

Original Article



Macro- and Micro-nutrient Intake Adequacy in Gastric Bypass Patients after 24 Months: a Cross-sectional Study

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ABSTRACT

Decreased food intake is an effective mechanism for gastric bypass surgery (GBS) for successful weight loss. This cross-sectional study aimed to assess dietary intake, micro-and macro-nutrients in the patients undergoing GBS and determine the possible associations with weight changes. We assessed anthropometric indices and food intake at 24 month-post gastric bypass surgery. Dietary data was evaluated using three-day food records. After the 24 months of surgery, among 35 patients (mean age: 43.5 ± 11.2 years; 82.85% females), with the mean body mass index (BMI) of 30.5 ± 4.5 kg/m², 17 cases were < 50% of their excess weight. The average daily calorie intake was 1,733 ± 630 kcal, with 14.88% of calories from protein. Consumption amounts of protein (0.82 ± 0.27 g/kg of the current weight), as well as fiber, and some micro-nutrients (vitamin B9, E, K, B5, and D3) were lower than recommended amounts. Patients were classified into three groups based on their success in weight loss after surgery. Calorie intake was not significantly different between groups, but successful groups consumed considerably more protein and less carbohydrate than the unsuccessful group (p < 0.05). Based on our findings, the patients undergoing GBS had inadequate macro- and micro-nutrient intake after 24 months. However, protein intake can affect patients' success in achieving better weight loss. Long-term cohort and clinical studies need to be conducted to comprehend this process further.

Keywords: Bariatric surgery; Eating; Gastric bypass; Nutrients; Weight loss

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The authors declare that they have no competing interests.

INTRODUCTION

Obesity is a global health crisis with a rising trend worldwide within the past two decades. According to the World Health Organization (WHO), more than half of Iranian adults have a body mass index (BMI) of more than 25 kg/m² [1]. Obese individuals are at high risk of disabilities and life-threatening chronic conditions, including diabetes, cardiovascular diseases, and hypertension [2]. Also, overweight and obese people may experience several acute and chronic situations more than people with normal BMI; such as stroke [3], pulmonary abnormalities like obstructive sleep apnea [3,4], fertility problems [5,6], osteoarthritis [7,8], and psychiatric disorders [9]. One of the main mechanisms responsible for obesity-related complications is inflammation [3]. The excess amount of lipid accumulation in adipose tissue resulted in high levels of pro-inflammatory cytokines and oxidative stress stimulators, which are associated with the development of chronic conditions mentioned [3,10-12]. Several studies revealed that weight loss had a significant relation with positive changes in serum levels of pro-inflammatory cytokines and inflammation status which may lead to prevention or even treatment of obesity-related complications [13].

However, most obese patients experience recurrent weight loss failure following conventional weight loss methods, such as dietary regimens, physical exercise, and medication [14]. Bariatric surgery is considered the most effective and long-term treatment of morbid obesity and its associated comorbidities [15].

Roux-en-Y gastric bypass (RYGB) is a successful procedure globally with its ability to maintain weight reduction and sustain health improvements [15,16]. Despite the benefits of RYGB for morbidly obese patients, they may face certain complications such as nutritional deficiency or inadequacy that must be recognized [17,18]. Changes in stomach volume, lacks of nutrient intake, food intolerance, and malabsorption are all possible factors that can lead to dietary deficiency. As a result, long-term monitoring is critical for perceiving threats as early as possible [19]. According to a recent report, micronutrient supplementation at a dose of the recommended daily intake might not be enough and double the daily dose be required after therapy related to inducing malabsorption, such as RYGB [20]. Therefore, laboratory assessment of patients' vitamin and mineral intake could improve nutrient supplementation to the RYGB patients based on their nutritional needs [21]. A recent study found that at 12 month-post GB surgery, a large percentage of patients had nutritional deficiencies, especially in iron, vitamin D, and B12 intake [22]. Also, one study demonstrated that the amount of daily micro-nutrient intake in many patients was lower than the amount of current recommendations for patients after weight loss related surgery [23].

Therefore, studies on the long-term postoperative nutritional status of patients are essential. To date, few studies have examined the long-term postoperative dietary intake of patients, and micro-and macro-nutrient intake adequacy has been rarely investigated in this regard [15]. The present study evaluated postoperative dietary intake adequacy in terms of energy and micro-and macro-nutrients based on three-day food records at 24 month-post RYGB surgery. Also, the study investigated the association between changes in nutrient intake and weight in patients at 24 month-post surgery.

MATERIALS AND METHODS

Patient selection

This cross-sectional study was conducted at a single bariatric clinic in Mashhad, Iran. The subjects were selected from the patients undergoing gastric bypass surgery from 1 January-31 December 2017. The inclusion criteria were adult patients with obesity aged > 18 years, undergoing gastric bypass surgery for morbid obesity (BMI \geq 40 kg/m²), and at least one or more obesity-related comorbidities.

In total, 35 patients were participated based on the sampling process. The selected participants were contacted via phone, and those who accepted to partake were asked to complete a three-day food record (including data for two weekdays and one weekend day). A trained interviewer instructed the patients on writing the information on the amount and quality of the foods they consumed. The food records were evaluated by a dietitian, an expert in dietary composition, and data analysis in Nutritionist IV software (Version 3.5.2, First Databank® Inc., Hearst Corp., San Bruno, CA, USA). In addition, the total daily intake of calories, micro-and macro-nutrients were obtained.

Anthropometric measurement

Height and weight were measured by a trained dietitian using a standard stadiometer and a clinical scale (SECA), respectively. The described weight metrics were excess body weight (EBW), BMI, percentage of total weight loss (%TWL), percentage of excess weight loss (%EWL), and lost BMI units. Notably, BMI is determined by dividing weight (kg) by the square of height (m²), and BMI loss was defined as the preoperative BMI minus the postoperative BMI in our study. The %TWL was calculated as the preoperative BW (kg) minus the postoperative BW (kg), divided by the postoperative BW, and multiplied by 100 [24]. The %EWL was calculated as the preoperative BW (kg) minus the postoperative BW (kg), divided by the preoperative BW (kg) minus the ideal body weight (kg), and multiplied by 100 [24]. The ideal body weight (IBW) was calculated based on the BMI of 25 kg/m², and EBW was defined as BW (kg) minus the IBW (kg).

Statistical analysis

Data analysis was performed in SPSS version 16 (IBM Corp., Armonk, NY, USA), and the normality of quantitative data was evaluated using the Kolmogorov-Smirnov test. Numerical data were expressed as mean and standard deviation, and the other variables were presented as median with its range. Besides, paired t-test was applied for assessing within-group differences. For comparing the differences between the means of two or more independent (unrelated) groups, an one-way analysis of variance was used. In all the statistical analyses, the p-value of less than 0.05 was considered significant.

Ethics statement

Ethics approval and consent to participate: All the procedures performed in the present study were approved by the Ethics Committee of Mashhad University of Medical Sciences, Mashhad, Iran with the registered number “IR.MUMS.MEDICAL.REC.1399.113”.

RESULTS

Characteristics and anthropometric changes of the participants

In total, twenty-nine women and six men with a mean age of 43.54 ± 11.17 years (age range: 22–68 years) were enrolled in the study. The mean preoperative BMI of the patients was 45.35 ± 7.02 kg/m² (range: 36.78–62.67 kg/m²), and the mean EBW was 54.24 ± 18.63 kg (range: 31.80–88.38 kg). According to the findings, the mean BMI reduced significantly to 30.50 ± 4.53 kg/m² ($p < 0.001$), and the mean body fat percentage also decreased to $31.90 \pm 8.41\%$ ($p < 0.001$). In addition, significant weight loss was observed in the patients during the study period within the range of 14–81 kg. At 24-month post-surgery, 4 patients (12%) reached normal weight (BMI: 18.5–25 kg/m²), 12 patients (34%) were still overweight (BMI ≥ 25 kg/m²), and 13 patients had grade I obesity ($35 > \text{BMI} \geq 30$ kg/m²), 6 of whom (17%) had the BMI of ≥ 35 kg/m² (grade II obesity). None of the patients were underweight, and the mean weight loss was estimated at 39.79 ± 16.35 kg with the mean EWL of $73.93 \pm 20.13\%$. After 24 months, only 8.57% of the patients showed less than 50% of EWL, while others experienced a successful surgery outcome with the EWL of $> 50\%$. **Table 1** shows the characteristics and anthropometric data of the study subjects before and after RYGB.

Energy, macro-nutrient, and micro-nutrient intake

Postoperative nutrient intakes were calculated using the three-day food records (**Table 2**). Accordingly, patients had a mean intake of 1,770 kcal/day (548.60 – $2,608.66$ kcal/day), representing 22.43 ± 7.80 kcal \times kg⁻¹ \times day⁻¹ of their current BW. No significant difference was observed in the energy intake per unit of body weight in the subjects experiencing weight loss. In terms of the percentage of the total energy, macronutrient intake comprised 14.88% proteins, 31.84% fats, and 53.28% carbohydrates. On average, the participants reported the consumption of 239.71 ± 73.82 grams of carbohydrate, with 64.17 ± 21.56 grams of fats a day. Protein intake was 64.91 ± 17.56 g/day, ranging from 25.95 to 94.08 g/day. Patients consumed 0.97 ± 0.25 g/kg IBW or 0.82 ± 0.27 g/kg current BW daily. Sixteen patients consumed 49.41 g of protein daily, which reached fewer EWL than those who consumed > 60 g protein daily ($70.80 \pm 14.34\%$ vs. $76.56 \pm 24.05\%$, $p = 0.039$). Based on the analysis of the food records, patients with an EWL of $\geq 50\%$ (successful surgery) consumed fewer calories than those with an EWL of $< 50\%$ (unsuccessful surgery; $1,759.40 \pm 488.01$ vs. $1,851.55 \pm 470.28$ kcal).

Table 1. Characteristics of study participants at 24th month

Variables	Mean
Age (yr)	43.5 ± 11.2
Height (m)	163.5 ± 10.0
Weight (kg)	81.5 ± 13.9
BMI (kg/m ²)	30.5 ± 4.5
EBW (kg)	54.2 ± 18.6
Pre-surgical BMI (kg/m ²)	45.3 ± 7.0
Pre-surgical weight (kg)	121.3 ± 22.1
Body fat percentage (%)	31.9 ± 8.4
Pre-surgical fat percentage (%)	47.5 ± 4.4
FFM (kg)	55.1 ± 10.0
FFM (%)	68.1 ± 8.4
WC (cm)	98.7 ± 14.9
Weight loss (kg)	39.8 ± 16.3
EWL (%)	73.9 ± 20.1
TWL (%)	32.0 ± 9.5

Data are presented as mean \pm standard deviation according to normal distribution respectively. BMI, body mass index; FFM, fat-free mass; WC, waist circumference; EBW, excess body weight; EWL, excess weight loss; TWL, total weight loss.

Table 2. Energy and macronutrient intake as estimated from 3-day food records

Variables	Mean (SD)/Median (Q1–Q3)	Minimum	Maximum
Total energy (kcal/day)	1,767.3 (480.4)	548.6	2,608.7
CHO (% of energy)	53.3 (6.3)	36.7	64.7
Protein (% of energy)	14.7 (2.5)	10.3	21.3
Total fat (% of energy)	31.8 (6.2)	20.3	45.3
Carbohydrate (g/d)	239.7 (73.8)	75.7	401.2
Protein (g/d)	64.9 (17.6)	26.0	94.1
Total fat (g/d)	64.2 (21.6)	17.8	129.1
SFA (g/d)	23.3 (7.8)	7.4	38.1
MUFA (g/d)	20.3 (8.5)	5.2	53.7
PUFA (g/d)	11.5 (6.9)	2.4	25.0
Fiber (g/d)	12.4 (9.6–16.1)	3.8	32.1
Food weight (g)	1,749.0 (492.9)	548.6	2,608.7
DED (kcal/g)	1.0 (1.0–1.0)	1.0	1.6

Data are presented as mean (SD) or median (range) according to normal and non-normal distribution respectively. SD, standard deviation; CHO, carbohydrate; SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; DED, dietary energy density.

However, the total daily calorie intake had no significant difference between these subjects ($p = 0.75$). Furthermore, no significant differences were observed in the total calories from protein, carbohydrates, and fats between the patients with successful and unsuccessful surgeries. Micronutrient daily intake is summarized in **Table 3**.

The dietary energy density (DED) refers to the energy amount (kilocalories) per weight of food (gram; kcal/g), which significantly had positive correlations with BMI loss, preoperative BMI, and %TWL ($p < 0.05$), however, it had no significant correlation with %EWL ($p = 0.55$) and %TWL ($p = 0.052$). On the other hand, the energy intake of the patients was negatively correlated with age ($p < 0.05$), and no correlation was denoted with weight change parameters, such as %EWL ($p = 0.345$). Of all the macronutrients, only carbohydrate intake was positively correlated with age, and fat and protein were unrelated ($p = 0.071$ and $p = 0.64$, respectively).

Table 3. Micronutrient intake as estimated from 3-day food records

Variables	Mean (SD)/Median (Q1–Q3)	Minimum	Maximum
Sodium (mg)	1,244.5 (973.8–118.9)	465.6	4,335.3
Potassium (mg)	1,923.0 (737.3)	738.7	4,012.0
Magnesium (mg)	157.3 (118.9–231.9)	63.6	419.5
Calcium (mg)	539.4 (188.5)	166.3	953.5
Iron (mg)	12.2 (3.4)	4.4	22.1
Zinc (mg)	7.7 (2.3)	2.7	13.2
Vitamin A (RE)	435.5 (291.4–614.2)	140.0	4,433.5
Vitamin B2 (mg)	1.3 (0.4)	0.6	2.4
Vitamin B1 (mg)	1.4 (0.5)	0.6	2.5
Vitamin B6 (mg)	1.0 (1.6–0.8)	0.4	3.0
Folic acid (mg)	195.1 (135.6–246.8)	76.0	472.2
Vitamin B12 (μ g)	2.7 (3.5–1.8)	0.7	25.6
Vitamin C (mg)	74.4 (51.3)	5.6	227.5
Vitamin E (mg)	2.7 (1.2–3.9)	0.7	28.0
Vitamin B7 (mg)	8.0 (4.6)	0.7	20.2
Vitamin K (μ g)	36.3 (19.7–79.9)	4.3	250.1
Vitamin B5 (mg)	3.4 (1.3)	1.5	7.0
Vitamin D (μ g)	0.3 (0.0–1.1)	0.0	2.7
Vitamin B3 (mg)	16.0 (5.6)	4.3	33.2

Data are presented as mean (SD) or median (range) according to normal and non-normal distribution respectively. SD, standard deviation.

Table 4. Within- and between-group comparisons of the changes from baseline to endpoint measures for anthropometric data and dietary intake based on weight loss success

Variables	Group 1 (n = 17)		Group 2 (n = 6)		Group 3 (n = 12)		p value*
	Value	p value [†]	Value	p value [†]	Value	p value [†]	
BMI (kg/m ²)							
Baseline	45.0 ± 7.5		52.0 ± 5.6		42.6 ± 4.9		
24 mon	33.5 ± 3.5		31.6 ± 1.5		25.8 ± 2.5		
Change [‡]	11.5 ± 4.5	< 0.001	20.4 ± 5.4	< 0.001	16.8 ± 4.6	< 0.001	< 0.001
FFM percentage (%)							
Baseline	53.4 ± 4.2		46.7 ± 2.8		54.5 ± 2.4		
24 mon	63.6 ± 7.0		67.0 ± 3.9		73.8 ± 8.4		
Change [‡]	-10.2 ± 6.4	< 0.001	-20.3 ± 2.6	< 0.001	-19.3 ± 8.1	< 0.001	< 0.001
Fat percentage (%)							
Baseline	46.6 ± 4.2		53.3 ± 2.8		45.5 ± 2.5		
24 mon	36.4 ± 7.0		33.0 ± 3.9		26.2 ± 8.4		
Change [‡]	10.2 ± 6.4	< 0.001	20.3 ± 2.6	< 0.001	19.3 ± 8.1	< 0.001	< 0.001
Age (yr)	46.7 ± 10.6	-	37.0 ± 8.1	-	33.8 ± 9.2	-	0.004
Mean calorie intake per current BW (kcal/kg)	20.6 ± 5.1	-	17.0 ± 4.9	-	27.7 ± 9.4	-	0.006
Mean calorie intake (kcal)	1,789.4 ± 398.5	-	1,416.6 ± 370.0	-	1,911.3 ± 574.3	-	0.114
CHO (% of energy)	56.0 ± 5.1	-	49.8 ± 7.2	-	51.2 ± 6.1	-	0.038
Protein (% of energy)	14.8 ± 2.1	-	15.3 ± 3.9	-	14.3 ± 2.4	-	0.714
Total fat (% of energy)	29.0 ± 5.7	-	34.8 ± 6.1	-	34.4 ± 5.6	-	0.026
Protein consumed per current BW (g/kg)	0.8 ± 0.2	-	0.6 ± 0.2	-	1.0 ± 0.3	-	0.020

Values are expressed as mean ± standard deviation.

BMI, body mass index; FFM, fat-free mass; BW, body weight; CHO, carbohydrate.

*p value for comparing the changes in variables between the groups. One-way analysis of variance was used. [†]p value for comparing baseline with endpoint values within each group. Paired sample t-test was used. [‡]End-baseline.

Subjects were also divided into 3 groups (group 1= unsuccessful, group 2= moderately-successful, and group 3= excellently-successful) based on 3 popular criteria: EWL < 50%, TWL ≤ 25%, BMI > 35 kg/m² related to fail in weight loss, EWL ≥ 50%, TWL ≥ 20%, 30–34.9 kg/m² BMI related to good weight loss. And EWL ≥ 50%, TWL ≥ 20%, BMI < 30 kg/m² related to excellent weight loss. Based on these groups' classification, significant between-groups differences in BMI, FFM, mean calorie intake per BW, carbohydrate, fat, and protein consumed per BW were seen (p < 0.05) (**Table 4**).

DISCUSSION

In this cross-sectional study of 35 patients at 24 months after gastric bypass surgery, we assessed the dietary intake adequacy of macro-nutrients and micro-nutrients. According to the current research, the mean total energy and protein daily intake long after the surgery were 1,767.30 ± 480.45 kcal and 0.82 ± 0.27 g/kg of the current weight, respectively. Intake amount of protein and some micro-nutrients (vitamin B9, E, K, B5, and D3) was less than recommended amount for bariatric surgery patients. Our results indicate that patients who consumed more protein lost more weight. The calorie intake was lower in the groups of successful weight loss, which is clinically meaningful, although there is no statistically significant difference between the groups.

As mentioned earlier, weight loss is significantly related to preventing and treating obesity-related complications, which are mainly stimulated by inflammation and oxidative stress [3,7,10,11]. Nowadays, bariatric surgery is one of the common methods for durable weight loss and improvement in these comorbidities. But achieving proper weight loss depends on several factors such as the quantity and quality of the patient's daily diet [25-27]. Our results emulate previous findings by Wardé-Kamar et al. [28], who have demonstrated an average

daily calorie intake of $1,733 \pm 630$ kcal for 69 RYGB patients 30 months postoperatively. While, a study that was conducted on Mediterranean subjects in 2013 regarding dietary intake and nutritional deficiencies following RYGB [23] indicated that 24 months after the surgery, the total calorie intake of the patients was 1,533 kcal/day, which is a little lower value compared to the results of the present study. The discrepancy in this regard could be due to the differences in the periods following bariatric surgeries. As we mentioned, our analysis has performed 24 months after the bariatric intervention; however, others evaluated food intake in different periods such as a year or three years after the surgery. Also, increased calorie intake long after the bariatric surgery has been a cause for concern; because the higher calorie intake may result in higher weight regain. Therefore, as the total calorie intake of our study population was higher than other studies, monitoring the possibility of weight regain in study subjects should be continued. Other possible reasons may be due to differences in study populations, geographical regions, and surgical procedures. Moreover, filling up the self-report daily calorie consumption form may produce unreliable results; since patients may overestimate or underestimate their food intake.

According to the literatures, adequate protein intake is essential after bariatric surgeries in considering its contribution to reduced satiety, improved body composition, and increased weight loss and fat-free mass [29,30]. Some studies have emphasized the role of high-protein diets in improving body composition and preventing postoperative weight regain, a common long-term complication of bariatric interventions [31]. The dietary reference intake for daily protein in the general population has been set at 0.8 g/kg of BW [32]. Due to reduced daily intake of macronutrients and malabsorption after surgeries, adequate daily protein consumption amount differs from recommended amount before surgery [29,30]. Some studies have evaluated subjects' adequate daily protein intake requirements after bariatric surgeries, although their recommendations are not definitive. The Endocrine Society Clinical Practice Guidelines recommend the daily protein consumption of 60–120 grams to maintain the fat-free mass during the postoperative weight-loss period in bariatric patients [33]. In this regard, Moize et al. [30] have recommended consuming 1.5 grams of protein per kg of the ideal BW per day to prevent lean tissue loss [30]. However, Rinaldi Schinkel et al. [34] have stated that the target protein intake in these patients is approximately 2.1 g/kg of the ideal BW or 1.2 g/kg of the current weight. Thus, they agreed upon the higher requirement of daily protein intake in bariatric patients compared to the requirement for the general population. In the present study, the daily intake of protein was estimated at 0.97 ± 0.25 g/kg of the ideal BW or 0.82 ± 0.27 g/kg of the current weight, which confirmed the inadequate protein consumption of the patients at two years after the gastric bypass surgery. Several possibilities could answer the low intake of protein in patients at 25 month-post bariatric surgery. For instance, some patients felt nauseous when eating eggs, fish, or even chicken. Also, some preferred to eat small amounts of food to avoid vomiting and gastric reflux. Notably, it is also important to consider that high-caloric, and high-density foods are poor in protein, resulting in low total daily protein intake. Therefore, dietary sources or protein supplements should be further considered to improve protein intake long after bariatric surgeries.

In the current research, we also evaluated the percentage of different fatty acids. We reported that the mean intake of fat was 64 g/day which about one-third was from sources rich in monounsaturated fatty acids. Also, more than one-third of total fat intake was from saturated fatty acids, which are much higher than the limited portion of saturated fatty acids intake in the Mediterranean diet. These data confirmed the importance of nutritional consultation long after bariatric surgeries to correct the dietary habits and the date even implicate

appropriate advice to prevent weight regain, other nutritional deficiencies and complications. Regarding fiber intake in the current study, patients consumed less than recommended amount which may be due to the limitation of gut function imposed by the surgery or due to poor intake of vegetables and fruits. The result is consistent with the report from Novais et al. [35] and Ziadlou et al. [36].

We compared our data with the recommended reference values after bariatric surgery to assess the adequacy of daily micronutrient intake in the subjects long after the surgical procedure. According to the current results, the dietary intake of calcium, magnesium, iron, and zinc in study subjects were 539.4 ± 188.4 mg, 157.3 mg, 12.16 ± 3.41 mg, and 7.7 ± 2.3 mg, respectively, and were significantly lower values than the reference values (1,200–2,400, 400, 45–60, and 15 mg, respectively). The consumption of fat-soluble and water-soluble vitamins was measured in the present study. According to the findings, the intake of vitamin A, D, E, and K was significantly lower than the reference values. In contrast, the dietary consumption of vitamins C and B was insufficient by more than 50% of the recommended daily allowance. Therefore, it could be inferred that the reduced absorption of micronutrients and their inadequate intake may lead to long-term complications such as hair loss, anemia, vitamin deficiencies, osteoporosis, and clinical manifestations, which previous studies confirm [37,38]. For instance, a review conducted in 2020 on the incidence of iron deficiency anemia reported that 16.7% of subjects became anemic one year after RYGB [39].

Moreover, the incidence of postoperative calcium deficiency and bone loss was reported to be 10% [40] and 8%–13%, respectively [38,41]. Some studies have also investigated the incidence of vitamins deficiency, reporting the reduced serum levels of fat-soluble and water-soluble vitamins long after mal-absorptive surgical procedures [38]. In summary, our findings indicated the inadequate dietary intake of micronutrients at 24 month-post bariatric surgery, highlighting the importance of long-term clinical and biochemical laboratory research to identify, thus, prevent postoperative complications.

EWL is a standard marker to evaluate whether bariatric surgeries are successful [42,43], the percentage estimated at $73.93 \pm 20.1\%$ in the present study. Several studies have indicated that achieving more than 50% EWL shows the favorable response of the patient to bariatric surgery [42,43]. However, our findings confirmed that the majority of patients experienced acceptable weight loss long after the surgery. As mentioned earlier, the mean daily energy intake per BW of the subjects was estimated at 22.4 ± 7.8 kcal/kg.

DED varies in different foods, with the lowest amount reported in the fruits and vegetables with high water content [44,45]. In addition, foods with higher fat content have higher DEDs than foods with higher carbohydrate and protein contents since each gram of fat produces 9 kcal, while each gram of carbohydrate and protein produces 4 kcal. A low DED diet is associated with increased nutrient quality and reduced energy intake [44,45]. Previous studies have confirmed that lower energy intake is achieved by constant food weight and reduced dietary energy density simultaneously, resulting in better weight loss [44]. In the present study, the mean DED was approximately 1 kcal/g in the bariatric patients at two years after the surgery.

Interestingly, a significant positive correlation was observed between dietary energy density and BMI loss. Moreover, positive correlations were denoted between the current DED and preoperative BMI. As mentioned earlier, successful weight loss could be attained with a diet with a low energy density, and preferably with foods with high water content.

Our assessment also demonstrated the significant changes in BMI and FFM percentage between groups of weight loss success category. Interestingly, among groups, the excellent-weight loss success group has shown lowest BMI and highest FFM percentage after bariatric surgery, which were consistent with previous reports [46,47].

CONCLUSION

Based on the current study findings, macro- and micro-nutrients inadequacy were seen in patients at 24 months after bariatric surgery. Compared to the reference values, the insufficient intake of protein and fiber and vitamin B9, E, K, B5, and D3 were reported. Patients who had fewer calories intake daily and consumed the recommended amount of protein experienced better weight loss. Therefore, this study indicates the importance of nutritional assessments after the bariatric surgery and, if necessary, applicable nutritional supports in both short and long terms after the surgery need to be provided.

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