vit D: 36.8** Hb: 7.8
de Torres et al. (2012)	The percentage of macronutrients contributing to the total dietary energy intake in comparison to the AMDR: • Protein: adequate in 100% • Fats: excessive for the OG by 43.2% and the NOG by 55.3% (NS) • CHO: adequate distribution was found for 81.8% in the OG and 81.6% in the NOG (NS)	NR	NR	NR	NR
Dias et al. (2006)	NR	NR	Nausea: 15% Vomiting: 15% Hair loss: 8% Other: weakness, abdominal pain, dizziness, and malaise	NR	NR
El Labban et al. (2015)	• No significant difference between RYGB and SG in caloric intake, macronutrient intake, and any of the eight FDC food categories • RYGB: trend for higher daily consumption of bread and cereals, vegetables, protein foods. Significant higher intake of fruit and juices************ • SG: trend to have more sweets and desserts, a higher mean percentage intake of dairy products and vegetables and lower mean percentage intake of bread and cereals, protein foods, fats and oils, and beverages************	NR	Abdominal rumbling, bloating, loss of appetite, belching, fullness, tiredness, and cold sweats (similar in both groups). Heartburn, vomiting**, nausea, regurgitation******, and constipation************** were significantly more frequent in SG. Flatulence, dizziness******, diarrhea, and fast heartbeat************** were significantly more prevalent in.	NR	NR
Ernst et al. (2009)	RYGB patients tend to have a healthier and a more balanced diet than LAGB	NR	NR	NR	NR
Freeman et al.	• The SG group reported consuming significantly less breads and cereals than that the control group • The SG and RYGBP groups reported consuming the least number of extra foods, which was significantly less than the control and the LAGB groups • There was no significant difference in the amount of extras consumed by the control group and the LAGB groups (9.2 and 7.7 serves/day respectively)	NR	The LAGB group reported a higher frequency of vomiting and regurgitation, thus achieving a median score that was significantly lower than SG, RYGB groups***************	NR	NR
Freire et al. (2012)	All groups had an: • Insufficient intake of fruits, vegetables, meats and eggs, dairy products, beans, and carbohydrate • Excessive intake of snack and sweets • The surgery-imposed restrictions and dumping syndrome, frequency of snacks and sweets and oils and fatty foods was lower in patients within the 2 first years after surgery compared to those patients in beyond 2 years post-op.	NR	NR	89	Nutritional deficiencies were not detected

Table 2 (continued)

	These were contributing factors to weight regain				
Gesquiere et al. (2017)	Low dietary intake of micronutrients (Fe, B12, C, Cu, and Zn) and the need for long-term medical nutrition therapy	NR	NR	NR	Anemia: 28.3 Iron deficiency: 34.0 Vit B12: 23.4 Zn: 0.0
Giusti et al.(2016)	The contribution of carbohydrate to total energy intake significantly decreased by 15% after an RYGB, whereas that of fat increased. These changes in dietary macronutrient composition persisted 3 years after surgery	NR	NR	NR	NR
Harbottle (2011)	NR	Food intolerances after 2 years in: 17 (60.7%) Meat: 9 (32.1%) Rice: 4 (14.2%) Pasta: 3 (10.7%)	NR for > 2 years	NR for > 2 years	NR for > 2 years
Kafri et al. (2011) (* data from G2 reported)	In group 2 > 1 year post-op: % of patients reported daily consumption of all food groups: Grains: 75.0, Veg: 87.5, fruits: 79.2, meat: 83.3, dairy: 87.5 % of patients reported daily intake of unhealthy foods: soft drink: 21.7, fast food: 4.2, sweets: 25, salty snacks: 16.7, energy snacks: 25.0	NR	NR	Yes, regularly: 54.2 Yes but not regularly: 25.0 No: 20.8	NR
Kanerva (2017)	NR	NR	NR	NR	NR
Kruseman et al. (2010)	• Dietary intake was suboptimal • Energy intake decreased • Protein (in 50% of patients) and carbohydrate intake was inadequate but fat intake was excessive • The pattern improved little between first year and last visit, which suggests that even broad dietary changes are difficult to achieve in this population	NR	NR	NR	NR
Laurenius et al. (2013)	• The decreased percentage intake from high DED foods was not maintained at 1 or 2 years post surgery compared with baseline intakes • EI from low and medium DED did not change post surgery at any time point • EI from fruits increased significantly and was maintained 1 and 2 years post surgery • Besides substantial reduction in EI and large variation in FW, patients reported decreased DED over 2 years following gastric bypass • Despite lack of association between the reduction in DED and %WL, changes in food choice were overall nutritionally beneficial.	NR	NR	NR	NR
Leiro et al. (2014)	Inadequate dietary intake of Fe, Ca, and vitamin D post RYGB and hence the need for supplementation	Intolerances were reported: 27.8% Milk and dairy: 11.1% Cereal: 11.1% Vegetables: 5.6%	NR	NR	NR
McGrice et al. (2014), McGrice (2012)	• Decreased energy intake but poor eating habits • Inadequate intake of foods from vegetable, dairy, lean meat or alternatives, and wholegrain • Poor micronutrients and protein intake but high fat intake for men and women	NR	NR	NR	NR
		NR	NR	NR	NR

Table 2 (continued)

Miller et al. (2014)	• Reduction of energy post RYGB is from selected food groups. Resulting in micronutrient deficiencies (D, E, C, folate, Ca, Mg, K) • Inadequate intake of fruit, milk/milk products, and whole grains • Low consumption of lean meats and fat-free dairy products indicating more fats from animal sources at 12 months relative to total intake • Low intake of protein (29.4) and fiber (94.1)$^{\Phi\Phi\Phi}$				
Moize et al. (2003)	Protein intake remained inadequate over the entire year and was lower for those with protein intolerance, and this relationship became significant at 12 months************	@ 1 Y: Food intolerance: 10.8%. Protein intolerance: 17%	NR	NR	Anemia: $n = 5$ No other deficiencies
Moize et al. (2013)	• RYGB and SG result in similar weight loss and no difference in terms of dietary intake. Both carry considerable nutritional consequences • The proportion of patients reporting dietary protein intake < 60 g per day for SG was 12.7% and for RYGB was 11.5%	NR	NR	NR	< 10% throughout the study period for: Mg, folate, Vit A, Vit B6, Vit B12, Vit B1: 24/12 Vit D: SG: 66.7, RYGB: 51.5 Elevated PTH: SG: 40.6, RYGB: 40.4 NS between groups
Novais et al. (2012) and Novais et al. (2011)	• The group that lost the least amount of weight (%EWL < 50) had a higher % of fat intake • Calcium and fiber intakes were extremely low in all groups • The proportion of women who ingested enough calcium to meet the AI was less than 20% in all groups • The probability that the fiber intake met requirements was less than 5% • Food restrictions are usually blamed for the low nutrient intakes observed in patients • The women in the group considered unsuccessful consumed foods that contained more fat and less essential nutrients, such as vitamins C and E, folate, and Mg	Red meats, rice, chicken, eggs, pasta, milk, fish, soda, and alcoholic beverages. When the food groups were compared, the groups that present statistical difference over time after surgery were meats, grains, non-starchy vegetables, and legumes	NR	NR	NR
Ortega et al. (2012)	The nutritional composition of the patients' diet is varied and appropriate, with a slight excess of fat and a slight deficit of protein in relation to the nutritional recommendations of the WHO	1/3 reported being intolerant to some food. Red meat: 36.4% Dry paella rice: 35% Sausages: 25% Milk: 7.5%	NR	NR	NR
Reid et al. (2016)	Inadequate protein intake (< 60 g/day) in: 37% (no difference between WR and WM groups)	NR	NR	74%	NR
Silver et al. (2006)	NR	10–50% avoiding some foods: chicken/turkey (3–2.1%), red meats (44–31.4%), bread/cereals (37–26.4%), nuts (20–14.3%), fish (10–7.1%), cheese and other dairy (10–7.1%), milk (46–32.9%), Veg (5–3.6%), fruit (8–5.7%), sweet desserts (86–61.4%), soda (100–71.4%) 6.4% not avoiding food groups	NR	NR	NR
Soares et al. (2014)	Inadequate intake of: • Protein and dairy: in 64.3%	NR	NR	> 1 Y: 25.97	NR

Table 2 (continued)

	• Vegetables: in 81.8% • Fruit: in 55.3% Higher than recommended intake of: • Grains/cereals: in 87.1% • Fats and sugars (% NR)				
Verger et al. (2016)	Inadequate protein intake (< 60 g/day): Total = 61%, RYGB: 64%, SG 58% (NS)	NR	NR	RYGB: 86 SG: 68	High PTH: RYGB: 43 SG: 21 Pre Alb: RYGB: 38, SG: 52 Alb: RYGB: 21, SG: 16
Warde-Kamar et al. (2004)	• Adequate protein (0.8–1.5 g/kg IBW) • Adequate fruit and vegetables (180 kcal—estimated to be equivalent to 2 fruits and 2–3 veg/day)	Sweets: 71%	Vomiting: 62% Self-induced vomiting: 27% Loose stools: 43%	MV: 77 Fe: 68 Ca: 66 B12: 28.6 Folic acid: 27.8 Vit D: 27.4	NR

NR not reported, *FFQ* food frequency questionnaire, *24 h-R* 24 hour recall, *DH* diet history, *FFQ* food frequency quest, *FTQ* food tolerance questionnaire, *FR* food record, *SAQ* self-administered questionnaire, *M* male, *F* female, *SWS* sweets/soda, *MIC* milk and ice cream, *NLS* non-liquid sweets, *HCL* high-calorie liquids, *SG* sleeve gastrectomy, *RYGB* Roux-en-Y gastric bypass, *EWL* excess weight loss, *T* total, *WR* weight regainers, *WM* weight maintainers, *Vit* vitamin, *PTH* parathyroid hormone, *Fe* iron, *Mg* magnesium, *Ca* calcium, *Zn* zinc, *Cu* copper, *Y* year/years, *OG* operated group, *NOG* non-operated group, *ADMR* acceptable macronutrient distribution ranges, *Alb* albumin, *Pre Alb* pre-albumin, *MV* multivitamin and minerals, *NS* no statistical difference, *HEI* Healthy Eating Index, *DED* diet energy density, *FW* food weight, *EI* energy intake, *GI* glycemic index, *WHO* World Health Organization

*$p < 0.005$, statistically different compared to the other group (SG vs. RYGB); **$p < 0.001$, statistically different compared to pre-op; ***$p \leq 0.05$, statistically different from the EER of the respective group; ****$p \leq 0.05$, statistically different to pre-op; *****$p = 0.03$, statistically different, # similar distribution of macronutrients as at baseline; ******$p < 0.01$, statistically different between the groups; *******$p < 0.0001$, statistically different to pre-op; ********$p < 0.05$ compared to the pre-operative period; *********p 0.05 compared to the pre-operative period; **********p 0.003; ***********$p \leq 0.05$, statistically different to the other group (WM); ************$p = 0.005$, statistically different to the other group; *************$p = 0.02$; **************$p < 0.05$, statistically different to the other group; ***************$p < 0.001$, statistically different to the other group

$^{\delta}$ SEM—standard error of mean

$^{\delta\delta}$ MIR: median interquartile range

$^{\delta\delta\delta}$ Insufficient for analysis

$^{\#}$ Below recommendations

$^{\Phi}$ Compared to RDI/RDA/ASMBS recommendations

$^{\Phi\Phi}$ Percentage of participants with values between EAR and RDI

$^{\Phi\Phi\Phi}$ Percentage of participants below the estimated average requirement (EAR)

$^{\Phi\Phi\Phi\Phi}$ There was statistically significant positive correlation between the time of surgery and the ingestion of iron, B12, and D

$^{+}$ Data is presented as percentage of daily energy intake mean ± SD (range) unless otherwise specified

$^{++}$ Percentage of patients with biochemical deficiencies unless otherwise specified

Table 3 Meeting macronutrient requirements compared to recommendations

Percentage of macronutrient contribution to energy compared to recommendations			
Study	20–25% of total energy intake from protein	40–45% of total energy intake from carbohydrates	≤ 35% of total energy intake from fat
Bavaresco at al. (2010)	✗	↑	✓
Benson-Davies et al. (2013)	✗	✓	↑
Brolin et al. (1994)	✗	↑	✓
Chou et al. (2017)	✓	✓	↑
Coluzzi et al. (2016)	↑	✓	✓
Coughlin et al. (1983)	✓	✓	↑
Dagan et al. (2017)	✗	✓	↑
da Silva et al. (2016)	✗	↑	✓
de Torres et al. (2012)	✓	✓	↑
El Labban et al. (2015)	✗	✓	↑
Freire et al. (2012)	✗	↑	✓
Kruseman et al. (2010)	✗	✓	↑
Laurenius et al. (2013)	NA	NA	↑
McGrice, et al. (2012), McGrice (2014)	✓	✓	↑
Miller et al. (2014)	✓	✓	↑
Moize et al. (2013)	RYGB: ✗ SG: ✗	RYGB: ✓ SG: ✓	RYGB: ↑ SG: ↑
Moize et al. (2003)	✓	↑	✓
Novais et al. (2012) and Novais et al. (2011)	< 50% EWL: ✗ 5 0–75% EWL: ✗ > 75% EWL: ✗	< 50% EWL: ↑ 50–75% EWL: ↑ > 75% EWL: ↑	< 50% EWL: ↑ 50–75% EWL: ✓ > 75% EWL: ✓
Ortega et al. (2012)	✗	↑	↑
Reid et al. (2016)	✗	✓	↑
Verger et al. (2016)	RYGB: ✗ SG: ✗	RYGB: ✓ SG: ✓	RYGB: ↑ SG: ↑
Warde-Kamar et al. (2004)	✗	✓	✓
Total and Macronutrient intake assessment	Protein intake: ✓: 6 ↑: 1 ✗: 14	CHO intake: ✓: 14 ↑: 7 ✗: 0	Fat intake: ✓: 8 ↑: 14 ✗: 0

✓: Meeting requirements, ↑: Excessive compared to requirements, ✗: Below requirements

suggesting an improvement in food tolerance and hence quality of nutrition over time. Freeman et al. [6] assessed food tolerance and diet quality in a control group and following LAGB, SG, and RYGB. They found a superior food tolerance score in the control and the SG group followed by the RYGB compared to the LAGB ($p < 0.001$).

Gastrointestinal Symptoms and Other Side Effects

Gastrointestinal side effects were reported by several studies [6, 9, 20, 24, 28, 32, 37, 38] and these included vomiting, nausea, reflux, regurgitation, hiccups, flatulence, dumping syndrome (fast heartbeat and diarrhea after eating), altered bowel motion (diarrhea and constipation), and, to a lesser extent, weakness, dizziness, abdominal pain, and general malaise. These were inconsistent, for example, vomiting reported from as low as 5.2% of patients [20] to as high as 67% [37]. In general, beyond 1-year post-operative, these symptoms were present in < 30% of patients following SG and RYGB. Compared to other procedures, in a small study, patients following LAGB reported a significant higher incidence of vomiting and regurgitation compared to RYGB and SG [6].

Adherence to Supplementation

Only a small number of studies reported on adherence to vitamin and mineral supplementation [10–12, 20, 30, 36, 37]. In general, they showed a better adherence to the multivitamin supplement compared to other specific supplements such as calcium, iron, B12, and vitamin D [37]. Furthermore, the adherence to taking supplements decreased over time with 20–32% of patients reporting stopping or never taking their recommended supplements by 1 year post-operative [10, 36, 42].

Discussion

This systematic review is the first to report on the available evidence on diet quality beyond 1 year following the current main bariatric procedures (SG, RYGB, and LAGB). The results suggest that despite the benefits of the procedure, dietary intake after a year or more remained unbalanced, with an excessive intake of fats and an inadequate intake of protein. There was evidence of nutrient imbalances before and after surgery, inconsistent adherence to supplements, and poor long-term follow-up. To maintain the benefits of surgery and achieve optimal nutritional status, changes in eating habits and adherence to nutritional supplements as well as long-term nutritional assessment and counseling by a qualified dietitian are recommended.

The main surgical intervention in most studies was RYGB ($n = 20$), with less data available for LAGB [3, 27] and SG [10, 20, 28, 29]. A few studies reported on combinations of procedures [4, 6, 9, 14, 32, 34]. This highlights the long history and international preference for the RYGB as the surgical choice for obesity management. LAGB has been performed for over 20 years; however, very few studies have studied its nutritional implications and despite the international rise in popularity of the SG [44], long-term nutritional and dietary information following this procedure is limited. We did not identify any studies on one anastomosis gastric bypass (OAGB) in this review. Hence, there is limited information on nutritional consequences following SG and LAGB and a gap in the literature on nutritional impact following OAGB.

The review exposed evidence of a significant weight loss following all bariatric procedures. The maximum weight loss appeared in the first year, followed by a period of weight stabilization and then subsequent weight regains [5, 11, 14, 29, 42]. Over 60% of patients appeared able to achieve a weight loss in excess of 50%, which is considered a successful result [11, 20, 37]. In those experiencing weight regain however, poor diet quality, excessive intake of carbohydrates, sweets, fats, and alcohol, and inadequate follow-up appeared to be contributing factors [11, 25, 33, 38, 42]. RYGB and SG were found to produce similar weight loss and nutritional consequences [30–32], but this was better than for LAGB [6, 34]. The LAGB is a purely restrictive procedure with no changes to the gastrointestinal peptides and hence may have a lesser impact on hunger and satiety as RYGB and SG [45]. Furthermore to date, LAGB has not been shown to affect energy metabolism, and hence, patients may still be hungry and dissatisfied with the volume of food that is tolerated. It is challenging to find the right volume of fluid adjustment for each patient. In fact, the fluid volume level needed to achieve adequate restriction, and hence, weight loss may result in obstructive symptoms and hence poor diet quality. This leads to reduced protein and micronutrient intake as well as maladaptive eating habits and hence inadequate weight loss [3, 6, 27]. These factors may explain the reduction in the number of LAGB being performed [44].

Bariatric procedures aim to reduce the volume of food consumed and consequently dietary energy. In patients presenting for bariatric surgery, pre-operative energy intake is reported to be excessive of energy requirements, albeit under-reported [30]. We found a large range in reported pre-operative energy intake which may reflect the variation in the dietary assessment tools in addition to the expected level of under-reporting [46]. The methodological problem may persist post-operatively, influencing reported outcomes. Our review was consistent with other studies in showing reductions in energy intake following RYGB and SG procedures, but with a gradual increase over the years [2, 20, 39]. Our data on LAGB was very limited, with only one article reported energy intake following this procedure [3]. The substantial variation reported here (4894 ± 2360 kJ; 1137 to 13,176 kJ (270–3137 kcal)) related to the nature of the LAGB and the need for an optimal adjustment of the band fluid levels. Over adjustment may adversely affect the adequacy of the diet leading to a lower energy intake than recommended for the general and post-bariatric population. Conversely, under adjustment may allow excessive intake in some patients contributing to suboptimal weight loss.

Our review found that patients presenting for bariatric surgery appeared to have adequate dietary protein intake, however were consuming a higher intake of fat compared to recommendations [43]. The details on types of fat were not provided [2, 4, 5, 14, 20, 28, 30, 31, 36, 40, 41], limiting further conclusions. Excessive energy intake from fats may be a contributing factor to the chronic condition of obesity and comorbidities such as coronary heart disease and hyperlipidemia. From a food perspective, two studies reported a low intake of dairy, fruit, vegetables, and whole grains compared to recommendations [30, 41]. Fiber intake was also below the recommendation of > 25 g/day for women and > 30 g/day for men [43], although fiber intake was only reported in three studies [2, 28, 41]. Regardless of the nutritional variable examined, there was consistent reporting of poor diet quality in patients with obesity and those presenting for weight loss surgery, which is consistent with other similar studies [47]. However, it should be noted that this pattern of dietary intake is very similar to that of the general population. National nutrition surveys report a suboptimal intake of fruit, vegetables, and high-fiber grains and an excessive intake of discretionary and processed foods. The western diet appears to continue to contribute the condition of obesity and related illnesses.

Overall, the results of this review suggest that the diet quality of post-bariatric surgical patients is unbalanced (Table 3). Only two studies were used as references to assess post-operative diet adequacy [14, 15]. The first developed a bariatric specific dietary and nutritional recommendations and presented these as a “bariatric food pyramid” in assisting patient education [15]. The second study proposed an optimal diet composition for better long-term weight loss [14]. Twelve studies reported an inadequate intake of protein and 13 studies reported an excessive intake of fats. The situation for carbohydrate intake was less consistent, reported as adequate in 14 studies and excessive in seven studies. Hence, it seems than an unbalanced dietary pattern may contribute to suboptimal weight loss, weight regains, and hence poor health outcomes in the long term [3, 12, 25, 38, 42].

Due to the expected restriction and reductive nature of bariatric procedures, it may be inappropriate for post-operative patients to be expected to meet the same recommendations for food volume as the general population. National dietary guidelines [43] are appropriate for a relatively healthy population and are not designed to meet the needs of the post-operative patient following significant weight loss. Bariatric patients suffer from the chronic and pro-inflammatory condition of obesity and its related comorbidities (diabetes, insulin resistance, fatty liver) [1]. They are also expected to experience a significant weight loss and change in metabolism after surgery and need specific dietary guidelines for the long term.

From a micronutrient perspective, intakes following bariatric surgery were assessed in several studies and compared to specific nutrient reference values of the relevant country. These results suggested inadequate dietary intakes of several micronutrients such as vitamins D, E, C, folate, B12, B1, copper, zinc, calcium, and iron [2, 7, 17, 21, 23, 24, 27, 31, 41]. The reasons for these findings were multifactorial and included a reduced volume of food intake [7], intolerance to certain food groups [6, 17, 27], and consuming an unbalanced diet by choice, with low intakes of associated sources of micronutrients [41]. This reinforces the need for adherence to vitamin and mineral supplementation ongoing nutritional assessment and counseling by a qualified dietitian as well as long-term follow-up as per bariatric guideline [13, 48, 49].

Food intolerances are common following bariatric surgery, however are inconsistently defined [6, 9, 10, 20, 22, 23, 26, 28, 33, 35–37]. Some of these intolerances observed could be beneficial as they may deter patients from choosing energy-dense food items through a negative feedback mechanism such as dumping syndrome, while others such as problems eating meat and dairy could be detrimental to the quality of the diet of the patient. Intolerances to breads and cereals, meat, and meat alternatives have been shown to be associated with reduced intake of these food groups [6]. In addition, other studies show a lower protein intake in those with protein intolerance [26]. The most reported food intolerances reported were red/tough meat, rice, bread, pasta, dairy, and fibrous vegetables and skin of fruit to a lesser extent. Some of these intolerances could persist up to 3 years following surgery but in general, it appears that food tolerance improves over time following RYGB and SG surgery [9]. This suggests an adaptation of the gastrointestinal system over time following these procedures [8].

Another nutritional aspect is changes in taste and food preferences, which was found in studies following RYGB [50, 51] where there was a tendency to dislike sweet, fatty, and calorie-dense foods. However, whether taste changes are sustained long term has not been fully evaluated. For example, one study on SG patients [28] found after an initial reduced interest in sweets, this was only sustained by 25% at 12 months and 23% at 24 months ($p = 0.001$). An increased interest in sweet foods can contribute to the excessive intake of sweets, increased energy intake, and leading to an unbalanced diet and weight regain [11]. This highlights the importance of improving eating habits in the first year following surgery and not relying solely on the initial benefits of the operation.

Our review did not specifically search for side effects of bariatric surgical procedures but these were noted when studies reported post-operative side effects [6, 9, 20, 24, 28, 32, 37, 38]. The reductive and restrictive nature of bariatric procedures contributes to the expected gastrointestinal side effects such as vomiting, nausea, reflux, regurgitation, hiccups, and constipation. These symptoms may be more prevalent and last longer following LAGB due to the presence of the foreign body and the need for optimal adjustment of the band alongside changes in eating habits. This may affect the quality of diet and digestion more than other procedures [6, 8, 34]. The response to LAGB surgery varies, so regular multidisciplinary monitoring, optimal fluid level adjustment of the band, and long-term nutritional assessment are recommended in this population. To avoid complications and nutritional inadequacies, follow-up screening should include early detection of non-responders to this procedure, including those with significant gastrointestinal symptoms, dietary intolerances, and for which an optimal band adjustment volume cannot be found, and may involve revisional or reversal procedures.

Following RYGB and SG, the change in transient time and in particular the re-routing of ingested food through the gastrointestinal system in the RYGB may lead to dumping syndrome and altered bowel motion (diarrhea and constipation) [32]. For example, in one study comparing outcomes for SG and RYGB patients, the SG group reported experiencing more heartburn and vomiting ($p < 0.001$), regurgitation and nausea ($p < 0.01$), and constipation ($p < 0.05$) and the RYGB group reported experiencing more flatulence, dizziness ($p < 0.001$), diarrhea, and fast heartbeat after eating ($p < 0.5$) [32]. These symptoms were more pronounced following a long-limb RYGB [52]. Assessment, prevention, and management of these gastrointestinal symptoms are an important part of the post-operative care. These symptoms, if unmanaged, may not only impact the diet quality but also affect the quality of life of patients. Other reported symptoms such as hair loss, weakness, and general malaise may be due to suboptimal protein intake shown in this population [26]; however, these areas are not well evaluated by current literature.

Overall, due to the physiological adaptation of the gastrointestinal system as well as cognitive adaptation of patients, these symptoms can improve with time; however, some patients may have persisting symptoms that could affect diet quality long-term.

Finally, a major negative clinical outcome is micronutrient deficiency and related conditions. These have been reported before and after all bariatric procedures [4, 27, 53]. We found the most commonly reported pre-operative nutritional deficiencies to relate to vitamin D status, hyper-parathyroid conditions, and low hemoglobin levels. This was consistent with the findings of other studies [53, 54]. The literature attributes the pre-operative nutritional deficiencies in this population to poor eating habits, chronic dieting, and the inflammatory nature of chronic obesity [53]. Post-operatively, reduced oral intake, food intolerances, changes in taste, and dietary preferences as well as malabsorption related to some procedures contributed to nutritional deficiencies [48]. Nutrient digestion and absorption occurs in the stomach and small bowel and this is affected in both RYGB and SG. A portion of stomach and the proximal small bowel is bypassed in RYGB. Varying length of the bypassed small intestine as well as the patient's individual response to surgery further affect absorption of nutrients especially vitamins and minerals, with macronutrient malabsorption being quite uncommon following the standard RYGB [52]. In SG, a portion of stomach is removed and hence reducing the gastric acid content, resulting in maldigestion and subsequently malabsorption of nutrients. Because of this, similar nutrient supplements are also recommended for the SG patients [49].

The studies that reported on adherence to vitamin and mineral supplementation showed a decrease in adherence to taking supplements over time [10, 36, 42]. This in combination with lower quality diet can potentially lead to significant nutritional deficiencies. Furthermore, as lost to follow-up increases with time from surgery, so does the potential detection and treatment of these deficiencies. As a result, weight regain and poor nutritional status may increase over time.

There are several limitations to this review. Firstly, the diet assessment methodologies used in the included studies were generally self-administered and retrospective and hence carry the limitation of recall bias and under-reporting. Secondly, in the absence of specific dietary guidelines for this population, best level evidence was used when interpreting the diet adequacy of the reported studies. Finally, we limited our search to published articles and those in English language only, and hence, potentially relevant articles may have been overlooked.

This review highlights the limitation of current studies reporting on dietary intake following bariatric surgery. The studies are generally from a single center, observational in nature, and have a weak to moderate quality with low-level study designs. Furthermore, the studies are relying on self-reported, retrospective dietary data collection and hence carry the risk of under-reporting, as reported by several authors [30]. These study limitations have been cited by other authors reviewing the literature in this field [47, 55], reinforcing the need for multicenter, larger, and more consistent study designs. The majority of participants were female, and hence, the findings cannot be extrapolated to all bariatric patients. This is consistent with the majority of studies in which patients seeking bariatric surgery are generally females. This may impact the data on dietary intake due to food preferences, some studies showing that females tended to eat less protein-rich foods and more carbohydrate-rich foods [12].

With growing chronic condition of obesity and its surgical treatment options, this review highlights a need for high-quality nutrition studies in developing long-term dietary recommendations for this population. Our review suggests that bariatric surgery results in a significant reduction in energy intake, subsequent weight loss, and hence improvements in health outcomes. However, the diet composition of bariatric patients is suboptimal, the adherence to vitamin and mineral supplementation inconsistent, and the long-term follow-up poor. To maintain weight loss and optimal nutrition after surgery, change in eating habits, lifestyle change, and adherence and review of nutritional status by a qualified dietitian are recommended. Further longer term and more robust studies are needed to assist clinicians in providing nutritional care for patients following their weight loss treatment.

Compliance with Ethical Standards

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

Ethical Approval and Informed Consent Not applicable to the study design.

Appendix

The search terms used in Scopus were as follows:

((TITLE-ABS-KEY ("bariatric surgery") OR TITLE-ABS-KEY ("sleeve gastrectomy") OR TITLE-ABS-KEY ("gastric banding") OR TITLE-ABS-KEY ("gastric bypass") OR TITLE-ABS-KEY ("roux-en-y gastric bypass"))) AND ((TITLE-ABS-KEY ("meal pattern") OR TITLE-ABS-KEY ("diet quality") OR TITLE-ABS-KEY (diet*) OR TITLE-ABS-KEY ("food groups") OR TITLE-ABS-KEY (nutri*))) AND (LIMIT TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "re")) AND (LIMIT-TO (SUBJAREA, "MEDI") OR LIMIT-TO (SUBJAREA, "NURS") OR LIMIT-TO (SUBJAREA, "NEUR") OR LIMIT-TO (SUBJAREA, "PSYC") OR LIMIT-TO (SUBJAREA, "HEAL") OR LIMIT-TO (SUBJAREA, "SOCI")) AND (LIMIT-TO (LANGUAGE, "English")) AND (EXCLUDE (EXACTKEYWORD, "Animals") OR EXCLUDE (EXACTKEYWORD, "Animal Experiment") OR EXCLUDE (EXACTKEYWORD, "Animal") OR EXCLUDE (EXACTKEYWORD, "Child") OR EXCLUDE (EXACTKEYWORD, "Rat") OR EXCLUDE (EXACTKEYWORD, "Animal Model")) AND (EXCLUDE (EXACTKEYWORD, "Adolescent") OR EXCLUDE (EXACTKEYWORD, "Nonhuman") OR EXCLUDE (EXACTKEYWORD, "Sibutramine") OR EXCLUDE (EXACTKEYWORD, "Unclassified Drug") OR EXCLUDE (EXACTKEYWORD, "Pregnancy") OR EXCLUDE (EXACTKEYWORD, "Adipose Tissue") OR EXCLUDE (EXACTKEYWORD, "Antiobesity Agent"))

References

1. Sjöström L, Lindroos A-K, Peltonen M, et al. Lifestyle, diabetes, and cardiovascular risk factors 10 years after bariatric surgery. N Engl J Med. 2004;351(26):2683–93.

2. Bavaresco M, Paganini S, Lima TP, et al. Nutritional course of patients submitted to bariatric surgery. Obes Surg. 2010;20(6): 716–21. https://doi.org/10.1007/s11695-008-9721-6.
3. McGrice MA, Porter JA. What are gastric banding patients eating one year post-surgery? Obes Surg. 2012;22(12):1855–8. https://doi.org/10.1007/s11695-012-0741-x.
4. Brolin RE, Robertson LB, Kenler HA, et al. Weight loss and dietary intake after vertical banded gastroplasty and Roux-en-Y gastric bypass. Ann Surg. 1994;220(6):782–90.
5. Kruseman M, Leimgruber A, Zumbach F, et al. Dietary, weight, and psychological changes among patients with obesity, 8 years after gastric bypass. Journal of the American Dietetic Association. 2010;110(4):527–34. https://doi.org/10.1016/j.jada.2009.12.028. Language: English. Entry Date: 20100423. Revision Date: 20150819. Publication Type: Journal Article
6. Freeman RA, Overs SE, Zarshenas N, et al. Food tolerance and diet quality following adjustable gastric banding, sleeve gastrectomy and Roux-en-Y gastric bypass. Obes Res Clin Pract. 2014;8(2): e115–200. https://doi.org/10.1016/j.orcp.2013.02.002.
7. Gesquiere I, Foulon V, Augustijns P, et al. Micronutrient intake, from diet and supplements, and association with status markers in pre- and post-RYGB patients. Clinical Nutrition (Edinburgh, Scotland). 2017;36(4):1175–81. https://doi.org/10.1016/j.clnu.2016.08.009.
8. Suter M, Calmes JM, Paroz A, et al. A new questionnaire for quick assessment of food tolerance after bariatric surgery. Obes Surg. 2007;17:2–8.
9. Cano-Valderrama O, Sánchez-Pernaute A, Rubio-Herrera MA, et al. Long-term food tolerance after bariatric surgery: comparison of three different surgical techniques. Obes Surg. 2017;27(11): 2868–72. https://doi.org/10.1007/s11695-017-2703-9.
10. Kafri N, Valfer R, Nativ O, et al. Health behavior, food tolerance, and satisfaction after laparoscopic sleeve gastrectomy. Surgery for obesity and related diseases : official journal of the American Society for Bariatric Surgery. 2011;7(1):82–8. https://doi.org/10.1016/j.soard.2010.09.016.
11. Freire RH, Borges MC, Alvarez-Leite JI, et al. Food quality, physical activity, and nutritional follow-up as determinant of weight regain after Roux-en-Y gastric bypass. Nutrition (Burbank, Los Angeles County, Calif). 2012;28(1):53–8. https://doi.org/10.1016/j.nut.2011.01.011.
12. Soares FL, Bissoni de Sousa L, Corradi-Perini C, et al. Food quality in the late postoperative period of bariatric surgery: an evaluation using the bariatric food pyramid. Obes Surg. 2014;24(9):1481–6. https://doi.org/10.1007/s11695-014-1198-x.
13. Aills L, Blankenship J, Buffington C, et al. Bariatric nutrition: suggestions for the surgical weight loss patient. Surg Obes Relat Dis. 2008;4(5):S73–S108.
14. Kanerva N, Larsson I, Peltonen M, et al. Changes in total energy intake and macronutrient composition after bariatric surgery predict long-term weight outcome: findings from the Swedish Obese Subjects (SOS) study. Am J Clin Nutr. 2017;106(1):136–45. https://doi.org/10.3945/ajcn.116.149112.
15. Moizé V, Pi-Sunyer X, Mochari H, et al. Nutritional pyramid for post-gastric bypass patients. Obes Surg. 2010;20:1133–41.
16. Moher D, Liberati A, Tetzlaff J, et al. Preferred reporting items for systematic reviews and metaanalyses: the PRISMA statement. BMJ (Clinical Research ed). 2009;339:b2535. https://doi.org/10.1136/bmj.b2535.
17. de Torres Rossi RG, Dos Santos MT, de Souza FI, et al. Nutrient intake of women 3 years after Roux-en-Y gastric bypass surgery. Obes Surg. 2012;22(10):1548–53. Epub 2012/06/13. https://doi.org/10.1007/s11695-012-0688-y.
18. ADA. American Dietetics Association. Evidence analysis manual: steps in ADA evidence analysis process. Chicago: Scientific Affairs and Research; 2010. p. 43–8.
19. NHMRC. National Health and Medical Research Council. Levels of evidence and grades for recommendations for developers of guidelines. Commonwealth of Australia.: Canberra; 2009.
20. Dagan S, Keidar A, Raziel A, et al. Do bariatric patients follow dietary and lifestyle recommendations during the first postoperative year? Obesity Surgery. 2017;27(9):2258–71. https://doi.org/10.1007/s11695-017-2633-6.
21. Novais PF, Rasera Jr I, Leite CV, et al. Food intake in women two years or more after bariatric surgery meets adequate intake requirements. Nutrition Research. 2012;32(5):335–41. https://doi.org/10.1016/j.nutres.2012.03.016.
22. Novais PF, Junior IR, Shiraga EC, et al. Food aversions in women during the 2 years after Roux-en-Y gastric bypass. Obes Surg. 2011;21(12):1921–7. https://doi.org/10.1007/s11695-010-0342-5.
23. Leiro LS, Melendez-Araújo MS. Diet micronutrient adequacy of women after 1 year of gastric bypass. Arquivos Brasileiros de Cirurgia Digestiva. 2014;27 Suppl 1:21–5.
24. Dias MC, Ribeiro AG, Scabim VM, et al. Dietary intake of female bariatric patients after anti-obesity gastroplasty. Clinics. 2006;61(2):93–8.
25. Benson-Davies S, Davies ML, Kattelmann K. Food preferences in patients after Roux-en Y gastric bypass surgery: a pilot study examining eating behaviors and weight maintenance. Topics in Clinical Nutrition. 2013;28(1):8–14. Language: English. Entry Date: 20130614. Revision Date: 20150818. Publication Type: Journal Article
26. Moize V, Geliebter A, Gluck ME, et al. Obese patients have inadequate protein intake related to protein intolerance up to 1 year following Roux-en-Y gastric bypass. Obes Surg. 2003;13(1):23–8.
27. McGrice MA, Porter JA. The micronutrient intake profile of a multicentre cohort of Australian LAGB patients. Obes Surg. 2014;24(3):400–4. https://doi.org/10.1007/s11695-013-1101-1.
28. Coluzzi I, Raparelli L, Guarnacci L, et al. Food intake and changes in eating behavior after laparoscopic sleeve gastrectomy. Obes Surg. 2016;26(9):2059–67. https://doi.org/10.1007/s11695-015-2043-6.
29. Chou JJ, Lee WJ, Almalki O, et al. Dietary intake and weight changes 5 years after laparoscopic sleeve gastrectomy. Obes Surg. 2017;27(12):3240–6. https://doi.org/10.1007/s11695-017-2765-8.
30. Verger EO, Aron-Wisnewsky J, Dao MC, et al. Micronutrient and protein deficiencies after gastric bypass and sleeve gastrectomy: a 1-year follow-up. Obes Surg. 2016;26(4):785–96. https://doi.org/10.1007/s11695-015-1803-7.
31. Moizé V, Andreu A, Flores L, et al. Long-term dietary intake and nutritional deficiencies following sleeve gastrectomy or Roux-en-Y gastric bypass in a Mediterranean population. Journal of the Academy of Nutrition & Dietetics. 2013;113(3):400–10. https://doi.org/10.1016/j.jand.2012.11.017. Language: English. Entry Date: 20130627. Revision Date: 20150711. Publication Type: Journal Article
32. El Labban S, Safadi B, Olabi A. The effect of Roux-en-Y gastric bypass and sleeve gastrectomy surgery on dietary intake, food preferences, and gastrointestinal symptoms in post-surgical morbidly obese Lebanese subjects: a cross-sectional pilot study. Obesity surgery. 2015;25(12 // (AUB) *American University of Beirut*): 2393–9. https://doi.org/10.1007/s11695-015-1713-8.
33. Harbottle L. Audit of nutritional and dietary outcomes of bariatric surgery patients. Obesity Reviews: An Official Journal Of The International Association For The Study Of Obesity. 2011;12(3): 198–204. https://doi.org/10.1111/j.1467-789X.2010.00737.x.
34. Ernst B, Thurnheer M, Wilms B, et al. Differential changes in dietary habits after gastric bypass versus gastric banding operations. Obesity Surgery. 2009;19(3):274–80.
35. Ortega J, Ortega-Evangelio G, Cassinello N, et al. What are obese patients able to eat after Roux-en-Y gastric bypass? Obesity facts. 2012;5(3):339–48. https://doi.org/10.1159/000339769.

36. Coughlin K, Bell RM, Bivins BA, et al. Preoperative and postoperative assessment of nutrient intakes in patients who have undergone gastric bypass surgery. Archives of Surgery (Chicago, Ill: 1960). 1983;118(7):813–6.
37. Warde-Kamar J, Rogers M, Flancbaum L, et al. Calorie intake and meal patterns up to 4 years after Roux-en-Y gastric bypass surgery. Obes Surg. 2004;14(8):1070–9. https://doi.org/10.1381/0960892041975668.
38. da Silva FB, Gomes DL, de Carvalho KM. Poor diet quality and postoperative time are independent risk factors for weight regain after Roux-en-Y gastric bypass. Nutrition (Burbank, Los Angeles County, Calif). 2016;32(11–12):1250–3. https://doi.org/10.1016/j.nut.2016.01.018.
39. Giusti V, Theytaz F, Di Vetta V, et al. Energy and macronutrient intake after gastric bypass for morbid obesity: a 3-y observational study focused on protein consumption. American Journal of Clinical Nutrition. 2016;103(1):18–24. https://doi.org/10.3945/ajcn.115.111732. Language: English. Entry Date: 20160115. Revision Date: 20160429. Publication Type: Article.
40. Laurenius A, Larsson I, Melanson KJ, et al. Decreased energy density and changes in food selection following Roux-en-Y gastric bypass. Eur J Clin Nutr. 2013;67(2):168–73. https://doi.org/10.1038/ejcn.2012.208.
41. Miller GD, Norris A, Fernandez A. Changes in nutrients and food groups intake following laparoscopic Roux-en-Y gastric bypass (RYGB). Obes Surg. 2014;24(11):1926–32. https://doi.org/10.1007/s11695-014-1259-1.
42. Reid RE, Oparina E, Plourde H, et al. Energy intake and food habits between weight maintainers and regainers, five years after Roux-en-Y gastric bypass. Canadian journal of dietetic practice and research. 2016;77(4):195–8. https://doi.org/10.3148/cjdpr-2016-013. Language: English. Entry Date: 20161121. Revision Date: 20161129. Publication Type: Article
43. NHMRC. Natonal Health and Medical Research Council. Departmnet of Health and Aging. Australian dietary guidelines: eat for health. 2013:https://www.eatforhealth.gov.au/sites/default/files/files/the_guidelines/n55_australian_dietary_guidelines.pdf.
44. Angarisani L, Santonicola A, Iovino P, et al. Bariatric surgery worldwide 2013. Obes Surg. 2015;25:1822–32.
45. Colquitt JL, Pickett K, Loveman E, et al. Surgery for weight loss in adults. Cochrane Database Syst Rev. 2014;8:1–244.
46. Goris A, Westerterp-Plantenga M, Westerterp KR. Undereating and underrecording of habitual food intake in obese men: selective underreporting of fat intake. Am J Clin Nutr. 2000;17:130–4.
47. Harbury CM, Verbruggen EE, Callister R, et al. What do individuals with morbid obesity report as a usual dietary intake? A narrative review of available evidence. Clin Nutr. 2016;13:15–22.
48. Mechanick JI, Youdim A, Jones DB, et al. Clinical practice guidelines for the perioperative nutritional, metabolic, and nonsurgical support of the bariatric surgery patient—2013 update: cosponsored by American Association of Clinical Endocrinologists, the Obesity Society, and American Society for Metabolic & Bariatric Surgery. Endocrine Practice. 2013;19(2):337–72. https://doi.org/10.4158/ep12437.Gl.
49. Parrott J, Frank L, Rabena R, et al. American Society for Metabolic and Bariatric Surgery integrated health nutritional guidelines for the surgical weight loss patient. Surgery for Obesity and Related Diseases. 2016;13:727–41.
50. le Roux CW, Bueter M, Theis N, et al. Gastric bypass reduces fat intake and preference. American Journal Of Physiology Regulatory, Integrative and Comparative Physiology. 2011;301(4):R1057–66. https://doi.org/10.1152/ajpregu.00139.2011.
51. Miras AD, Jackson RN, Jackson SN, et al. Gastric bypass surgery for obesity decreases the reward value of a sweet-fat stimulus as assessed in a progressive ratio task. American Journal of Clinical Nutrition. 2012;96(3):467–73. https://doi.org/10.3945/ajcn.112.036921.
52. Odstrcil EA, Martinez JG, Santa Ana CA, et al. The contribution of malabsorption to the reduction in net energy absorption after long-limb Roux-en-Y gastric bypass. American Journal of Clinical Nutrition. 2010;92(4):704–13. https://doi.org/10.3945/ajcn.2010.29870. Language: English. Entry Date: 20101119. Revision Date: 20151008. Publication Type: Journal Article.
53. Zarshenas N, Nacher M, Loi KW, et al. Investigating nutritional deficiencies in a group of patients 3 years post laparoscopic sleeve gastrectomy. Obes Surg. 2016;26(12):2936–43.
54. Toh SY, Zarshenas N, Jorgensen J. Prevalence of nutrient deficiencies in bariatric patients. Nutrition (Burbank, Los Angeles County, Calif). 2009;25(11–12):1150–6. https://doi.org/10.1016/j.nut.2009.03.012.
55. Dodsworth A, Warren-Forward H, Baines S. A systematic review of dietary intake after laparoscopic adjustable gastric banding. Journal Of Human Nutrition And Dietetics. 2011;24:327–41.