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ORIGINAL ARTICLE

Nutrient Intake and Deficiency of Patients 1 Year After Bariatric Surgery: Tehran Obesity Treatment Study (TOTS)

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Abstract

Purpose This study aimed at assessing nutrient adequacy after 1 year in patients who had undergone gastric bypass (GB) surgery or sleeve gastrectomy (SG) and to investigate the association of nutrient adequacy with anthropometric indices.

Methods A total of 180 severely obese patients (BMI ≥ 35 kg/m^2) were selected among the participants of Tehran Obesity Treatment Study. Nutritional assessments were performed over 3 days of 24-h dietary recall. To evaluate the nutrient adequacy ratio (NAR), the subject's nutrient intake was divided by the dietary reference intakes. The mean adequacy ratio (MAR) was also determined as the sum of NARs divided by the number of involved nutrients ($n = 11$).

Results The mean age of SG (67%) and GB (32%) patients was 39.2 ± 12 and 41.4 ± 10 years, respectively. SG patients had more postoperative fat-free mass (52.0 ± 12 kg) than GB patients (49.7 ± 8 kg) ($P < 0.05$). The most common postoperative serum nutrient deficiencies were related to vitamin B12 (30%), ferritin (19%), and 25-hydroxyvitamin D (16.2%). Moreover, high inadequacy of protein (> 80%) and total fat (> 70%) intake was reported. The MAR score showed that almost 45% of the patients had possibly adequate intakes of some nutrients. The adequacy of nutrients was positively associated with fat-free mass (β = 8.67, $P < 0.05$).

Conclusion These findings revealed that patients had inadequate nutrient intakes 1 year after bariatric surgery, which was accompanied by serum nutritional deficiencies. Compared to GB patients, SG patients had a better body composition. Overall, compliance of patients with dietary guidelines and supplementations needs to be carefully monitored in the postoperative period.

Keywords Bariatric surgery · Sleeve gastrectomy · Gastric bypass · Nutrient adequacy

Introduction

Bariatric surgery is a useful treatment for sustainable weight loss in individuals with severe obesity (grades II and III). This type of surgery can also resolve comorbidities associated with obesity, including type 2 diabetes, hypertension, dyslipidemia, and obstructive sleep apnea.[1–3] The beneficial effects of bariatric surgery are attributed to alterations in the anatomy and

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motility of the gastrointestinal tract, dietary behaviors, gut hormones, bile acid flow, and gut microbiota.[3]

Among various techniques of bariatric surgery, gastric bypass (GB) and sleeve gastrectomy (SG) were the most frequently performed procedures worldwide in 2014.[4,5] However, bariatric surgery exposes the patients to some risks, which need to be considered.[5] These risks include the recurrence of obesity or associated comorbidities and nutritional deficiency due to the reduction of bioavailability and nutrient digestion. Therefore, long-term follow-up is of major concern for identifying the risks as early as possible.[3]

Energy-restricted diets, besides macronutrient imbalance and micronutrient deficiencies, can lead to nutritional complications, such as protein malnutrition, anemia, and osteoporosis, as most obese patients have nutritional deficiencies prior to surgery due to unbalanced diets.[6,7] In a recent study, it was found that the mean daily micronutrient intakes of patients were lower than the recommendations 5 years after GB and SG.[8] In this study, most patients had iron, vitamin B12, folic acid, and vitamin D deficiencies.[6,9] Research suggests that consumption of sufficient amounts of heme iron in meat and vitamin C, along with compliance with iron supplementation, can prevent iron deficiency following GB.[1]

Currently, there is limited information about the nutritional intake, nutrient adequacy, and weight maintenance of patients after SG and GB surgeries. The aim of this study was to assess the adequacy of dietary nutrients based on the current guidelines after 1-year follow-up of patients who had undergone SG and GB surgeries and to investigate the association of nutrient adequacy with anthropometric indices.

Materials and Methods

Study Design and Sample

This study was conducted within the framework of Tehran Obesity Treatment Study (TOTS), which is an ongoing single-institution, prospective study initiated in March 2013. TOTS registers patients undergoing a bariatric procedure based on an individualized clinical decision plan. In TOTS, the patients are referred to three university hospitals for clinical assessments and surgical procedures. More information regarding the study protocol is available elsewhere.[10]

The inclusion criteria were as follows in this study: age range of 18–65 years; body mass index (BMI) ≥ 40 kg/m^2 or $35 \leq \text{BMI} < 40$ kg/m^2; having a comorbidity or failure of intensive medical treatment for at least 1 year; acceptable surgical risk; willingness to provide an informed consent; and referral for regular follow-ups. Postoperation care team included an obesity expert, nutritionist, and exercise medicine physician. Patients of both groups received a similar calorie-restricted diet.

Of 383 severely obese patients (BMI ≥ 35 kg/m^2), who had undergone bariatric surgery by an experienced surgical team from March 2017 to March 2018, those using anti-reflux ($n = 38$) due to their interactions with vitamin B12 absorption or corticosteroids ($n = 15$) due to their side effects, such as weight gain and muscle weakness; gastrointestinal complications related to surgery ($n = 42$); and incomplete 24-h dietary recalls 12 months after surgery ($n = 108$) were excluded. Finally, 180 individuals entered the study. All of the participants had undergone bariatric surgery (SG or GB) and were assessed for dietary, anthropometric, and metabolic outcomes 1 year after the surgery.

All procedures were completed via laparoscopy by a single surgical team under general anesthesia. The type of surgery was mainly SG, which was performed using a 36-F bougie with excision of 80% of the stomach. On the other hand, Roux-en-Y GB was conducted using an alimentary limb of 100–150 cm and a biliopancreatic limb of 50 cm or mini-gastric bypass (loop gastroenterostomy of 160 cm).[10]

All procedures concerning human participants were approved by the Ethics Committee of Research Institute for Endocrine Sciences, Shahid Beheshti University of Medical Sciences, Tehran, Iran (IR.SBMU.ENDOCRINE.REC.1395.203). This study was performed in accordance with the ethical standards of Declaration of Helsinki (1964) and its later amendments or comparable ethical standards. Written informed consents were obtained from all of the participants included in the study.

Measurements

The patients attended routine postoperative follow-up visits, based on the standard protocol at 1, 3, 6, and 12 months after surgery, and measurements including blood indices were documented in each visit. Anthropometric measurements were taken before surgery and 12 months after surgery. BMI was calculated by dividing weight in kilograms by height in meters squared. The waist circumference (WC) was measured to the nearest 0.5 cm at the midpoint between the lowest rib and the iliac crest. The body composition analyzer, InBody 370 (Biospace, Seoul, Korea), was also used to measure the body fat percentage and fat-free mass. Weight loss was determined as change in BMI and percentage of excess weight loss (EWL%), with ideal weight defined as BMI of 25 kg/m^2.

Nutritional Assessment

The patients received a calorie-restricted diet with regard to their age, sex, and daily activity level by a trained dietician in the follow-up visits. The energy balance was negative, and daily calorie intake ranged from 400 to 500 kcal on the first postoperative day to about 1000 kcal at the end of the first year; protein intake should not be less than 60 g/day.[11] Daily vitamin and mineral supplements were prescribed for up to

12 months. The postoperative oral multivitamin/mineral supplements included one Pharmaton® capsule (containing 2 mg of copper, 10 mg of ferrous sulfate, 100 mg of folic acid, and 1 mcg of vitamin B12, vitamin A, vitamin B group, vitamin C, vitamin D, vitamin E, nicotinamide, and biotin; Boehringer Ingelheim Inc., Germany) and one Calcicare tablet (200 IU of vitamin D, 400 mg of calcium, 100 mg of magnesium, and 4 mg of zinc) daily.

Nutritional assessments were conducted by a trained dietician 12 months after surgery. The 3-day 24-h dietary recalls were conducted on 2 non-consecutive weekdays and 1 day of the weekend. The United States Department of Agriculture[12] and Iranian Food Composition Tables[13] were used to convert crude data to grams, milligrams, or micrograms of nutrients. To evaluate the adequacy of nutrient intake, the subjects' intakes were compared to the current dietary reference intakes (DRIs),[14] including the acceptable macronutrient distribution ranges (AMDR) and estimated average requirements (EAR). Adequate intake (AI) was alternatively used for nutrients without an available EAR.

The nutrient adequacy ratio (NAR) was calculated as the individual's intake divided by the recommended nutrient intake for each age and sex category.[15] The NAR of 11 nutrients, including thiamin, vitamin B12, folate, iron, calcium, copper, zinc, and vitamins A, D, E, and K, was truncated at 1 so that a nutrient with a high NAR did not compensate for a nutrient with a low NAR. The nutrients were selected based on the guidelines of the American Society for Metabolic and Bariatric Surgery (ASMBS).[16] In addition, the mean adequacy ratio (MAR) was computed as the sum of NARs for each nutrient divided by the number of nutrients. A value of 1.0 represents meeting the requirements for both NAR and MAR.

Analytical Measurements

Blood samples were taken from the participants at baseline and 1 year after surgery to assess the serum concentrations of vitamins (B12 and D), minerals (calcium, phosphorus, copper, and zinc), iron (iron and ferritin), and albumin. The serum levels of vitamin B12 and vitamin D were measured using a chemiluminescent immunoassay and enzyme immunoassay, respectively. Calcium and phosphorus were also measured by methylthymol blue colorimetry and UV-endpoint phosphomolybdate method, respectively. In addition, copper and zinc were measured using the colorimetric method with 3,5-dibromo-2-paridylase and 5-bromo-2-paridylase, respectively. Serum ferritin level was measured using the human ferritin enzyme immunoassay, and serum iron concentration was assessed using the spectrophotometric and colorimetric methods. Finally, serum albumin concentration was determined using bromocresol green. The reference values are summarized in Table 2.

Statistical Analysis

SPSS version 20 (IBM Corp., Chicago, USA) was used for all statistical analyses. Continuous variables are expressed as mean ± standard deviation (SD), and categorical variables are shown as frequency (percentage). To determine differences in qualitative and quantitative variables between SG and GB patients, Chi-square and independent t test were used, respectively. Moreover, to evaluate differences in variables between postoperative and preoperative stages, paired t-test was conducted. Linear regression analysis adjusted by preoperative weight was also used for determining the association between nutrient adequacy and anthropometric indices in postoperative patients.

Results

The characteristics of the study population (preoperative and postoperative) are presented in Table 1. The mean age of SG (67%) and GB (32%) patients was 39.2 ± 12 and 41.4 ± 10 years, respectively. There were significant differences between pre- and postoperative patients in terms of all anthropometrical indices. However, there was no significant difference regarding excess weight loss between SG and GB patients. However, SG patients had more postoperative fat-free mass (52.0 ± 12 kg) than GB patients (49.7 ± 8 kg) ($P < 0.05$).

Table 2 presents the pre- and postoperative serum nutrient status of SG and GB patients. There was no significant difference in the postoperative serum levels of nutrients between SG and GB patients. The most prevalent postoperative nutrient deficiencies were related to vitamin B12 (30%), ferritin (19%), and 25-hydroxyvitamin D (16.2%). Moreover, there were significant differences in the mean concentrations of serum nutrients (albumin, calcium, copper, phosphate, zinc, vitamin B12, and 25-hydroxyvitamin D) in all patients before and after surgery.

Table 3 presents the mean daily energy intake, micro- and macronutrient intakes, and nutrient inadequacy percentage in postoperative SG and GB patients. No significant difference was observed in terms of nutrient intake between SG and GB patients, except for carbohydrate (energy percentage) and vitamin D. Both groups showed high inadequacy of dietary nutrient intake. The percentage of n-3 polyunsaturated fat from energy intake in comparison with AMDR indicated its inadequacy in all patients.

Considering the total fat intake, more than 70% of the patients had inadequate intake (higher than recommended) versus AMDR. Dietary protein (energy intake percentage) was lower than the required level in almost 80% of the patients. Regarding the intake of other minerals and vitamins, it was found that more than 70% of the patients had inadequate

Table 1 Characteristics of study participants

Characteristics	Pre-operative		Post-operative (1 year)	
	SG ($n = 122$)	GB ($n = 58$)	SG† ($n = 122$)	GB† ($n = 58$)
Age (years)	39.2 ± 12	41.4 ± 10		
Sex (% female)	72.1	89.7*		
Marital status (%)				
Married	70.0	74.1		
Education (%)				
> 12 years	43.4	43.1		
Smokers (%)	16.4	15.5		
Alcohol consumers (%)	13.1	12.1		
BMI (Kg/m^2)	45.2 ± 7	45.2 ± 6	30.6 ± 5	30.0 ± 5
Waist circumference (cm)	126 ± 14	124 ± 14	96.7 ± 13	96.6 ± 11
Fat mass (%)	49.2 ± 6	50.5 ± 4**	35.9 ± 10	34.8 ± 7
Fat free mass (Kg)	61.4 ± 14	57.6 ± 9	52.0 ± 12	49.7 ± 8**
Lean mass (Kg)	58.6 ± 13	54.3 ± 8	49.0 ± 11	47.1 ± 8
Excess weight loss (%)			75.8 ± 20	75.0 ± 23
Weight loss (Kg)			−39.4 ± 13	−38.6 ± 13
BMI loss (Kg/m^2)			−14.5 ± 4.3	−14.9 ± 5.0

SG, sleeve gastrectomy; GB, Roux-en-Y gastric bypass

Values are mean ± SD unless otherwise listed. *P* values derived from Chi-square for categorical variables and t-test for numerical variables

* $P < 0.01$ for the difference between SG and GB patients

** $P < 0.05$ for the difference between SG and GB patients

† $P < 0.01$ for the difference of postoperative vs preoperative subjects

nutrient intakes, compared to the recommendations. There was no significant difference in terms of the mean nutrient adequacy score between SG and GB patients. The obtained scores, regardless of dietary supplements, showed that almost 45% of the patients had possibly adequate intakes of some nutrients.

The MAR was lower in patients with serum albumin deficiency (0.31 ± 0.03), compared to non-deficient patients (0.50 ± 11) ($P < 0.05$). The MAR was not significantly different between deficient and non-deficient subjects regarding other serum nutrient parameters. Linear regression analysis of the association between nutrient adequacy and postoperative anthropometric indices is presented in Table 4. Nutrient adequacy was positively associated with fat-free mass ($\beta = 8.67$, $P < 0.05$).

Discussion

This study demonstrated that some individuals had deficiencies in iron (19%), vitamin B12 (30%), and vitamin D (16.2%) 1 year after SG and GB surgeries. More than 75% of the patients had inadequate dietary intake of vitamins and minerals, regardless of dietary supplements; the mean score of nutrient adequacy was less than 0.5. The MAR was lower in patients with serum albumin deficiency, compared to non-deficient patients. Excess weight loss and lean body mass were similar after both surgeries, although SG patients had a better body composition than their GB counterparts.

Based on the present findings, postoperative serum levels of nutrients were similar in SG and GB groups, which is in line with previous studies. However, the frequency of vitamin B12 deficiency in GB patients was more than three times higher than SG patients.[17] In the present study, bariatric surgery induced weight loss both in fat mass and fat-free mass. Most studies have shown that rapid weight loss occurs 1 year after surgery, following modest weight gain for 3 to 5 years.[18,19] In our study, GB patients had a lower fat-free mass than SG patients 1 year after surgery. In this regard, two studies reported that reduction of fat-free mass was not significantly different between SG and GB patients at 12–17 months after surgery.[20,21] Moreover, two other studies showed that weight loss following SG was slightly less than GB 1 year after surgery.[8,19]

Lifelong monitoring of nutritional deficiency and supplementation is advised after GB. However, there are no definitive guidelines available for SG patients. Protein and energy needs should be managed based on lean mass to avoid

Table 2 Pre- and postoperative serum nutrient status of patients

Characteristics	Preoperative		Deficient subjects (%)	Postoperative (1 year)		Deficient subjects (%)	Reference values		P^{**}
	SG	GB		SG	GB		Male	Female	
Albumin (g/dl)	4.24 ± 0.33 (n = 72)	4.38 ± 0.34* (n = 37)	0.6	4.23 ± 0.36 (n = 34)	4.12 ± 0.49 (n = 21)	5.4	3.5–5.0		0.005
Calcium (mg/dl)	9.30 ± 0.68 (n = 122)	9.47 ± 0.62 (n = 58)	3.1	9.22 ± 0.57 (n = 111)	9.17 ± 0.49 (n = 55)	8.8	8.5–10.5		< 0.001
Copper (µg/dl)	117 ± 37 (n = 102)	119 ± 32 (n = 49)	3.2	103 ± 21 (n = 114)	103 ± 19 (n = 50)	1.7	70–140	80–155	< 0.001
Iron (µg/dl)	76.7 ± 34 (n = 116)	70.1 ± 29 (n = 54)	8.4	88.3 ± 33 (n = 111)	73.2 ± 31 (n = 51)	2.8	40–170	37–165	0.008
Phosphate (mg/dl)	3.62 ± 0.60 (n = 122)	3.80 ± 0.69 (n = 58)	2.1	3.84 ± 0.44 (n = 118)	3.88 ± 0.52 (n = 56)	0	2.6–4.5		0.03 0.04
Zinc (µg/dl)	90.4 ± 21 (n = 122)	82.3 ± 19* (n = 58)	1.5	83.7 ± 19 (n = 122)	78.0 ± 17 (n = 58)	0.9	50–150		
Ferritin (ng/ml)	60.1(23.3–83.1) (n = 43)	61.7(19.6–124) (n = 29)	7.6	53.0(18.5–145) (n = 53)	51.4(8.76–90.0) (n = 36)	19.0	15–200	12–150	0.71
Vitamin B12 (pmol/l)	119(60.2–244) (n = 117)	160(56.7–326) (n = 56)	55.3	194(85.0–323) (n = 114)	272(178–462) (n = 54)	30.0	160–950		< 0.001
25 (OH) vitamin D (ng/ml)	19.6(13.9–32.0) (n = 122)	22.3(15.5–39.1) (n = 58)	52.6	32.5(22.4–50.0) (n = 122)	36.7(25.0–50.0) (n = 58)	16.2	≥ 20		< 0.001

SG, sleeve gastrectomy; GB, Roux-en-Y gastric bypass

Values are mean ± SD unless otherwise listed. P values derived from Chi-square for categorical and t-test for numerical variables

* $P < 0.05$ for the difference between SG and GB patients

** P for the difference of postoperative vs preoperative subjects

depletion of fat-free mass and to maintain long-term weight loss after surgery. In addition, the level of physical activity, age, and gender modulate the risk of fat-free mass depletion.[22] On the other hand, laboratory analysis of vitamins and minerals can improve supplementation recommendations according to the patient's needs.[17]

Hypoalbuminemia was observed in 5.4% of patients 1 year after surgery. In line with our findings, postoperative hypoalbuminemia was reported in 3% to 18% of the patients[22] due to the disruption of dietary protein intake, digestion, and absorption.[23] Moreover, our findings showed that after both SG and GB surgeries, daily protein intake was less than the recommended level in almost 80% of the patients in the first postoperative year, which is in agreement with previous studies.[8] Therefore, adherence to nutritional guidelines and adequate protein intake after bariatric surgery are of utmost importance for avoiding malnutrition and ensuring the beneficial effects of proteins on body composition.[23,24] In fact, recommendations for protein intake must be emphasized by a dietician, based on the patient's age, sex, and weight. In addition to protein-rich foods, supplementation should reach the daily amount of 60 g.[24]

In the present study, the patients' energy intake was similar to previous studies, which evaluated the dietary intake of patients 1 year after GB or SG surgery.[8,18,25,26] Our findings showed that the energy intake percentage from macronutrients was similar in both groups. Daily macronutrient intake of a large proportion of GB and SG patients was inadequate, which is consistent with the results reported by Moize and colleagues.[8] Nearly 75% of the patients had a total fat intake more than the recommended level. According to previous longitudinal studies, favoring protein over carbohydrate and fat induces greater weight loss and better body composition over a long follow-up.[24] In addition, nutrition counseling for appropriate fat intake must be emphasized to avoid dyslipidemia and atherosclerosis.[4] Also, macronutrient adequacy of fiber, protein, and n-3 and n-6 polyunsaturated fatty acids (PUFAs) is important, as the prescribed supplements do not contain these nutrients.

In the present study, a large proportion of SG and GB patients had low intakes of micronutrients (below the recommended levels), and all subjects had inadequate vitamin D intake. In line with our study, low serum ferritin, vitamin B12, and 25-hydroxyvitamin D levels were reported in a large percentage of patients 1 year after surgery.[6,8] Moreover, a systematic review reported a twofold increase in anemia 12 months after surgery.[27] Another study reported the prevalence of vitamin D deficiency to be 24–85%.[6] The lower

Table 3 Nutrient intakes 1 year after surgery compared with dietary recommendations

	Dietary intakes		% of inadequacy		Recommended intakes	
	SG	GB	SG	GB	Men	Women
Energy (kcal)	1199 ± 617	1260 ± 773				
Carbohydrate (% of energy)	48.9 ± 17	54.3 ± 18*	54.1	55.2	45–65**	
Protein (% of energy)	11.4 ± 7	11.1 ± 6	83.6	84.5	10–35**	
Fat (% of energy)	43.0 ± 16	38.3 ± 17	72.1	72.4	20–35**	
n-6 PUFA (% of energy)	8.64 ± 6	7.28 ± 6	71.3	60.3	5–10**	
n-3 PUFA (% of energy)	0.66 ± 0.7	0.53 ± 0.4	100	100	0.6–1.2**	
Fiber (gr)	9.78 ± 8	11.8 ± 9	95.0	93.0	14–50 y: 38†	14–18 y: 26 19–50 y: 25
Calcium (mg)	236 ± 191	233 ± 148	97.5	100	14–18 y: 1100†† 19–50 y: 800	
Phosphorus (mg)	468 ± 321	435 ± 274	70.5	73.2	14–18 y: 1055†† 19–50 y: 580	
Magnesium (mg)	143 ± 133	145 ± 128	88.5	92.9	14–18 y: 410†† 19–30 y:400 31–50 y: 420	14–18 y: 360 19–30 y: 310 31–50 y: 320
Manganese (mg)	1.68 ± 1.8	2.01 ± 3.4	82.8	83.9	14–18 y: 2.2† 19–50 y: 2.3	14–18 y: 1.6 19–50 y: 1.8
Copper (mg)	0.83 ± 0.9	0.89 ± 1.0	100	100	14–18 y: 685†† 19–50 y: 700	
Iron (mg)	6.09 ± 4	6.41 ± 4	70.5	72.4	14–18 y: 7.7†† 19–50 y: 6	14–18 y: 7.9†† 19–50 y: 8.1
Zinc (mg)	4.36 ± 4	4.23 ± 4	86.1	89.3	14–18 y: 8.5†† 19–50 y: 9.4	14–18 y: 7.3†† 19–50 y: 6.8
Selenium (µg)	27.7 ± 20	26.3 ± 16	87.7	91.1	14–50 y: 45††	
Folate (µg)	143 ± 129	136 ± 111	90.2	96.6	14–18 y: 330†† 19–50 y: 320	
Thiamin (mg)	0.56 ± 0.4	0.56 ± 0.5	84.4	93.1	14–50 y: 1††	14–50 y: 0.9
Riboflavin (mg)	0.57 ± 0.4	0.49 ± 0.3	86.1	91.4	14–50 y: 1.1††	14–50 y: 0.9
Niacin (mg)	8.54 ± 7	7.72 ± 6	74.6	77.6	14–50 y: 12††	14–50 y: 11
Pantothenic acid (mg)	1.43 ± 1.04	1.36 ± 0.82	100	100	14–50 y: 5†	
Vitamin B6 (mg)	0.53 ± 0.4	0.61 ± 0.5	92.6	86.2	14–50 y: 1.1††	14–18 y: 1 19–50 y: 1.1
Vitamin B12 (µg)	2.20 ± 5	1.78 ± 2	82.0	87.9	14–50 y: 2††	
Vitamin C (mg)	34.7 ± 30	46.2 ± 60	82.8	82.8	14–18 y: 63†† 19–50 y: 75	14–18 y: 56 19–50 y: 60
Vitamin A (µg)	206 ± 466	180 ± 232	95.9	96.6	14–18 y: 630†† 19–50 y: 625	14–18 y: 485 19–50 y: 500
Vitamin D (µg)	0.31 ± 0.4	0.17 ± 0.2*	100	100	10††	
Vitamin E (mg)	9.0 ± 15	10.0 ± 20	79.5	84.5	14–50 y: 12††	
Vitamin K (µg)	32.0 ± 27	34.5 ± 34	94.3	92.9	14–18 y: 75† 19–50 y: 120	14–18 y: 75 19–50 y: 90
Mean nutrients adequacy ratio	0.43 ± 0.15	0.45 ± 0.13			Range: 0–1	

SG, sleeve gastrectomy; GB, Roux-en-Y gastric bypass

Values are mean ± SD unless otherwise listed. *P* values derived from Chi-square for categorical variables and t-test for numerical variables

* $P < 0.05$ for the difference between SG and GB patients

**Based on dietary reference intakes (DRIs) and acceptable macronutrient distribution ranges for adults

† Based on dietary reference intakes (DRIs)

†† Based on dietary reference intakes (DRIs) and estimated average requirements

Table 4 Linear regression analysis of the association between nutrient adequacy and anthropometric changes in postoperative subjects after 1 year

Nutrients adequacy	β	*P* value
Excess BMI loss	6.58	0.51
Postoperative lean mass	5.98	0.27
Postoperative fat free mass	8.67	0.04
Postoperative fat mass	− 9.42	0.07
Postoperative waist circumference	1.70	0.78

Adjusted by preoperative weight

prevalence of vitamin D deficiency in our study may be attributed to the patients' better compliance with vitamin D supplements.

On the other hand, the results of previous studies showed that the prevalence of postoperative vitamin B12 deficiency varies from 10% to 60%. Many patients showed intolerance of red meat and were unable to increase their heme iron intake. Impairments in the absorption of iron and vitamin B12 may also induce these deficiencies.[1,6] Overall, these deficiencies highlight the consequences of iron, vitamin D, and vitamin B12 inadequacy and represent the individuals' low adherence to vitamin and mineral supplementations. Therefore, additional iron and vitamin B12 supplementation is essential for patients to overcome these deficiencies.[16] These patients are prone to calcium deficiency postoperatively due to low dietary intake, reduced absorption of minerals and vitamins, and vitamin D deficiency; according to the guidelines, calcium supplementation is advised for all of these individuals.[6,9,16]

In the current study, more than 75% of the patients had inadequate intake of vitamins (vitamins A, E, K, B1, B2, and B6; folate; niacin; and pantothenic acid) and minerals (magnesium, manganese, copper, zinc, and selenium); these results are in line with previous studies.[25,26] Moreover, the nutrient adequacy score was determined in our study based on the American Society for Metabolic and Bariatric Surgery (ASMBS) guidelines,[16] without considering the prescribed vitamin and mineral supplements; the mean score of the patients was below 0.5, which indicates <50% probability of adequate intake. Nutrient adequacy of GB patients was assessed using the probability of adequate nutrient intake score for up to 3 months after surgery. The adequacy subscore decreased 1 and 3 months after surgery, compared to the baseline. The greatest reduction of food intake after surgery was reported for red meat and vegetables due to digestion difficulties; this study also indicated the higher consumption of sugar than starch.[28]

The main strength of this study was the measurement of a large group of dietary nutrients in foods. Few studies have explored the dietary intake and nutrient adequacy of SG and GB patients 1 year after surgery, especially in Middle-Eastern populations, who have different food preferences from Western communities. In addition, experienced interviewers could help patients recall their food intake, as well as the quality and quantity of food items, thereby decreasing the memory limitation. This study also had some limitations. First, the food preferences of patients after surgery were not considered. Second, this study was performed only 1 year after surgery, and the findings cannot be applied or compared with long-term follow-up studies. Finally, we had no information about the physical activity of the subjects.

Conclusion

The present findings showed that SG and GB patients had inadequate nutrient intake 1 year after surgery. In fact, a high percentage of patients had nutritional deficiencies, especially iron, vitamin D, and vitamin B12 deficiencies. Despite similar weight loss in both surgeries, SG patients had a better body composition than their GB counterparts. It is recommended to monitor the patients' compliance with healthy dietary behaviors and conduct regular nutritional follow-ups for balanced diet during the postoperative period in order to maintain weight loss and fat-free mass and avoid the risk of obesity. In addition, promotion of a healthy lifestyle, self-monitoring by regular weight measurement, and food diaries are encouraged to prevent weight regain.

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Author's Contributions F.H.E. and M.B. designed the study, analyzed and interpreted the data, and drafted the manuscript. M.V., F.A., P.M., and A.K. contributed to manuscript review, critical appraisal, and specialist advice. M.B. and A.K. supervised the study. All authors reviewed and approved the final draft of the manuscript.

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Compliance with Ethical Standards

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

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