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Opinion Paper

Assessment of nutritional status, body composition and blood biochemical parameters of patients following sleeve gastrectomy: 6 months follow up

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SUMMARY

Background and aims: Today, Sleeve gastrectomy (SG) has recently become the most common bariatric procedure among various bariatric surgical procedures due to its advantages. The aim of this study is to investigate nutritional status, body composition and biochemical parameters following SG.

Methods: This was a prospective study, the subjects were patients who underwent SG at a special obesity clinic in İstanbul, Turkey, between 01.05.2017 and 01.11.2017. The mean body mass index (BMI) of the participants was 42.15 ± 4.84 kg/m^2 for men and 41.44 ± 4.34 kg/m^2 for women, preoperatively. Nutritional status, some anthropometric measurements and blood sampling were taken at each visit. Data were collected and analyzed for the present study at the following periods: pre-operation (pre-op), 1 month, 3 months and 6 months after surgery.

Results: A total of 47 SG patients (20 men, 27 women) were evaluated. The mean BMI was 30.23 ± 3.56 kg/m^2 for men and 30.35 ± 4.36 kg/m^2 for women after 6 months and the amount of excess weight loss (EWL) increased in the 3 months ($p < .001$). Mean energy, fiber, vitamin A, vitamin C, vitamin B_1, niacin, vitamin B_{12}, folate, calcium, magnesium, iron, zinc, phosphorus and iodine were above the Dietary Reference Intake (DRI) recommendations. A significant association was found between protein intake and fat free mass loss in both genders after SG at 6 months ($p < .05$).

Conclusion: Nutrition deficiencies are common for patients after SG. Therefore, it is important to routinely monitor these patients with a professional team.

1. Introduction

The prevalence of obesity in Turkey is increasing day by day. According to the World Health Organization (WHO), Turkey has the highest prevalence of obesity in the European country 32.1% [1]. Obesity is defined as an adult having a Body Mass Index (BMI) greater than or equal to 30.0 kg/m^2 and is associated with leading multi organ dysfunction [2]. Unhealthy food choices, increased fast food consumption, sedentary lifestyle, are one of the most common community conditions worldwide, leading to obesity [3].

Today, bariatric surgery (BS) has been shown to be the most effective way to treat obesity [4–6]. BS ameliorates obesity-related complications by reducing excess body weight, improving body function and decreasing mortality [7]. Several surgical procedures have thus been described over the last 40 years. Sleeve gastrectomy (SG) has recently become the most common bariatric procedure among various bariatric surgical procedures [8]. SG was endorsed in 2011 by the American Society for Metabolic and Bariatric Surgery as a stand-alone treatment for morbid obesity [9]. The health benefits associated with different bariatric surgery procedures are well documented [7]. However, nutritional risks after SG have not been frequently described [10,12].

Nutritional deficiencies are noteworthy among the possible complications of bariatric surgery. Studies have shown that micronutrient deficiencies are present in a significant proportion of patients with morbid obesity even before surgery [13–15]. Micronutrient deficiencies are common in BS and this is a disadvantage for patients. Especially, vitamin B_{12}, D, folate and iron deficiencies

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are prevalent in BS post-operatively [15]. Therefore, the role of the dietitian and of a professional team is very important in these patients for preventing and ameliorating nutritional deficiencies. However, in patients who undergo SG there is a lower incidence of mineral and vitamin deficiencies can provide an additional advantage for SG [11]. Also, limited studies have described nutrient status after SG. The aim of this study was to investigate nutritional status, body composition and biochemical parameters for patients following SG.

2. Materials and methods

2.1. Study design

A prospective study was conducted in a special obesity clinic, Bariatriklab in Istanbul, Turkey between 01.05.2017 and 01.11.2017. Power analysis has been performed in the sample selection; the prevalence was calculated as 20%, type 1 error rate $\alpha = .05$, type 2 error rate $\beta = .20$, and test power 1- $\beta = .80$. The main hypothesis was that the nutritional status, body composition and biochemical findings of SG patients before and after the operation differ statistically. Accordingly, a total of 50 patients were included in the study, and 3 people were excluded from the study because they did not meet the inclusion criteria. Therefore, a total of 47 patients (20 men, 27 women) who underwent SG were included in this study. The decision for surgery was taken after a multidisciplinary meeting of our team, following recommendations of international consensus conferences or expert panels American Society for Metabolic and Bariatric Surgery (ASMBS) [16]. Inclusion criteria are age between 18 and 65 years old, BMI >40 or BMI >35 kg/m^2 with comorbidities and patients who received surgery approval by the doctor. and, exclusion criteria are ages <18 or >65 years old, pregnant or lactating status for women, BMI<35 kg/m^2, excessive alcohol consumption, chronic renal failure, mental illness or cognitive deterioration and psychiatric history or other contraindications for surgery.

Before the operation, the nutrition principles of the 1st stage diet (only liquid), the 2nd stage diet (soft foods) and the 3rd stage diet (solid and rich in protein), which are stated in the nutrition principles of ASMBS, are explained individually. Vitamins-mineral supplements: 60 mg magnesium, 90 mg vitamin C, 30 mg vitamin B_3, 30 mg vitamin E, 15 mg zinc, 2 mg copper, 2 mg manganese, 70 μg selenium, 10 mg vitamin B_5, 1,5 mg vitamin B_1, 1,7 mg vitamin B_2, 4 mg vitamin B_6, 160 μg vitamin K, 1000 μg vitamin A, 120 μg chromium,20 μg vitamin D, 600 μg folic acid, 600 μg biotin, 500 μg vitamin B_{12}, 150 μg iodine, 14 mg iron contains. In addition, Vitamin D (20 μg) was recommended if necessary considering the biochemical parameters of the patients [16]. Table 1 shows the nutrition programs (1st stage diet, 2nd stage diet and 3rd stage diet) recommended after bariatric surgery.

Table 1
Nutrition programs recommended after bariatric surgery.

Diet Stages	Start	Liquids/foods
Stage-1	Post-op 1/2.days	Clear liquids; Carbohydrate, calorie-free, sugar-free, decaffeinated beverages
Stage-1 *Vitamins-minerals supplements have started under the control of the physician.* Chewable multivitamin[a] IV 350–500 μg/day vitamin B_{12} Vitamin D 3000 IU/day[b] Liquid anti-acid preparations	Post-op 3.days (*discharge*)	Clear liquids: Sugar free liquids (sweetener can be used) Full liquid diet: Salt-added liquids (Turkish ayran) Protein powder 1 cup/day (27g whey protein isolate)
Stage-2 *Vitamins-minerals supplements were continued under physician control.* Chewable multivitamin[a] IV 350–500 μg/day vitamin B_{12} Vitamin D 3000 IU/day[b] Liquid anti-acid preparations	Post-op 10–14.days	Clear fluid consumption should be increased. >1200–1800 mL Liquid diet replacement; should leave it to soft, mashed protein-rich foods. Protein powder 1 cup/day (27g whey protein isolate) Protein sources of Stage-2: egg, ground beef, pureed chicken or turkey meat, boiled or baked fish, thick soups, cottage cheese, low-fat cheese, yoghurt.
Stage-2: *Vitamins-minerals supplements were continued under physician control* Chewable multivitamin[a] IV 350–500 μg/day vitamin B_{12} Vitamin D 3000 IU/day[b] Liquid anti-acid preparations	Post-op 2–4. week	Toleration should be considered. Protein powder 1 cup/day (27g whey protein isolate) Protein-rich foods Well-cooked vegetables Soft or pureed fruit
Stage-2: *Vitamins-minerals supplements were recommended in tablet form under the supervision of the physician.* Tablet/Chewable multivitamin[a] IV 350–500 μg/day vitamin B_{12} Vitamin D 3000 IU/day[b] Capsule proton pump inhibitor	Post-op 5.week	Protein consumption should be continued with vegetables and fruits. Protein powder 1 cup/day (27g whey protein isolate) According to tolerance, salad consumption can be recommended after the 1st month.
Stage-3 *Daily vitamins-minerals support was continued under the control of the physician.* Tablet/Chewable multivitamin[a] IV 350–500 μg/day vitamin B_{12} Vitamin D 3000 IU/day[b]	Post-op 5.week – 6.month Increased sense of hunger and more tolerable amounts of food	Choosing healthy solid foods by considering tolerance Protein-rich foods, well cooked meat products, raw salads, dried legumes

[a] Vitamins-mineral supplements: 60 mg magnesium, 90 mg vitamin C, 30 mg vitamin B_3, 30 mg vitamin E, 15 mg zinc, 2 mg copper, 2 mg manganese, 70 μg selenium, 10 mg vitamin B_5, 1,5 mg vitamin B_1, 1,7 mg vitamin B_2, 4 mg vitamin B_6, 160 μg vitamin K, 1000 μg vitamin A, 120 μg chromium,20 μg vitamin D, 600 μg folic acid, 600 μg biotin, 500 μg vitamin B_{12}, 150 μg iodine, 14 mg iron contains.
[b] Vitamin D is recommended, if necessary, considering the patient's biochemical findings.

Nutritional status, anthropometric measurements (weight, height, percentage of body mass and fat) and blood sampling were taken at each follow-up visit. Data were collected and analyzed for the present study at the following periods: pre-operation, 1 month, 3 months and 6 months after SG.

Body composition was analyzed by Tanita SC-330 (Accurate Technology Co., Ltd. Tianjin, China) which regularly calibrated and the body height, weight, percentage of body lean mass and fat of the participants were recorded. BMI was calculated using weight (in kilograms) divided by the height squared (in square meter).

Food intake was assessed by 3-day food diaries (including 2 week day and one day on the weekend) by using a photographic atlas of food portion size [17]. The Nutrient Database (BeBİS, BEBIS pro for Windows, Willstaett, Germany; Turkish Version, BeBiS 7) was used to determine the daily energy and nutrient intake and the results were compared with the Turkish Dietary Reference Intake (RDI) according to the age and gender Dietary Guidelines for Turkey [18]. We also used 3-day food diaries (for 1, 3 and 6 months) to evaluate the relationship between the mean protein intake and fat-free mass.

After 12 h of starvation, biochemical parameters of blood were determined: hemoglobin, hematocrit, ferritin, plasma iron, iron-binding capacity, glucose, HbA1c, lipid profile, hepatic enzymes, kidney enzyme tests, thyroid tests (thyroid-stimulating hormone, triiodothyronine, thyroxine), vitamin D, calcium, sodium, potassium, folic acid and vitamin B_{12} levels.

Ethical Approval: All procedures performed according to the Principles of the Declaration of Helsinki. The study was approved (Approval number: 2017–10) at Istanbul Gelisim University on 13.04.2017. Written and verbal informed consent was obtained from all subjects.

2.2. Statistical analyses

Study data were evaluated with the statistical program SPSS 25.0 (Statistical Package for the Social Sciences, Inc.; Chicago, Illinois, United States). Categorical data were expressed as the frequency (percentage), and differences were analyzed using Fisher's exact test (when including any expected p value $\leq .05$) or the chi-square test. Anthropometric measurements, blood test results, and calorie and nutrient intakes were compared and presented as mean values and standard deviations. Differences between continuous variables (baseline vs. follow-up) were evaluated using the analysis of variance (ANOVA) test. For all statistical tests, a P value of $\leq .05$ was considered statistically significant.

3. Results

A total of 27 women (the mean age: 40.93 ± 9.48 years) and 20 men (the mean age: 42.30 ± 12.04 years) participated in the study. Most patients had co-morbidities. The characteristics of patients are shown in Table 2.

Table 3 shows the body composition of patients before and after SG. The mean height was 178.90 ± 5.73 cm in men and 164.59 ± 6.89 cm in women patients (not shown in table). After 6 months, the mean body weight, BMI, body fat and fat-free mass (FFM) was decreased compared to pre-op and these results were statistically significant ($p < .01$).

A total of 25 patients (17 women, 8 men) at 1 month, 35 patients (22 women, 13 men) at 3 months and 31 patients (21 women, 10 men) at 6 months received <60 g/day protein (not shown in table). Changes in FFM with protein intake are shown in Table 4. Only 6 months after SG, a significant association was found between protein intake and FFM loss in all genders ($p < .05$).

Table 2
Demographic characteristics of patients.

	Men (n = 20)	Women (n = 27)	Total (n = 47)	p value
	n (%)	n (%)	n (%)	
Age[a] (years)	42.30 ± 12.04	40.93 ± 9.48	41.51 ± 10.54	
Working status				.105
Yes	17 (85.0)	16 (59.3)	33 (70.2)	
No	3 (15)	11 (40.7)	14 (29.8)	
Comorbidities[b]				.148
Hypothyroidism	2 (10.5)	2 (7.4)	4 (8.7)	1
Hypertension	3 (15.8)	3 (11.1)	6 (13.0)	.68
Diabetes mellitus	3 (15.8)	2(7.4)	5 (10.9)	.635
Polycystic ovary syndrome	–	3 (11.1)	3(6.5)	.257
Sleep apnea	1 (5.3)	1 (3.7)	2 (4.3)	1
İnsülin resistance	3 (15.8)	11 (40.7)	14 (30.4)	.106
Reflux	–	2 (7.4)	2 (4.3)	.504
Anemia	–	1 (3.7)	1 (2.2)	1
Chronic gastritis	–	1 (3.7)	1 (2.2)	1
Ways to lose weight				
Using Drugs	3 (15.0)	2 (7.4)	5 (10.6)	.638
Acupuncture treatment	8 (40.0)	3 (11.1)	11 (23.4)	.035*
Nutritionist support	11 (55.0)	12 (44.4)	23 (48.9)	.561
Doctor support	1 (5.0)	–	1 (2.1)	.426
By exercising	8 (40.0)	10 (37.0)	18 (38.3)	1
Cigarette				.374
Yes	6 (30.0)	12 (44.4)	18 (38.3)	
No	14 (48.3)	15 (55.6)	29 (61.7)	
Alcohol				.386
Yes	11 (55.0)	11 (40.7)	22 (46.8)	
No	9 (45.0)	16 (59.3)	25 (53.2)	
Main meals[a]	2.90 ± .91	2.42 ± .70	2.93 ± .83	
Snacks[a]	1.45 ± .51	1.23 ± .43	1.33 ± .47	

*P < .05.
[a] Mean± standard deviation.
[b] Values calculated more than one disease in the same patient.

Table 3
Body composition of patients before and after (1,3 and 6 months) sleeve gastrectomy.

	Preop		After 1 month		After 3 months		After 6 months		p value	
	Men (n = 20)	Women (n = 27)	Men (n = 20)	Women (n = 27)	Men (n = 20)	Women (n = 27)	Men (n = 20)	Women (n = 27)	P^1 value	P^2 value
Body weight (kg)	134.90 ± 16.23	112.25 ± 13.15	121.06 ± 14.31	101.68 ± 13.49	108.14 ± 13.30	91.79 ± 13.52	96.70 ± 11.62	82.23 ± 13.03	<.001*	<.001*
BMI (kg/m^2)	42.15 ± 4.84	41.44 ± 4.34	37.83 ± 4.27	37.51 ± 4.35	33.80 ± 4.07	33.86 ± 4.40	30.23 ± 3.56	30.35 ± 4.36	<.001*	<.001*
Percentage of body fat (%)	42.12 ± 8.36	47.23 ± 4.08	38.43 ± 8.95	45.18 ± 5.23	32.61 ± 8.37	41.57 ± 6.66	28.85 ± 9.03	37.80 ± 7.56	<.001*	<.001*
Fat free mass (FFM) (kg)	72.96 ± 9.35	57.25 ± 4.51	69.51 ± 9.44	53.33 ± 4.29	69.64 ± 8.66	51.71 ± 4.81	66.52 ± 9.19	49.72 ± 4.43	<.001*	<.001*

*$P < .01$, P^1 differences between groups in men, P^2 differences between groups in women.

Table 4
Changes in fat free mass according to daily protein intake goals.

FFM loss relatively to body weight loss (%)			
Protein intake	1 month	3 months	6 months
<60 g/day	59.10 ± 11.92	57.85 ± 10.67	54.17 ± 9.31*
≥60 g/day	61.47 ± 8.99	63.69 ± 11.85	62.10 ± 11.81*

*$P < .05$, Data are expressed as mean ± sD.

Blood tests showed fasting plasma glucose (FPG), HbA1c, TG and urea were higher at pre-op, whereas they came to the reference levels after SG. T_4 and vitamin D levels were found lower than reference values before and after SG. Plasma iron, AST levels were lower and potassium levels were higher at pre-op in women, but it came to the reference value after the 6th months of SG. Detailed biochemical parameters of patients before and after surgery are given in Table 5.

Table 6 shows mean energy and nutrients intake of patients before and after (1,3 and 6 months) SG and mean energy, protein (except 1st month), fiber, vitamin A, vitamin E (except 1st month), vitamin C, vitamin B_1, vitamin B_2 (except 1st month), niacin, vitamin B_{12}, folate, calcium, magnesium, iron, zinc, phosphorus and iodine (except 1st month) were above the DRI recommendations.

Table 5
Biochemical parameters of patients before and after (1,3 and 6 months) sleeve gastrectomy.

Parameters	Pre-op	After 1 month	After 3 months	After 6 months	P value	Reference values
FPG	108.56 ± 35.81	94.02 ± 15.31	94.06 ± 14.59	92.68 ± 14.59	.005*	75–106 mg/dL
HbA1c	5.88 ± 1.10	5.45 ± .66	5.23 ± .39	5.11 ± .46	<.001**	<3.5–5.7%
Total cholesterol	203.79 ± 34.92	178.88 ± 38.85	184.46 ± 43.15	182.21 ± 41.49	<.001**	≥240 mg/dL
HDL	44.13 ± 6.70	37.54 ± 5.77	48.38 ± 11.57	52.04 ± 11.99	<.001**[1]	For men: >40 mg/dL
	44.96 ± 9.47	39.95 ± 7.32	44.17 ± 6.71	47.61 ± 7.29	<.001**[2]	For women: >50 mg/dL
LDL	128.69 ± 32.49	112.75 ± 32.04	119.43 ± 30.47	117.56 ± 29.92	<.001**	<130 mg/dL
Triglycerides	161.77 ± 122.26	126.35 ± 87.25	111.16 ± 67.34	102.26 ± 57.23	<.001**	35–150 mg/dL
Hemoglobin	14.81 ± 1.11	15.01 ± .96	14.66 ± .88	14.60 ± .89	.143[1]	For men: 13.5–17.5 g
	12.74 ± 1.51	13.38 ± 1.37	13.24 ± 1.20	13.16 ± 1.28	.065[2]	For women: 12–15.5 g
Hematocrit	44.88 ± 3.00	45.52 ± 2.54	43.96 ± 2.70	43.26 ± 2.89	<.001**[1]	For men: %41-50
	39.21 ± 3.78	41.07 ± 2.81	40.84 ± 2.78	40.57 ± 2.83	.068[2]	For women: %35-46
Ferritin	135.18 ± 110.83	175.91 ± 149.52	199.89 ± 128.76	180.76 ± 106.98	.024*[1]	For men: 22–322 mg/dL
	29.31 ± 19.15	52.94 ± 40.41	47.59 ± 36.78	54.36 ± 36.9	<.001**[2]	For women: 13–150 mg/dL
ALT	43.75 ± 24.59	46.60 ± 25.29	29.94 ± 16.37	27.45 ± 15.38	.003*[1]	For men: 0–45 U/L
	27.12 ± 13.86	36.67 ± 28.25	22.31 ± 12.31	17.07 ± 8.32	<.001**[2]	For women: 0–34 U/L
AST	29.60 ± 12.80	33.45 ± 12.58	23.03 ± 5.22	21.95 ± 4.69	.010*[1]	For men: 0–25 U/L
	26.05 ± 14.82	33.72 ± 29.90	17.46 ± 7.22	16.41 ± 5.02	.001*[2]	For women: 0–31 U/L
Urea	22.11 ± 7.97	19.96 ± 8.09	20.90 ± 8.80	20.49 ± 8.01	.151	7.9–21 mg/dL
Uric acid	6.54 ± 1.63	9.52 ± 2.09	6.94 ± 1.52	6.03 ± 1.19	<.001**[1]	For men: 3.5–7.2 mg/dL
	5.69 ± 1.45	7.47 ± 1.82	5.31 ± 1.06	4.71 ± .79	<.001**[2]	For women: 2.6–6.0 mg/dL
Creatinine	.88 ± .12	.86 ± .15	.83 ± .12	.79 ± .12	.011*[1]	For men: .8–2.4 mg/dL
	.67 ± .09	.70 ± .09	.70 ± .15	.66 ± .08	.092[2]	For women: .6–1.8 mg/dL
Total protein	7.28 ± .68	7.22 ± .61	7.10 ± .54	7.10 ± .56	.058	6.6–8.3 g/dL
PTH	68.31 ± 30.80	59.24 ± 26.23	57.98 ± 19.94	55.10 ± 19.50	.026*	12–65 ng/L
TSH	2.33 ± 1.01	2.07 ± .80	2.24 ± 1.07	2.18 ± .97	.004*	<25 mU/L
T_3	3.69 ± .98	3.3 ± .80	3.26 ± .69	3.13 ± .73	<.001**	2.5–4.55 pg/mL
T_4	4.71 ± 6.10	3.65 ± 4.94	3.97 ± 5.56	3.86 ± 5.38	.119	6.1–11.2 pg/mL
Plasma iron	93.46 ± 27.27	82.21 ± 27.13	99.12 ± 25.99	107.05 ± 29.56	.021*[1]	For men: 70–180 mg/dL
	57.38 ± 20.23	64.15 ± 22.68	72.65 ± 25.89	87.07 ± 29.89	<.001**[2]	For women: 60–180 mg/dL
Iron Binding capacity	328.19 ± 61.10	292.71 ± 66.26	273.74 ± 68.77	271.98 ± 73.56	<.001**	155–300 mg/dL
Plasma Zinc	101.20 ± 12.99	98.22 ± 16.18	92.17 ± 13.17	93.43 ± 12.85	<.001**	70–150 mg/dL
Vitamin D	18.21 ± 8.06	20.57 ± 7.38	28.52 ± 14.28	26.57 ± 12.48	.001*	>30 ng/mL
Calcium	9.40 ± .45	9.57 ± .41	9.65 ± .26	9.69 ± .30	<.001**	8.8–10.6 mg/dL
Sodium	139.92 ± 1.77	140.18 ± 1.97	140.94 ± 1.85	140.78 ± 1.64	.005*	136–146 mmol/L
Potassium	4.42 ± .24	4.41 ± .24	4.33 ± .34	4.39 ± .25	.590[1]	For men: 3.5–4.5 mmol/L
	6.26 ± 9.72	4.32 ± .40	4.28 ± .31	4.36 ± .29	.379[2]	For women: 3.4–4.4 mmol/L
Folic Acid	6.31 ± 3.16	8.66 ± 4.07	8.13 ± 2.90	8.08 ± 3.27	.001*	3–17 ng/mL
Vitamin B_{12}	355.94 ± 146.67	439.83 ± 181.24	461.87 ± 151.65	430.47 ± 124.45	<.001**	250–1100 pg/mL

*$P < .05$ **$P < .01$, P^1 differences between groups in men, P^2 differences between groups in women, p value: differences between time points (pre-op, after 1, 3, and 6 months); FPG: fasting plasma glucose, HbA1c: Hemoglobin A1c, HDL: high-density lipoprotein, LDL: low-density lipoprotein, ALT: Alanine aminotransferase, AST: Aspartate Aminotransferase, T3: Triiodothyronine T4: Thyroxine TSH: Thyroid Stimulating Hormone, PTH: parathyroid hormone.

Table 6
Energy and nutrients intake of patients before and after (1,3 and 6 months) sleeve gastrectomy.

	After 1 month		After 3 months		After 6 months		P value	
	Men (n = 20)	Women (n = 27)	Men (n = 20)	Women (n = 27)	Men (n = 20)	Women (n = 27)	P^1 value	P^2 value
Energy (kcal)	762.46 ± 173.21	684.58 ± 166.88	697.76 ± 144.22	675.60 ± 237.39	821.38 ± 223.14	675.11 ± 132.29	.148	.948
Total Protein (g)	64.27 ± 13.43	60.88 ± 17.26	48.19 ± 17.17	43.30 ± 16.66	56.97 ± 11.09	46.23 ± 13.21	.004*	<.001**
Carbohydrate (g)	52.88 ± 34.64	47.89 ± 29.03	38.04 ± 16.06	32.55 ± 13.39	42.38 ± 27.28	38.09 ± 14.62	.180	.016*
Sugar (g)	24.00 ± 12.40	23.33 ± 11.47	22.38 ± 10.69	19.98 ± 7.50	19.19 ± 9.74	17.80 ± 6.39	.097	.013*
Fat (g)	33.36 ± 7.92	30.47 ± 10.54	37.51 ± 8.39	33.23 ± 12.91	38.40 ± 10.72	32.83 ± 6.44	.269	.475
Saturated fatty acid (g)	17.32 ± 5.85	18.48 ± 9.19	16.05 ± 5.29	19.44 ± 5.33	15.71 ± 3.42	17.90 ± 3.96	.291	.119
MUFA (g)	9.53 ± 2.64	8.89 ± 3.31	11.14 ± 3.65	11.74 ± 3.36	15.16 ± 8.44	12.97 ± 5.82	.042*	.002*
PUFA (g)	4.78 ± 2.91	3.29 ± 2.52	5.26 ± 2.57	5.51 ± 4.87	4.73 ± 2.00	3.49 ± 1.25	.748	.079
Dietary cholesterol (g)	238.01 ± 126.20	216.07 ± 112.84	341.94 ± 174.88	311.75 ± 141.47	408.07 ± 157.82	317.30 ± 152.26	.001*	.002*
Fiber (g)	7.15 ± 1.09	7.55 ± 1.53	2.97 ± 2.27	3.09 ± 2.23	4.94 ± 4.53	4.20 ± 2.86	.001*	<.001**
Vitamin A (mg)	826 ± 711.25	893.20 ± 955.19	461.80 ± 220.86	560.90 ± 546.35	471.78 ± 126.25	448.35 ± 135.90	<.001**	.003*
Carotene (mg)	.78 ± .54	.88 ± .82	.79 ± 1.45	1.34 ± 1.95	.62 ± .44	.74 ± .73	.532	.363
Vitamin E (mg)	17.94 ± 4.72	18.52 ± 2.17	4.55 ± 1.11	4.80 ± 5.03	6.46 ± 4.19	4.45 ± 1.97	<.001**	<.001**
Vitamin C (mg)	52.89 ± 14.70	53.22 ± 14.23	22.44 ± 20.53	21.74 ± 12.97	28.33 ± 35.72	37.00 ± 37.57	<.001**	<.001**
Vitamin D (mg)	381.90 ± 89.83	401.49 ± 1.03	188.88 ± 93.00	166.67 ± 77.01	206.56 ± 141.18	168.89 ± 76.97	<.001**	<.001**
Vitamin B_1(mg)	1.02 ± .18	1.03 ± .78	.28 ± .06	.29 ± .16	.51 ± .24	.35 ± .17	<.001**	<.001**
Vitamin B_2 (mg)	1.80 ± .37	1.80 ± .43	1.08 ± .28	1.01 ± .40	1.13 ± .33	1.02 ± .24	<.001**	<.001**
Niacin (mg)	14.53 ± 4.73	14.13 ± 3.63	5.71 ± 2.87	10.11 ± 14.85	8.38 ± 2.75	6.96 ± 1.98	<.001**	<.001**
Vitamin B_6 (mg)	.50 ± .16	.44 ± .17	.57 ± .17	.56 ± .19	1.29 ± 2.51	.65 ± .23	.057	.002*
Vitamin B_{12} (mg)	9.35 ± 2.17	9.66 ± 1.30	5.55 ± 2.01	5.99 ± 2.01	5.75 ± 1.36	5.71 ± 1.38	<.001**	<.001**
Folate (mcg)	279.17 ± 51.20	287.54 ± 26.24	107.62 ± 51.38	99.07 ± 41.59	133.18 ± 46.32	115.09 ± 39.18	<.001**	<.001**
Calcium (mg)	703.91 ± 256.69	726.23 ± 301.23	565.08 ± 201.78	517.41 ± 215.02	532.16 ± 157.02	521.34 ± 131.25	.012*	<.001**
Magnesium (mg)	159.84 ± 25.43	143.74 ± 25.16	102.07 ± 19.38	96.66 ± 35.55	117.68 ± 54.90	106.71 ± 25.85	<.001**	<.001**
Iron (mg)	11.29 ± 2.10	11.34 ± .78	3.96 ± 1.65	4.02 ± 2.25	5.08 ± 1.45	4.48 ± 1.29	<.001**	<.001**
Zinc (mg)	10.83 ± 2.17	10.96 ± 1.39	5.67 ± 2.62	5.87 ± 2.35	6.43 ± 2.17	5.89 ± 1.95	<.001**	<.001**
Potassium (mg)	1298.44 ± 257.30	1164.73 ± 303.93	1102.36 ± 251.45	1070.45 ± 347.47	1224.98 ± 390.24	1163.62 ± 214.07	.009*	.330
Sodium (mg)	1018.40 ± 382.77	2346.54 ± 3007.69	1095.99 ± 433.24	890.99 ± 294.38	1107.07 ± 286.20	1029.75 ± 368.47	.583	.053
Phosphorus (mg)	688.49 ± 118.16	642.82 ± 204.87	767.01 ± 183.08	661.31 ± 210.20	780.89 ± 179.33	742.30 ± 190.40	.154	.070
Iodine (mg)	151.52 ± 32.65	155.43 ± 51.14	76.41 ± 25.52	89.66 ± 66.30	81.28 ± 26.76	73.84 ± 21.17	<.001**	<.001**

*$P < .05$ **$P < .01$, P^1 differences between groups in men, P^2 differences between groups in women.

4. Discussion

Obesity prevalence is increasing day by day worldwide, and given the increasing obesity and its complications, the incidence and prevalence of morbid obesity has increased substantially as well [5] and considering the effectiveness of bariatric surgeries in these patients, the number of individuals with morbid obesity will undergo bariatric surgery in the future. Therefore, it must know the understanding of the treatment of nutritional deficiencies that can arise after bariatric surgery. Nutritional deficiencies have been frequently reported after bariatric surgery and may affect the long-term health of bariatric patients [11,19,20]. Little is known about the nutritional status and optimal nutritional care plan after SG. The decreased dietary intake, as well as a degree of micronutrient malabsorption prevents patients from meeting their nutrient requirements from food alone. Adherence to micronutrient supplementation is therefore essential to prevent or treat nutrient deficiencies post-operatively [21]. Most of the patients in our study generally reported to be compliant with multi-vitamin and mineral supplementation; however, nutritional deficiencies were common after SG in the current study. In this study, mean energy, protein (except 1st month), fiber, vitamin A, vitamin E (except 1st month), vitamin C, vitamin B_1, vitamin B_2 (except 1st month), niacin, vitamin B_{12}, folate, calcium, magnesium, iron, zinc, phosphorus and iodine (except 1st month) were above the DRI recommendations.

Studies have shown that SG can provide rapid weight loss in a short time [22,23], It can increase the percentage of EWL by more than 72% after 12 months [24]. In another study showed that at the end of the 6th month after SG, the weight loss was 23 kg in both sexes [25]. In our study, body weight of the participants before SG was 134.90 ± 16.23 kg for men (BMI 42.15 ± 4.84 kg/m^2) and 112.25 ± 13.15 kg for women (BMI 41.44 ± 4.34 kg/m^2); body fat percentages were 42.12 ± 8.36% and 47.23 ± 4.08%, respectively. In our study, at the 6th month after SG, the weight loss was 38 kg in men and 30 kg in women. The present study confirms that for this group of patients, SG is a highly effective procedure regarding weight loss at short and medium term, and in fact, excess weight loss was greater when compared to other studies [22,23,25].

Bariatric surgery is caused lower energy intake in patients. Gjessing et al., showed that post-op daily energy intake was only about 700 kcal at 3 months and increased to 918 kcal at 12 months after surgery [24]. According to Verger et al., energy intake was found as 833 kcal and 1078 kcal, respectively [25]. Also, Coluzzi et al., indicated that energy intake was found 672 kcal after surgery at 1st month, 891 kcal at 3rd month and 971 kcal/day at 6th month [26]. In our study, while energy intake decreased at 3 months compared to 1 month after SG, it increased in men at 6 months but showed similar mean values in women. Energy intake was 762.46 ± 173.21 kcal in men and 684.58 ± 166.88 kcal in women at 1st month after SG; at 3rd months, it was 697.76 ± 144.22 kcal and 675.60 ± 237.39 kcal respectively, and at 6th months, it was 821.38 ± 223.14 kcal and 675.11 ± 132.29 kcal, respectively. According to the data despite being primarily a restrictive procedure, SG patients are at risk for long-term nutritional deficiencies due to the combination of reduced food intake, decreased hydrochloric acid and intrinsic factor secretion, vomiting, poor food choices, and food intolerance [27]. Low energy intake indicates that post-operative patients need a more detailed diet plan and dietary supplement to ensure adequate nutrition.

A low protein intake following SG has previously been described. The mean of protein intake after SG was 41.2 g/day at 3rd month and 51.8 g/day at 12 months was observed by Verger et al. [25]. Coluzzi et al., showed that the mean protein intake was 39 g/day, after SG at 3rd month and 54 g/day at 6th month [26]. In our study, daily protein intake 64.27 ± 13.43 g in men and

60.88 ± 17.26 g in women at 1st month, 48.19 ± 17.17 g and 43.30 ± 16.66 g after 3 months, and 6 months after, 56.97 ± 11.09 g and 46.23 ± 13.21 g, respectively. According to the American Association of Clinical Endocrinologists (AACE) clinical practice guideline, the mean protein intake 46 g/day for women and 56/day for men are the recommended values for these patients [28]. Our results are similar to the previous studies, and protein intake after SG was enough for the last guideline.

Loss of FFM is undesirable as non-adipose tissues are responsible for the majority of function as the body ages [29]. Studies have also suggested that higher protein intake (80–90 g/day) is associated with lower FFM loss, but Andreu et al., showed protein intake ≥60 g/kg was not associated with FFM [29–31]. Also, the last AACE guideline, recommended that protein intake is 50 g/day for men and 46 g/day for women [28]. In our study, protein intakes of patients were within the recommended ranges in guideline after SG and protein intake ≥60 g/day was associated with lower FFM but there was no significant difference except for at 6th month after SG. After SG at 6th month, a significant association was found between protein intake and FFM loss in all genders. Our study suggested that the protein intake goal of ≥60 g/day is an effective strategy for lower FFM loss after SG.

Macronutrient deficiencies are not common after SG. According to Verger et al., total carbohydrate intake was found as 37.4 g/day at the 3rd month and 42.4 g/day at 12 months after SG [25]. In another study, carbohydrate intake was found 38.6 g/day at 1st month, 55.7 g/day at 3rd month and 105.7 g/day at 6th month after SG [26]. In our study, the mean carbohydrate intake was 52.88 ± 34.64 g in men, 47.89 ± 29.03 g, in women at 1st month; 38.04 ± 16.06 g and 32.55 ± 13.39 g, respectively at 3rd months; and 42.38 ± 27.28 g and 38.09 ± 14.62 g, respectively at 6th months after SG. Sugar consumption decreased in every visit. Although our study was similar to the previous studies for the 3rd month after SG, carbohydrate intakes were lower than recommended in both sexes except men after SG at 1st month [28].

The limited study evaluated the fiber intake. In one study, the mean fiber intake was 7 g/day at 1st month, 11 g/day at 3rd month and 10 g/day at 6th month after SG [26]. In our study, the mean fiber intake was 7.15 ± 1.09 g in men and 7.55 ± 1.53 g in women at 1st month, 2.97 ± 2.27 g and 3.09 ± 2.23 g, respectively at 3rd month and 4.94 ± 4.53 g and 4.20 ± 2.86 g, respectively at 6th month after SG. Fiber intake was found to be quite low compared to DRI [18]. As known, fiber can improve satiety and reduce the cholesterol level. In this study, cholesterol intake was higher compared to DRI. Although serum cholesterol levels were within the reference values, they were close to the upper limit. Therefore, these patients may require fiber supplements.

In our study, vitamin C intakes were 52.89 ± 14.70 mg in men and 53.22 ± 14.23 mg in women at 1st month; 22.44 ± 20.53 mg and 21.74 ± 12.97 mg at 3rd month; 28.33 ± 35.72 mg and 37.00 ± 37.57 mg respectively at 6 months after SG. Guan et al., showed the same results, vitamin C intakes were lower after SG than pre-op [14]. In addition, insufficient intake of fruits and vegetables may affect vitamin C intake [32].

The worsening hypovitaminosis A after SG alone is not clearly defined. According to the recent AACE guideline [28], vitamin A levels were shown to be low in 70% of patients, even after an average of 4 years. Caron et al., noted that the mean vitamin A intake decreased after the 3rd month after SG [33]. In our study, while mean vitamin A intakes were close to DRI at 1 month (826 ± 711.25 mg in men, 893.20 ± 955.19 mg in women), it decreased at 3 months (461.80 ± 220.86 mg in men, 560.90 ± 546.35 mg in women), and a slight increase in men and decreased in women at 6th month after SG (471.78 ± 126.25 mg in men, 448.35 ± 135.90 mg in women). Our results showed that there was a temporarily increased prevalence of vitamin A insufficiency immediately after SG. This might be explained by reduced total food intake in the first months post-op. A routine dose of vitamin A is currently recommended within the first post-operative year, but our results show that it might be beneficial to do so earlier, especially in the first months after SG [13].

According to the last AACE guideline, the prevalence of vitamin B_{12} deficiency is in the range of 4–20%, 2–5 years after SG [28]. Analysis of total serum vitamin B_{12} levels was found between reference values. In a study, serum vitamin B_{12} levels showed a significant decrease at 6 months after SG [34]. Guan et al., found that 345.8 pg/mL at 2nd month and 370.0 pg/mL at 6th month after SG [14]. In another study conducted by Dagan et al., although serum B_{12} levels were within the reference range, a decrease in food intake was observed [15]. In our study, serum vitamin B_{12} levels were within the reference values and found a significant decrease in nutritional intake of B_{12} especially at the 3rd month after SG. Some potential mechanisms play a role after SG, such as food intolerance, poor food choices, decreased food intake, and postoperative nausea and vomiting [35].

It is well described that obese people are predisposed to vitamin D deficiency [36]. The theory is reduced bioavailability of vitamin D because of sequestration by adipose tissue [37]. In addition, vitamin D deficiency in the body reduce the intestinal absorption of calcium, however, SG does not exclude any segment of the small bowel therefore, it is expected to not decrease the micronutrient absorption [38,39]. Damms-Machado et al., found that patients after SG have vitamin D deficiency and, calcium deficiency in 5% of patients in the first month after SG was observed [40]. Other studies showed that the serum levels of calcium were normal after SG [12,41]. In our study, the mean vitamin D levels were found to be lower before and after SG and the mean calcium intake was lower than DRI however, serum levels are in the reference values [18]. This may be due to increased calcium absorption and serum levels as a result of supplementing patients with vitamin D deficiency.

Iron deficiency is common after bariatric surgery and although the most used treatment of iron deficiency is a vitamin-mineral supplement (routinely used in these patients). IV therapy is the most efficient treatment, but if iron deficiency is seen in the biochemical tests performed after the 1st month of BS, IV therapy is used by the doctor [42]. Gehrer et al., detected iron deficiency after SG in 3% of patients [12]. Guan et al., showed that although the levels of serum iron were slightly lower, they were in reference values, dietary intake was found to be lower [14]. In our study, serum iron levels were lower only in women before SG, while no decrease was observed in both sexes after SG; but their dietary intake decreased significantly, especially after SG at 3rd month. Also, plasma iron, iron-binding capacity and total protein levels were slowly decreased after SG, but the values were near to the reference values. In addition, studies have shown that the value of ferritin is more specific to describe anemia [12,42]. In our study, ferritin levels increased compared to the pre-op. This could be the result of supplementation.

5. Conclusion

Nutrition deficiencies are common for patients after SG. Preoperative nutritional abnormalities can contribute to the postoperative nutrient balance. Therefore, it is important to routinely monitor these patients with a professional team. The presence of a dietitian specialized in this field is indispensable in this team and it is important in ameliorating the nutritional status. In addition, the decreased dietary intake, as well as a degree of micronutrient malabsorption prevents patients from meeting their nutrient requirements from food alone. Micronutrient supplementation is essential to prevent or treat nutrient deficiencies post-operatively.

Authorship statement

Batar, Pulat-Demir and Bayram had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Concept and design: Pulat-Demir and Bayram. Acquisition, analysis, or interpretation of data: All authors. Drafting of the manuscript: Pulat-Demir and Bayram. Critical revision of the manuscript for important intellectual content: All authors. Statistical analysis: Bayram. Administrative, technical, or material support: Batar. Supervision: Batar and Pulat-Demir.

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Declaration of competing interest

None of the authors has any conflict of interest to declare in relation to this quality improvement project.

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