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ORIGINAL CONTRIBUTIONS

Dietary Intakes and Biochemical Parameters of Morbidly Obese Patients Prior to Bariatric Surgery

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Abstract

Background Patients with morbid obesity appear to have adequate nutritional intake, but some studies suggest deficiencies in the micronutrient intake in these patients. Present study aimed to determine dietary intakes and their associated biochemical parameters in an Iranian population of patients with morbid obesity prior to bariatric surgery.

Methods One hundred seventy patients with morbid obesity who have referred to surgery clinic of Firoozgar Hospital were enrolled in the study. Ideal Body Weight (IBW) and Adjusted Ideal Body Weight (AIBW) were calculated. The dietary data were collected using a Food Frequency Questionnaire (FFQ). Anthropometrics and biochemical parameters were assessed. All the statistical analyses were done using the SPSS with an alpha of 0.05.

Results Mean age of participants was 37.4 ± 10.17 years. The mean and standard deviation (SD) of the BMI and EBW values was 45.75 ± 6.49 kg/m and 47.6 ± 13.74 kg, respectively. All the micro- and macro-nutrient intakes are significantly different from the recommended values, except for vitamin A in the men and calcium in the 51–70-year-old women. 47.1% and 17.1% of the participants were classified as patients with diabetes and pre-diabetes, respectively. Majority of participants had lower serum iron levels than the reference values. Almost all the participants (97%) had normal albumin levels.

Conclusions Despite their excess intakes of energy, patients with obesity usually suffer from micronutrient deficiencies, such as vitamin D, iron, and vitamin B12, which can be accompanied by complicated biochemical disorders like impaired glucose metabolism and dyslipidemia. Therefore, bariatric surgery candidates require close nutritional monitoring before and after their surgical operations.

Keywords Obesity · Bariatric surgery · Metabolic · Weight · Nutritional status · Biochemical parameters · Dietary intakes

Introduction

Obesity as the major contributor to a wide range of metabolic disorders, such as type 2 diabetes, cardiovascular disease, dyslipidemia, and hypertension, is a cause of public health concern both in the developed and developing countries [1]. Iran is among the countries, in which a surge in its prevalence has led to its remarkable upward trend, e.g., from 12.6 to 25.9% during 2005–2014 [2, 3]. According to the inconclusive evidence supporting the efficacy of medical treatments and lifestyle modifications over the long run, bariatric surgery has been proposed to provide a golden treatment procedure leading to sustained weight losses in patients with morbid obesity [4–6]. Moreover, bariatric surgery has beneficial effects on blood glucose, inflammation, and gut hormones [7]. Morbid obesity is usually accompanied by serious deficiencies in a wide range of micronutrients [8]. The excessive dietary intakes by patients with morbid obesity seem not to be

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comprised of nourishing food items at all. This is the reason why a great number of them usually suffer from low levels of micronutrients, including iron and vitamins of B6, B12, C, and E, as well as 25-hydroxy vitamin D [9, 10]. In such a context, it is highly important to detect and improve micronutrient deficiencies in the candidates of bariatric surgery in order to further offset any subsequent adverse impacts. After surgery due to reduced dietary intake and surgically bypassing, the areas of the GI tract that is known to absorb many micronutrients, vitamin deficiencies may occur without proper supplementation.

The biochemical indices representing nutritional statuses of pre-bariatric surgery patients have been repeatedly discussed in the former surveys. However, this is the first study seeking to investigate the involved dietary intakes of patients prior to bariatric surgery in an Iranian population. To get a broader picture of their nutritional statuses and compare with recommend dietary allowance, the present retrospective study aimed to determine dietary intakes and their associated biochemical parameters in an Iranian population of patients with morbid obesity prior to bariatric surgery.

Materials and Methods

Study Population

The participants of the present study were selected from patients who referred to the surgical clinic of Firoozgar Hospital using availability sampling method. Availability sampling is a method of choosing subjects who are available or easy to find. The inclusion criteria for the bariatric surgery candidates were a BMI of more than 40 without any co-existing medical problems or more than 35 with some severe co-morbidities relevant to obesity [11]. The patients taking vitamin or mineral supplementations (because we decided to determine nutrients intake from food sources) or with a history of previous bariatric surgery were excluded. BMI was calculated as weight/height. Ideal Body Weight (IBW) and Adjusted Ideal Body Weight (AIBW) were calculated via the following equations [12, 13]:

$$\mathrm{IBW\ (men)} = 50 + 0.91 \times ((\mathrm{height} \times 100) - 152)$$
$$\mathrm{IBW\ (women)} = 45 + 0.91 \times ((\mathrm{height} \times 100) - 152)$$
$$\mathrm{AIBW} = \mathrm{IBW} + 0.25 \times (\mathrm{weight} - \mathrm{IBW})$$

AIBW was subtracted from Actual Body Weight (ABW) to calculate Excess Body Weight (EBW). All the participants were registered at Firoozgar General Hospital, Tehran, Iran between October 2017 and February 2018.

Nutritional, Anthropometric, and Biochemical Assessments

The dietary data were collected using a validated semi-quantitative Food Frequency Questionnaire (FFQ) with 147 food items. The participants were questioned by trained dietitians about their frequencies of each food item intake during the previous year on a daily, weekly, and monthly basis. Our FFQ reliability and validity for the studied food group intakes were assessed as acceptable [14].

A tape meter was used to measure their heights and waist circumferences to the nearest 0.5 and 0.1 cm (at anatomical landmarks) in a standing position without shoes and at the widest portion without any pressure to the body over light clothing, respectively. Their hip circumferences were measured at the level of the greater trochanter. Waist circumference was divided by hip circumference to calculate their waist-to-hip ratios. A digital scale was utilized to measure their weights without shoes over minimal clothing to the nearest 100 g. Their BMIs were calculated as weight (kg) divided by height square (m).

Biochemical parameters, including Fasting Blood Sugar (FBS), Total Cholesterol (TC), triglyceride (TG), Low-Density Lipoprotein Cholesterol (LDL-C), High-Density Lipoprotein Cholesterol (HDL-C), LDL-C/HDL-C, iron, ferritin, transferrin, albumin (Alb), hemoglobin A1C (Hb A1c), vitamin B12, vitamin D, insulin, aspartate transaminase (SGOT), and alanine transaminase (SGPT), were assessed prior to surgery.

Statistical Analysis

To test normality, one-sample Kolmogorov-Smirnov test was used. Variables were compared with cutoffs through a one-sample *t* test or one-sample non-parametric test. We used Nutritionist 4 software to analyze the nutrients extracted from FFQ. All the statistical analyses were done using the Statistical Package for Social Sciences software (SPSS Inc., Chicago, IL, 1996, version 20). A p value of < 0.05 was considered significant.

Results

In this survey, 170 (145 female) participants with a mean age of 37.4 ± 10.17 years were recruited. The mean and Standard Deviation (SD) of the BMI and EBW values were 45.75 ± 6.49 kg/m and 47.6 ± 13.74 kg, respectively. All the baseline characteristics are represented in Table 1.

Table 1 Baseline characteristics of the participants ($n = 170$)

Demographics	Mean ± SD
Age (years)	37.4 ± 10.17
Weight (kg)	122.43 ± 21.32
Height (cm)	163.45 ± 9.01
Waist circumference (cm)	114.18 ± 10.37
Hip circumference (cm)	116.36 ± 9.15
W/H ratio	0.99 ± 0.25
Body mass index (kg/m)	45.75 ± 6.49
Excess weight (kg)	47.6 ± 13.74

Dietary Assessment

Table 2 demonstrates the subjects' dietary intakes compared to those of American Diabetes Association (ADA) guidelines and Dietary Reference Intake (DRI) values for macronutrients and micronutrients, respectively. As is shown, all the micro- and macro-nutrient intakes are significantly different from the recommended values, except for vitamin A in the men and calcium in the 51–70-year-old women. Although carbohydrate and fat intakes were reported to be higher than the acceptable percentages, dietary protein intakes were remarkably lower than the recommended range. In the case of micronutrients, 44% of the women aged between 19 and 50 years had consumed insufficient amounts of vitamin A. All the subjects had inadequate dietary intakes of vitamin D. None of the participants had deficiency in selenium intake besides fiber intake in women aged 51–70 years and iron in men and women aged 19–50 and 51–70 years, respectively. Riboflavin and thiamin were also sufficient in the studied men.

Moreover, the majority of the women had adequate iron and calcium intakes, while only 20.4% and 24.3% of the 19–50-year-old women had their low intakes. One hundred percent of the subjects had higher sodium intakes than the recommended values.

Biochemical Assessment

The patients' biochemical analyses prior to bariatric surgery are demonstrated in Table 3. According to the FBS level, about 47.1% and 17.1% of the participants were classified as diabetic and pre-diabetic patients, respectively. 57.1% and 48.8% of them had an insulin level of higher than the accepted value and impaired HbA1c, respectively. Based on the results, 45.9%, 47.3%, 35.9%, 32.9%, and 30.6% of them had impaired TC, TG, LDL-C, HDL-C, and LDL-C/HDL-C, respectively. 80% and 86.2% of the men and women had lower serum iron levels than the reference values, respectively. Although the studied men had acceptable transferrin levels, 56.8% of the women represented insufficient values. Almost all the participants (97%) had normal albumin levels. In addition, about 50% and 83% of them were reported to have inadequate levels of vitamin B12 and vitamin D, respectively. Finally, 15.5% and 20.8% of them showed high AST and ALT levels, respectively.

Discussion

In the current research, dietary intakes and main biochemical parameters were assessed in the candidates of bariatric surgery. There was a huge discrepancy between their dietary micro- and macro-nutrient intakes and the recommended values. Although 59% and 62% of the participants had excess intakes of carbohydrate and fat, respectively, about 90% of them consumed insufficient amounts of protein. In addition, all the subjects had inadequate intakes of vitamin D as a micronutrient. Vitamin B12 intake was also insufficient in almost 16% of the subjects. Iron and calcium intakes were lower than the recommended values in 20% and 24.3% of the 19–50-year-old females, respectively. A remarkable number of the patients were diagnosed to be involved in impaired glucose metabolism, i.e., 64.2% of them were defined as pre-diabetic and diabetic patients, while 57.1% and 48.8% had impaired insulin levels and HbA1c, respectively. About 30–47% of the participants were reported to have dyslipidemia. In terms of vitamin status, about 50% and 83% of them showed vitamin B12 and vitamin D deficiencies, respectively. However, the serum levels of ferritin in the majority of the subjects were found to be in a sufficient range.

According to the previous investigations, nutritional deficiencies are deemed to be common prior to bariatric surgery. In a retrospective data analysis conducted by Al-Mutawa [8] during 2008–2015, vitamins D (76%) and B12 (16%) were observed to have imposed the most common deficiencies on 1538 obese patients undergoing bariatric surgeries. Most of the patients had been involved in anemia and deficiencies of such parameters as transferrin saturation (60%), serum iron (51%), Mean Corpuscular Volume (MCV) (48%), ferritin (28%), and hemoglobin (20%) prior to the surgery. Also, the excessive levels of vitamin B6 (24%) were reported to have significantly led to hypervitaminosis pre-operatively. Low albumin and transferrin levels were seen in 10% and 9% of the patients, respectively. In another pre-operative survey, Asghari et al. [15] found vitamin D (53.6%), vitamin B12 (34.4%), and serum iron (10.2%) deficiencies, as well as low levels of hemoglobin (16.6%). In 2016, Wang et al. [16] investigated the prevalence of electrolyte and nutritional deficiencies in 211 bariatric surgery candidates and discovered deficient blood levels of hemoglobin, albumin, globulin, folate, vitamin B12, calcium, phosphorus, iron, ferritin, vitamin D, potassium, sodium, and chloride. Higher BMI was

Table 2 Dietary intake of patients prior to bariatric surgery ($n = 170$)

Dietary intake parameters	Age group (year)	Gender	Number of patients	Sample mean	Reference cutoff	*P* value	% deficient/ Low	% excess
Carbohydrate	19–70	F/M	170	57.36 ± 7.28	55%	0.00	41	59
Fat	19–70	F/M	170	32.64 ± 7.28	30%	0.00	37.8	62.2
Protein	19–70	F/M	170	12.72 ± 2.41	15%	0.00	89.9	10.1
Vit A	19–70	F	145	722.69 ± 525.18	700 mcg/d	0.02	44.1	55.9
		M	25	1089.64 ± 722.27	900 mcg/d	0.24	44	56
Vit C	19–70	F	145	213.43 ± 254.08	75 mg/d	0.00	13.1	86.9
		M	25	307.21 ± 260.76	90 mg/d	0.00	12	88
Vit D	19–70	F/M	170	64.8 ± 78	600 IU/d	0.00	100	–
Vit E	19–70	F/M	170	29.41 ± 16.61	15 IU/d	0.00	34.1	65.9
Vit K	19–70	F	145	179.15 ± 217.18	90 mcg/d	0.00	13.8	86.2
		M	25	201.97 ± 158.06	120 mcg/d	0.00	20	80
Thiamin	19–70	F	145	3.02 ± 1.25	1.1 mg/d	0.00	0.07	99.3
		M	25	4.07 ± 1.99	1.2 mg/d	0.00	–	100
Riboflavin	19–70	F	145	2.68 ± 1.1	1.1 mg/d	0.00	1.4	98.6
		M	25	3.83 ± 2.06	1.3 mg/d	0.00	–	100
Niacin	19–70	F	145	34.28 ± 14.56	14 mg/d	0.00	2.1	97.9
		M	25	50.05 ± 25.69	16 mg/d	0.00	3.5	96.5
Vit B6	19–50	F/M	144	2.81 ± 1.31	1.3 mg/d	0.00	2.9	97.1
	51–70	F	26	2.48 ± 0.83	1.5 mg/d	0.00	7.7	92.3
		M	–	–	1.7 mg/d	–	–	–
Folate	19–70	F/M	170	826.08 ± 320.14	400 mcg/d	0.00	3.4	96.6
Vit B12	19–70	F/M	170	4.43 ± 4.13	2.4 mcg/d	0.00	15.7	84.3
Biotin	19–70	F/M	170	42.87 ± 22.65	30 mcg/d	0.00	28.7	71.3
Iron	19–50	F	119	27.52 ± 11.43	18 mg/d	0.00	20.4	79.6
		M	25	35.36 ± 17.52	8 mg/d	0.00	–	100
	51–70	F	26	26.61 ± 12.43	8 mg/d	0.002	–	100
		M	–	–	8 mg/d	–	–	–
Calcium	19–50	F/M	144	1520.41 ± 724.68	1000 mg/d	0.00	24.3	57.7
	51–70	F	26	1353.15 ± 547.25	1200 mg/d	0.16	24.3	57.7
Sodium	19–50	F/M	144	6.26 ± 2.81	1.5	0.00	–	100
	51–70		26	6.28 ± 3	1.3	0.00	–	100
Copper	19–70	F/M	170	2870 ± 1390	900 mcg/d	0.00	1.2	98.8
Selenium	19–70	F/M	170	180.56 ± 80.6	55 mcg/d	0.00	–	100
Fiber	19–50	F	119	58.96 ± 49.49	25 g/d	–	6.8	93.2
		M	25	72.52 ± 63.35	38 g/d	0.00	16	84
	51–70	F	26	52.71 ± 54.14	21 g/d	0.00	–	100

For parameters with similar reference cutoff according to age and gender, the total values are reported, however for parameters with different reference cutoff for age and gender the values are reported separately

The reference cutoffs for macronutrients and micronutrients are ADA and DRI, respectively

One-sample *t* test for normally distributed variables, one-sample nonparametric test for not normally distributed variable (vitamins A, C, D, E, K, B12, and fiber)

associated with lower albumin and folate and higher globulin and phosphorus levels.

Due to the prevalence of micronutrient deficiencies in patients with morbid obesity before bariatric surgery, it is highly important to provide bariatric surgery candidates with nutritional status pre-assessments. Diet seems to play a critical role in this process though the volumetric dilution factor has been discussed as a possible factor leading to lower micronutrient levels in obese individuals due to their higher amounts of total body water and expanded extracellular compared to intracellular compartments [17, 18]. Unhealthy dietary and lifestyle habits seem to be

Table 3 Biochemical analysis of patients prior to bariatric surgery ($n = 170$)

Biochemical parameters	Sample mean	Description
FBS (mg/dl)	114.23 ± 37.6	Normal (< 100) 35.9%
		Pre-diabetic (100–126) 47.1%
		Diabetic (> 126) 17.1%
HbA1c	6.16 ± 1.25	Normal (< 5.9) 51.2%
		Diabetic (> 5.9) 48.8%
Insulin (μIU/mL)	36.24 ± 21.36	Normal (6–27) 41.8%
		High (> 27) 57.1%
TC (mg/dl)	196.65 ± 41.3	Normal (< 200) 54.1%
		Hyper-cholesterolemic (> 200) 45.9%
TG (mg/dl)	168.62 ± 88.68	Normal (< 150) 52.7%
		Hyper-triglyceridemic (> 150) 47.3
LDL-C (mg/dl)	120.41 ± 34.78	Normal (< 130) 64.1
		High (> 130) 35.9
HDL-C (mg/dl)	46.06 ± 14.3	Normal (> 40) 67.1%
		Low (< 40) 32.9%
LDL-C/HDL-C	2.8 ± 1.06	Normal (< 3.3) 69.4%
		High (> 3.3) 30.6%
Iron (mmol/L)	4.09 ± 3.47	F: Normal (7.2–26.9) 13.8%
		Low (> 7.2) 86.2%
		M: Normal (8.9–28.7) 20%
		Low (> 8.9) 80%
Transferrin (mg/dl)	267.41 ± 60.15	F: Normal (250–380) 43.2%
		Low (< 250) 56.8%
		M: Normal (215–365) 100%
Albumin (g/dl)	4.48 ± 2.86	Normal (3.5–5) 97%
		Low (< 3.5) 3%
Vitamin B12 (fL)	262.15 ± 136.9	Normal (80–100) 50%
		Low (< 80) 50%
AST (U/L)	26.92 ± 15.01	Normal (0–35) 84.5%
		High (> 35) 15.5%
ALT (U/L)	29.62 ± 16.53	Normal (4–36) 79.2%
		High (> 36) 20.8%
Ferritin (ng/mL)	45.83 ± 50.60	F: Normal (10–150) 97.1%
		Low (< 10) 2.9%
		M: Normal (12–300) 100%
		Low (< 12) 0%
25 (OH) Vitamin D	14.75 ± 16.11	Normal (30–100) 17.1%
		Low (< 30) 82.9%

Median ± IQR

FBS fasting blood sugar, *TC* total cholesterol, *TG* trigelyceride, *LDL-C* low-density lipoprotein cholesterol, *HDL-C* high-density lipoprotein cholesterol, *HbA1c* hemoglobin A1C, *AST* aspartate amino transferase, *SGPT* alanine amino transferase

closely related to nutritional deficiencies among bariatric surgery candidates [17, 19]. The most distinctive characteristic of morbidly obese individuals is following an unbalanced diet consisting of high-calorie and high-fat meals [8]. The dietary assessments of obese patients have revealed replacements of high-calorie meals rich in fats and refined carbohydrates with a nutritious diet. Such food restrictions can commonly degenerate their nutritional statuses as a result of chronic dieting [8].

As shown in this study, almost 90% of the studied participants had lower protein intakes than ADA recommended values, while 56.8% of the women demonstrated

lower transferrin levels and 3% of all the participants revealed lower albumin levels. These conditions mostly seemed to be caused by the altered metabolism of acute phase proteins, including transferrin and albumin, as a result of chronic low-grade inflammation rather than an insufficient protein intake by the obese patients [20]. Hence, though not investigated in this research, it is highly recommended to also have inflammation, liver disease, or nephrotic syndrome assessments to detect any other possible conditions affecting serum protein levels [21]. Vitamin B12 and iron were among the studied parameters for evaluating both dietary intake and serum level status in the participants. Despite the higher dietary intakes of iron and vitamin B12 than the recommended values in roughly all the patients, more than 80% and 50% of them were reported to have their serum deficiencies, respectively, which seem to be mostly related to the use of anti-*Helicobacter pylori* and anti-gastroesophageal reflux drugs known as Proton Pump Inhibitors (PPI) leading to decreased B12 absorption, especially in obese patients, due to the high prevalence ranges of the mentioned diseases (29.2–32.3% and 26–38%, respectively) [22, 23]. As evidenced by the low dietary intakes of vitamin D reported in the present study, vitamin D deficiency could be the result of sequestration and its enhanced uptake in adipose tissues and obese individuals' tendencies to consume its lower levels as proposed by several studies [24, 25]. Moreover, reduced vitamin D synthesis in the livers of obese patients results from their impaired liver functions caused by fatty liver diseases [26]. Besides, obese individuals' limited outdoor activities and lower exposures to sunlight can further exacerbate the situation.

To the best of our knowledge, there are few surveys investigating obese patients' dietary intakes prior to bariatric surgery. However, it is important to evaluate their dietary intakes, correct their wrong eating behaviors, and resolve their nutrient deficiencies if we are to conduct more effective nutritional interventions prior to bariatric surgery. In such a context, it is the strength of our study to simultaneously assess both dietary and biochemical variables. However, the principle limitation of our research was its cross-sectional design, which could not predict the cause-and-effect associations. It would be very beneficial to evaluate all the biochemical parameters reflecting obese patients' nutritional statuses and dietary intake factors simultaneously if we are to reach a more overwhelming conclusion. In this investigation, we only assessed iron and vitamins B12 and D since we did not have access to the laboratory results of other micronutrients consumed by the bariatric surgery candidates. Furthermore, we had no access to such confounding factors as physical activity and socioeconomic status. The unbalanced male and female proportion could be another limitation to our study.

Conclusion

Despite their excess intakes of energy, patients with obesity usually suffer from micronutrient deficiencies, such as vitamin D, iron, and vitamin B12, which can be accompanied by complicated biochemical disorders like impaired glucose metabolism and dyslipidemia. Therefore, bariatric surgery candidates require close nutritional monitoring before and after their surgical operations.

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Compliance with Ethical Standards

Conflict of Interest Author 5 reports grants from Iran University of Medical Sciences during the conduct of the study. All of other authors report no conflict of interest.

Ethical Approval Statement The study was conducted according to the Declaration of Helsinki and study protocol was approved by the ethics committee of the Iran University of Medical Sciences number IR.IUMS.REC 1396-31585.

Informed Consent Statement Informed written consents were obtained from all participants.

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