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Research Article
Effects of Weight Loss Percentage on Vitamin and Mineral Levels in Patients Undergoing Sleeve Gastrectomy

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Abstract
Background and Objective: The prevalence of obesity has increased rapidly in the past 30 years worldwide. In line with this, bariatric surgery, one of the common treatment methods, has become more frequent. Bariatric surgery could be associated with nutritional deficiencies. The aim of this study was to determine the effect of weight loss percentages on some micronutrient levels in patients undergoing Sleeve Gastrectomy. **Materials and Methods:** The study was conducted as a retrospective clinical research on 41 obese patients who underwent laparoscopic sleeve gastrectomy (LSG) in a private hospital in Antalya/Turkey. Clinical findings and anthropometric measurements were evaluated at 4 different time points. **Results:** Vitamin D, vitamin B12, folic acid, sodium, potassium, calcium, phosphorus, iron and magnesium mean values increased compared to pre-operative measurements. Only zinc values linearly decreased, but the mean values were not measured at deficiency in any month. There was a significant negative correlation in between the change of folic acid levels and the change of weight loss percentages from pre-operative to post-operative 1st month measurements. **Conclusion:** In this study, when the micro nutrients were evaluated alone, without consideration of the weight change, only the level of zinc decreased. In patients with high weight loss rates, the decrease in folic acid values was statistically significant for the post-operative 1st month measurements. Considering this result, folic acid supplements in larger amounts may be recommended to eliminate this risks that may occur in people who lose weight faster. Based on this result, the relationship between folic acid levels according to weight loss percentages should be examined in more detail.

Key words: Obesity, sleeve gastrectomy, micro nutrient deficiency, weight loss, folic acid, anthropometric measurements

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Obesity is a chronic disease related to increased body mass by many causes. The prevalence has increased rapidly in the past 30 years[1]. Worldwide estimates declared that there were over 500 million obese people above the age of 18 years. Therefore, research on treatment methods related to obesity has gained importance[2]. Treatment of obesity is not an easy process. The treatments have demonstrated limited sustainable weight management efficacy with diet, exercise, behavioral changes, medical treatment and pharmacotherapy. With these treatment methods, loss of 5-10% of initial body weight is often observed[3,4]. When all treatment methods were evaluated, obesity treatment required a multi disciplinary approach. Several other tests are needed besides anthropometric measurements. To find out the nutritional status and co-morbidities of patients and to assess the scope of therapy, biochemical evaluation and history of patients are required. All of these in combination can give the health risk profile of patients[5]. Before it was realized that SG was highly efficient, after which it has been used as a primary surgery, it was the first step before more complicated procedures such as biliopancreatic diversion and gastric bypass in patients with a BMI above[6] 60 kg m^{-2}. In recent years, bariatric surgery has become the gold standard treatment for morbid obesity. It showed better results compared to other clinical treatments[7]. With a reported weight loss range of 12-39% or an excess body weight loss of 40-71%, bariatric surgery has recently become the gold standard treatment for morbidly obese patients[8]. There are different types of bariatric surgery and all types modify the structure of the digestive system. All interventions cause either restrictive or malabsorptive effects, or both[9,10].

It is thought that bariatric surgery may exacerbate the existing deficiencies or lead to a decrease in normal micronutrient levels[11]. Laparoscopic sleeve gastrectomy (LSG) is a restrictive surgical method where a curved portion of the stomach is resected and a tube shape stomach remains[12]. LSG reduces food intake via many factors and thus reduce the body weight[13]. The aim of restrictive methods is to reduce the food consumed, thus reducing the volume of the stomach and achieving weight loss. LSG is one such example, where the food capacity of the stomach is restricted to provide early filling of the stomach. Malabsorptive methods, on the other hand, aim at altering the anatomy of the intestines to limit nutrients and lead to an earlier feeling of satiety, therefore reducing calorie intake[14]. LSG is performed to provide weight loss by restricting the food capacity of the stomach and early stomach filling[15]. Lazzati *et al.*[16] found an excess weight loss of 66% comparable to the general population for 2 years. In vertical SG, the most commonly applied operation, perioperative mortality range was similar to the general population. Boza *et al.*[17] reported LSG to be a safe and beneficial stand-alone method for morbidly obese patients. While other methods bypass the intestine and are more invasive, LSG does not do so and has been estimated to minimally affect micronutrient levels[18]. However, the operation includes removing the area that secretes important enzymes and co-factors for nutrient[19]. Thus, it could involve the risk of micronutrient-related mal-absorption. Moreover, the fact that nutrients pass more rapidly through the stomach after LSG may harden their absorption in the stomach. Common nutritional deficiencies following bariatric surgery include vitamin B12, iron, folate, calcium and vitamin D[20-22]. In their study, Parrott *et al.*[23] recommended the daily doses of micronutrient supplementation to complement these deficiencies after LS.

In this direction, the aim of this study was to determine the changes in vitamin and mineral values according to weight loss percentages after laparoscopic sleeve gastrectomy (LSG).

MATERIALS AND METHODS

Ethical approval: Ethic committee code is 2012-KAEK-20 and decision number is 458.

Study area: The data were collected from 41 patients between January, 2016 and February, 2018 in a private hospital (Antalya LA Hospital) in Antalya/Turkey.

Study design: In this study, a retrospective data analysis, weight loss percentages and some biochemistry values were determined. The effects of weight loss percentages on changing some vitamin and mineral values were investigated. Blood tests and body mass index measurements were performed in the pre-operative period and post-operative 1st, 3rd and 6th months. Pre-operative measurements were usually performed 1 day before surgery. The data were collected from 41 patients between January 15, 2016 and 2018. The percentage of weight loss was calculated by dividing the total weight loss of the patients in the 1st, 3rd and 6th months by their initial weight and multiplying by 100.

The evaluated blood test parameters included vitamin D, B12, folic acid, sodium, potassium, calcium, zinc, magnesium, phosphorus, iron and in addition to these vitamins and minerals, uric acid, glucose, hemoglobin A1c (HbA1c), parathyroid hormone (PTH), thyroid stimulating hormone (TSH), albumin, total cholesterol, high density lipoprotein (HDL), low density lipoprotein (LDL) and triglyceride values.

The deficiencies detected in the tests were examined and the necessary treatments were applied. Apikobal® tablet (Santa Farma, Turkey) was used in cases of vitamin B deficiency, Devit-3® ampules (Deva Holding, Turkey) were used for vitamin D deficiency, Magnorm® tablets (Vitalis, Turkey) were used for magnesium deficiency, Ferro Sanol® capsule (Adeka, Turkey) was used for iron deficiency, Zinco® capsule (Berko, Turkey) was used for zinc deficiency, Folbiol® tablets (I.E. Ulagay, Turkey) were used for folic acid deficiency, Calcimax-D3® effervescent tablet (Basel, Turkey) was used for calcium deficiency and Dodex® ampul (Deva Holding, Turkey) was used for B12 deficiency. Nutritional supplements and protein pump inhibitors were prescribed to each patient. A protein supplement was given at 60-80 g daily postoperatively for at least 2 months. Protifar® 225 g (Nutricia, Netherlands) was used as a protein supplement. Pharmaton® Multivitamin (Sanofi, Sweden) and Polivit Syrup® (Abdi İbrahim, Turkey) were used as nutritional supplements. Pharmaton was used after surgery at least for 1 year and as one capsule per day. Polivit syrup was used after surgery at least for 1 month and as 15 mL/day.

Department of nutrition and dietetics in Hacettepe University has determined the daily reliable recommended vitamins, mineral intake levels[10] for Turkey in 2015. In this direction, calculate the daily percentage of vitamins and minerals provided by Polivit Syrup and Pharmaton capsule according to age ranges and sex (Table 1 and 2).

Table 1: Content of polivit syrup

	Daily requirements of Turkey (11)						Supplied percentages by polivit syrup (15 mL)					
	Gender											
	Female			Male			Female			Male		
Parameters												
Age	19-30	31-50	51-65	19-30	31-50	51-65	19-30	31-50	51-65	19-30	31-50	51-65
Vitamin A (µg)	700	700	700	900	900	900	*	*	*	*	*	*
Vitamin B1 (mg)	1.1	1.1	1.1	1.2	1.2	1.2	*	*	*	*	*	*
Vitamin B2 (mg)	1.0	1.1	1.1	1.3	1.3	1.3	*	*	*	*	*	*
Vitamin B6 (mg)	1.3	1.3	1.3	1.3	1.3	1.7	*	*	*	*	*	*
Vitamin C (mg)	90	90	9	90	90	90	83	83	83	83	83	83
Vitamin D3 (µg)	10	10	10	10	10	10	*	*	*	*	*	*
Vitamin E (mg)	15	15	15	15	15	15	*	*	*	*	*	*

*All needs are supplied

Table 2: Content of pharmaton capsule

	Daily requirements of Turkey (11)						Supplied percentages by pharmaton (1 capsule)					
	Gender											
	Female			Male			Female			Male		
Parameters												
Age	19-30	31-50	51-65	19-30	31-50	51-65	19-30	31-50	51-65	19-30	31-50	51-65
Vitamin A (µg)	700	700	700	900	900	900	*	*	*	89	89	89
Vitamin C (mg)	1.1	1.1	1.1	1.2	1.2	1.2	*	*	*	92	92	92
Vitamin E (mg)	1.0	1.1	1.1	1.3	1.3	1.3	*	*	*	*	*	*
Vitamin B3 (niacin) (mg)	1.3	1.3	1.3	1.3	1.3	1.7	*	*	*	*	*	*
Vitamin B6 (pyridoxine) (mg)	90	90	90	90	90	90	67	67	67	67	67	67
Vitamin B2 (riboflavin) (µg)	10	10	10	10	10	10	50	50	50	50	50	50
Vitamin B1 (thiamine) (mg)	15	15	15	15	15	15	80	80	80	80	80	80
Vitamin B12 (cobalamin) (mg)	14	14	14	16	16	16	*	*	*	*	*	*
Vitamin D (µg)	2.4	2.4	2.4	2.4	2.4	2.4	*	*	*	*	*	*
Folic acid (µg)	400	400	400	400	400	400	50	50	50	50	50	50
Biotin (µg)	30	30	30	30	30	30	*	*	*	*	*	*
Calcium (mg)	1000	1000	1200	1000	1000	1200	12	12	10	12	12	10
Iron (mg)	18	18	10	10	10	10	58	58	*	*	*	*
Manganese (mg)	1.8	1.8	1.8	2.3	2.3	2.3	*	*	*	87	87	87
Zinc (mg)	10	10	10	11	11	11	15	15	15	14	14	14
Copper (µg)	900	900	900	900	900	900	*	*	*	*	*	*
Selenium (µg)	55	55	55	55	55	55	*	*	*	*	*	*

*All needs are supplied

Patients were selected according to the appropriate criteria for this study. Surgery date, age, complete blood and anthropometric measurements as body mass index (BMI) and co-morbidities were evaluated for the inclusion criteria. We considered height and weight as body composition parameters. In the process, Jawan GAIA Plus was utilized for weight measurements and Secca for height measurements. Patients who underwent surgery before February 1st 2018, were weighed and those who completed blood tests (pre-operative and post-operative 1st, 3rd and 6th month) and who were aged 18-65 and whose BMI was >35 kg m^{-2} with comorbid disease (Diabetes, hypertension, sleep apnea and severe joint disorders were evaluated as comorbid diseases) and BMI >40 kg m^{-2} with no comorbidities were included in the study.

Statistical analysis: For statistical analysis, NCSS (Number Cruncher Statistical System) 2007 (Kaysville, Utah, USA) software was used. For the evaluation of the non-normally distributed variable data Friedman test was used, while Wilcox on Signed Ranks test was used for paired comparison evaluation. Spearman's Correlation Analysis method was used for the evaluation of the correlation between the non-normally distributed variables. The p-level of 0.05 was taken as the min level to have a meaningful data result. The p<0.05 was considered significant.

RESULTS

The data of a total of 41 patients, 78% (n = 32) female and 22% (n = 9) male, who had undergone LSG surgery in a private hospital between January 15th, 2016 and February 1st, 2018, were used in the study. The ages of the patients ranged from 18-58 years and the mean value was 40.66±11.10. Pre-operative and post-operative 1st, 3rd and 6th months weight measurements were evaluated and the change was statistically significant (p = 0.001, p = 0.001, p = 0.001, p<0.01, respectively). The decrease in post-operative 3rd and 6th month weight measurements compared to 1st month measurements were statistically significant (p = 0.001, p = 0.001, p<0.01 respectively). The decrease in weight measurements at the 6th month were also statistically significant compared to the 3rd month (p = 0.001, p<0.01) (Table 3).

As a result of paired comparisons, the decreases in post-operative 1st, 3rd and 6th month BMI measurements statistically significant compared to pre-operative measurement (p = 0.001, p = 0.001, p = 0.001, p<0.01, respectively). The decreases in the post-operative 3rd and 6th month BMI measurements were also statistically significant compared to post-operative 1st month measurements (p = 0.001, p = 0.001, p<0.01, respectively). The decrease in BMI measurement at the post-operative 6th month was also statistically significant compared to the post-operative 3rd month (p = 0.001, p<0.01) (Table 4).

As a result of paired comparisons, the increases in post-operative 1st, 3rd and 6th month vitamin D measurements were statistically significant compared to pre-operative measurements (p = 0.001, p = 0.001, p = 0.005, p<0.01, respectively). The decrease in vitamin D values at the post-operative 6th month were also statistically significant compared to the post-operative 3rd month (p = 0.034, p<0.05). The decreases in vitamin B12 values at the post-operative 3rd and 6th months were also statistically significant compared to the pre-operative values were (p = 0.001, p = 0.001, p<0.01, respectively). The decrease in vitamin B12 values at the post-operative 6th month was also statistically significant compared to the post-operative 3rd month (p = 0.021, p<0.05). The folic acid changes were not statistically significant in paired comparisons (p>0.05). The increases in post-operative 1st and 3rd month sodium values were statistically significant compared to the pre-operative

Table 3: Evaluation of weight measurements in follow-up

Parameters	Treatments	Min-Max (median)	Mean±SD
Weight (kg)	Pre-op	84.9-198.7 (114.7)	118.31±23.11
	Post-op 1st month	75.4-184 (103.2)	104.35±22.51
	Post-op 3rd month	64.0-166.9 (88.3)	91.48±20.78
	Post-op 6th month	57.1-144 (77.1)	81.35±18.08
[a]p		0.001**	
Paired comparisons	Pre-op-post-op 1st month	0.001**	
[b]p	Pre-op-post-op 3rd month	0.001**	
	Pre-op-post-op 6th month	0.001**	
	Post-op 1st month-3rd month	0.001**	
	Post-op 1st month-6th month	0.001**	
	Post-op 3rd month-6th month	0.001**	

[a]Repeated measures test, [b]Adjustment for multiple comparisons: Bonferroni, **p<0.01, Pre-op: Pre-operative, Post-op: Post-operative

Table 4: Evaluation of BMI measurements in follow-up

Parameters	Treatments	Min-Max (median)	Mean±SD
BMI (kg m^{-2})	Pre-op	35.3-68.8 (42.8)	44.08±7.17
	Post-op 1st month	29.0-63 1(37.1)	38.89±7.13
	Post-op 3rd month	24.5-57.4 (33)	34.09±6.70
	Post-op 6th month	22.6-50.8 (28.8)	30.28±6.01
[a]p		0.001**	
Paired comparisons	Pre-op-post-op 1st month	0.001**	
[b]p	Pre-op-post-op 3rd month	0.001**	
	Pre-op-post-op 6th month	0.001**	
	Pre-op-post-op 1st month- 3rd month	0.001**	
	Pre-op-post-op 1stmonth-6th month	0.001**	
	Pre-op-post-op 3rd month-6th month	0.001**	

[a]Repeated measures test, [b]Adjustment for multiple comparisons: Bonferroni, **p<0.01

Table 5: Evaluation of micronutrient values

		Patient values (Mean±SD)				
Micronutrients	Reference ranges	Pre-operative	1st month	3rd month	6th month	p-values
Vitamin D 25-OH (ng mL^{-1})	<20, 20-29, 30-100	26.61±21.26	33.22±20.05	40.32±40.32	33.76±11.40	0.001**
Vitamin B12 (pg mL^{-1})	187-833	286.29±103.69	428.34±130.77	359.15±135.12	311.49±121.26	0.001**
Folic acid (ng mL^{-1})	3.1-20.5	7.14±3.36	8.11±3.28	8.27±3.81	8.75±5.03	0.565
Sodium (mmol L^{-1})	136-145	138.95±1.70	141.12±1.75	140.95±1.58	140.47±3.10	0.001**
Potassium (mmol L^{-1})	3.5-5.1	4.41±0.32	4.35±0.40	4.64±0.35	4.640±0.36	0.001**
Calcium (mg dL^{-1})	8.4-10.2	9.51±0.35	9.50±0.36	9.53±0.40	9.53±0.39	0.307
Zinc (μg dL^{-1})	70-130	86.36±11.97	85.58±16.49	72.80±16.58	72.80±14.96	0.001**
Magnesium (mg dL^{-1})	1.6-2.6	2.03±0.35	1.94±0.18	2.48±0.19	2.48±2.89	0.020**
Phosphorus (mg dL^{-1})	2.3-4.7	3.28±0.45	3.55±0.59	3.83±0.53	3.83±0.48	0.001**
Iron (μg dL^{-1})	50-170	64.41±28.38	63.40±25.27	81.82±28.67	81.82±32.57	0.001**

**p<0.01

value (p = 0.001, p = 0.001, p<0.01, respectively). The increase in post-operative 6th month value was statistically significant compared to pre-operative and post-operative 1st and 3rd month values (p = 0.002, p = 0.005, p = 0.009, p<0.01, respectively). The decrease in post-operative 6th month zinc values were statistically significant compared to pre-operative and post-operative 1st month values (p = 0.001, p = 0.001, p<0.001). The values decreased linearly, but the mean values were not valued as zinc deficiency in any month. The increases in post-operative 3rd and 6th month magnesium values statistically significant compared to post-operative 1st month value were (p = 0.027, p = 0.018, p<0.05, respectively).

The increases in post-operative 1st, 3rd and 6th month phosphorus values were statistically significant compared to pre-operative values (p = 0.018, p = 0.001, p = 0.001, p<0.05, respectively).

The increases in post-operative 3rd and 6th month iron measurements were statistically significant compared to pre-operative value (p = 0.047, p = 0.010, p<0.05, respectively). The numerical data of all investigated micronutrients are given in Table 5.

According to blood tests, patients were classified at deficiency, insufficiency and optimal value ranges. The percentage was calculated according to the number of people in these value ranges. This method was evaluated separately for each measurement period. All numbers are shown in Table 6.

The relationship between micronutrient levels weight loss change and weight loss change was examined in 4 time intervals. The relationship between micronutrients and weight loss change was examined in four-time intervals. The correlation data and time intervals are given in Table 7.

In Table 7, the correlation of the weight loss percentages and vitamin and mineral differences were evaluated. Correlation coefficient (r) indicates the degree of correlation between any two values. The coefficient sign, '-', defines a negative correlation and coefficient sign, '+' defines a positive correlation. There was no statistically significant correlation between the pre-operative and post-operative 1st month weight loss percentages, the changes in vitamin D, vitamin B12, sodium, potassium, calcium, zinc, magnesium, phosphorus and iron measurements (p>0.05). There was a statistically significant negative correlation between the pre-operative and post-operative 1st month weight loss percentages and the changes in folic acid measurements (r = -0.347, p = 0.026, p<0.05). There was no statistically significant correlation between the pre-operative and post-operative 3rd month weight loss percentages, the

Table 6: Pre-post operative micronutrient status by month

		Number				Percentage			
Micronutrients	Status	Pre-op	1st month	3rd month	6th month	Pre-op	1st month	3rd month	6th month
Vitamin D 25-OH (ng mL^{-1})	Deficiency	19	8	2	2	46.3	20.0	4.9	4.9
	Insufficiency	13	14	12	15	31.7	35.0	29.2	36.6
	Optimal	9	19	27	24	22.0	45.0	65.9	58.5
Vitamin B12 (pg mL^{-1})	Deficiency	8	0	2	5	19.5	0.0	4.9	12.2
	Optimal	33	41	39	36	80.5	100.0	95.1	87.8
Folic acid (ng mL^{-1})	Deficiency	1	1	3	2	2.4	2.4	7.3	4.9
	Optimal	40	40	38	39	97.6	97.6	92.7	95.1
Sodium (mmol L^{-1})	Deficiency	0	0	0	1	0.0	0.0	0.0	2.4
	Optimal	41	41	41	40	100.0	100.0	100.0	97.6
Potassium (mmol L^{-1})	Deficiency	0	0	0	0	0.0	0.0	0.0	0.0
	Optimal	41	41	41	41	100.0	100.0	100.0	100.0
Calcium (mg dL^{-1})	Deficiency	0	0	1	0	0.0	0.0	2.4	0.0
	Optimal	41	41	40	41	100.0	100.0	97.6	100.0
Zinc (µg dL^{-1})	Deficiency	1	9	12	17	2.4	22.0	29.3	41.5
	Optimal	40	32	29	24	97.6	78.0	70.7	58.5
Magnesium (mg dL^{-1})	Deficiency	1	3	0	0	2.4	7.3	0.0	0.0
	Optimal	41	38	41	41	97.6	92.7	100.0	100.0
Phosphorus (mg dL^{-1})	Deficiency	0	0	0	0	0.0	0.0	0.0	0.0
	Optimal	41	41	41	41	100.0	100.0	100.0	100.0
Iron (µg dL^{-1})	Deficiency	12	15	7	6	29.3	36.6	17.1	14.6
	Optimal	29	26	34	35	70.0	63.4	82.9	85.4

Table 7: Relation between changes in weight loss percentages and micronutrient levels

	Pre-operative post-operative time (month)			
Micronutrients	1st	3rd	6th	Post-operative 1-6 month
Vitamin D 25-OH (ng mL^{-1})	r = 0.121	0.045	0.021	-0.148
	p = 0.449	0.781	0.896	0.355
Vitamin B12 (pg mL^{-1})	r = -0.222	0.010	0.028	0.304
	p = 0.163	0.953	0.860	0.054
Folic acid (ng mL^{-1})	r = -0.347	0.080	0.180	0.205
	p = 0.026*	0.620	0.359	0.198
Sodium (mmol L^{-1})	r = -0.250	-0.122	-0.110	0.075
	p = 0.115	0.448	0.498	0.642
Potassium (mmol L^{-1})	r = 0.250	-0.053	-0.143	-0.049
	p = 0.114	0.744	0.372	0.763
Calcium (mg dL^{-1})	r = 0.078	-0.062	0.083	0.053
	p = 0.626	0.701	0.607	0.740
Zinc (µg dL^{-1})	r = 0.164	0.237	0.116	0.128
	p = 0.306	0.135	0.469	0.425
Magnesium (mg dL^{-1})	r = 0.183	0.041	0.081	-0.093
	p = 0.252	0.798	0.651	0.563
Phosphorus (mg dL^{-1})	r = 0.185	0.006	0.002	0.144
	p = 0.248	0.972	0.989	0.370
Iron (µg dL^{-1})	r = 0.057	0.252	-0.036	-0.150
	p = 0.726	0.112	0.821	0.350

Mann Whitney U test, *p<0.05, -: Negative correlation

changes in vitamin D, vitamin B12, folic acid, sodium, potassium, calcium, zinc, magnesium, phosphorus and iron measurements (p>0.05). There was no statistically significant correlation between the post-operative 1st month and post-operative 6th month weight loss percentages and the changes in vitamin D, vitamin B12, folic acid, sodium, potassium, calcium, zinc, magnesium, phosphorus and iron values (p>0.05). There was no statistically significant correlation between the post-operative 1st month and post-operative 6th month weight loss percentages and the changes in vitamin D, vitamin B12, folic acid, sodium, potassium, calcium, zinc, magnesium, phosphorus and iron measurements (p>0.05).

There was a positive correlation between vitamin B12 values (as percentage of weight loss increases, percentage changes in vitamin B12 also increase). Although this was not statistically significant, but it was found to be close to significant (r = 0.304, p = 0.054, p>0.05).

DISCUSSION

The study population consisted of 41 patients as 78% (n = 32) female and 22% (n = 9) male. The patients in this study were aged between18-58. The mean age of the patients was 40.66±11.10. When the BMI values of the patients included in the study were examined, the lowest value was calculated as 35.3 kg m^{-2} and the highest value as 68.8 kg m^{-2}. The mean BMI of the patients was 44.08±7.17 kg m^{-2}. A negative correlation was found between weight loss and folic acid values.

Even though many models exist to predict successful body weight loss and absolute body weight after bariatric surgery, no models are certain. Furthermore, models that aim to predict minimal weight loss are limited. Even between these models, there is a lack of a standard determination of how to measure minimal weight loss[24]. We observed that the mean change in BMI (kg m^{-2}) was 13.85 kg m^{-2} in our study. In a systematic review and meta analysis study, mean change in BMI (kg m^{-2}) at the 6th month after SG surgery was -11.5 (-8.8, -14.2). So, the values were approximately similar to our values[25]. Lee *et al.*[26] stated that changes in mean weight results in 6 months after SG in the Medicare-eligible population (n = 48) as 23.5 kg of weight lost, 7.8 of BMI reduction (kg m^{-2}) and 18.5 of weight loss percentage. Vitamin B12, iron, folate, calcium and vitamin D are the most frequent nutritional deficiencies after bariatric surgery. Luger *et al.*[21] and Williams[22] reported these deficiencies should be detected early and treated to prevent post-operative complications. In this study, results showed that frequent follow-up and nutritional support were safe in patients with SG. On the other hand, some researchers defend that SG does not lead to malabsorption, thus no subsequent need for nutritional supplementation[27]. The mean value of vitamin D in our study was found class of deficiency according to biochemical references. The optimization of vitamin D levels may be interpreted as the effect of weight loss or supplementation. Daily vitamin D requirement depends on body weight, season and sensitive sunlight. Thus, Holick *et al.*[28] stated that optimization in vitamin D levels may be related to both oral supplementation and reduction in daily requirements as patients lost weight. A cross-sectional study in China showed a significant adverse association between 25(OH) D levels and waist circumference and waist-to-hip ratio. Results showed that adiposity was related to low 25(OH) D levels[29,30]. There was no correlation between the changes of vitamin B12 levels and weight loss percentages. There were no mean values under the biochemical range defined as deficiency in any month in this study. ASMBS Integrated Health Nutritional Guidelines have reported that the prevalence of B12 deficiency to be 2-18% in patients with obesity and the prevalence of B12 deficiency post bariatric surgery (BS) at 2-5 years to be <20% in roux-en-Y gastric bypass (RYGB) and 4-20% in SG[23]. Reduction of the amount of hydrochloric acid produced and the rapid passage of nutrients through the stomach may make it difficult to absorb iron in the stomach after LSG[15,31]. On the contrary previous references, in this study, after the 1st month the iron values increased. There were no mean values under the biochemical range as deficiency in any month. In a previous study, approximately 63% of the patients were reported to have pre-operative deficiencies in either iron or zinc or water-soluble vitamins and these deficiencies were observed postoperatively as well. The given oral supplementation of multivitamin was effective in about 30% of patients after SG[15]. In a study by Gregory *et al.*[32], post-LSG weight was negatively correlated with 25(OH) D at the 6th, 12th and 18th months (r = -0.31, -0.32 and -0.41, respectively) and calcium at the 18th month (r = -0.24). All significant correlations were weak except for the moderate associations with 25(OH) D. In a study conducted with 200 people, 24% deficiency in folic acid was found preoperatively. In the same study, 12.5% deficiency and 6% de novo deficiency in folic acid was found postoperatively[33]. When we evaluated our results, pre-operative and post-operative 1st, 3rd and 6th month deficiency of folic acid percentages were 2.4, 2.4, 7.3 and 4.9%, respectively. In the results of the correlation analysis according to weight loss percentages, only folic acid change was significant compared to the post-operative 1st month.

CONCLUSION

In conclusion, the results of this study showed that weight loss and BMI decreases were achieved as expected. In this study, nutritional supplements recommended for patients before and after surgery corrected the deficiencies, except for zinc. Vitamin D, vitamin B12, folic acid, sodium, potassium, calcium, phosphorus, iron and magnesium values were increased compared to pre-operative measurements. This result reveals the importance of periodic monitoring for patients undergoing SG. When correlations between the change rate of all micronutrients and the change in weight loss percentages were examined, only the pre-operative and post-operative 1st month measurements of the change between folic acid weight loss level and percentage were significantly negatively correlated. Based on this result, the relationship folic acid levels according to weight loss percentages should be examined in more detail.

SIGNIFICANCE STATEMENT

In this study, when the micronutrients were evaluated alone, without consideration of the weight change, only the level of zinc decreased. Our study could help researchers become aware that frequent monitoring is essential to keep micronutrients at normal levels after SG. Moreover, more frequent monitoring is required for folic acid supplementation in patients losing weight comparably faster. Therefore, to prevent the risks, folic acid supplementation can be increased above the doses suggested for the early period following the operation.

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