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Micronutrient and physiologic parameters before and 6 months after RYGB

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Abstract

Background: Bariatric surgery is considered an effective method for sustained weight loss, but may cause various nutritional complications. The aim of this study was to evaluate the nutritional status of minerals and vitamins, food consumption, and to monitor physiologic parameters in patients with obesity before and 6 months after Roux-en-Y gastric bypass surgery (RYGB).

Methods: Thirty-six patients who had undergone RYGB were prospectively evaluated before and 6 months after surgery. At each phase their weight, height, body mass index (BMI), Electro Sensor Complex (ES Complex) data, food consumption, and total protein serum levels, albumin, prealbumin, parathyroid hormone (PTH), zinc (Zn), B12 vitamin (VitB12), iron (Fe), ferritin, copper (Cu), ionic calcium (CaI), magnesium (Mg), and folic acid were assessed.

Results: The mean weight loss from baseline to 6 months after surgery was 35.34 ± 4.82%. Markers of autonomic nervous system balance ($P < .01$), stiffness index ($P < .01$), standard deviation of normal-to-normal R-R intervals (SDNN) ($P < .01$), and insulin resistance ($P < .001$) were also improved. With regard to the micronutrients measured, 34 patients demonstrated some kind of deficiency. There was a high percentage of Zn deficiency in both pre- (55.55%) and postoperative (61.11%) patients, and 33.33% of the patients were deficient in prealbumin postoperatively. The protein intake after 6 months of surgery was below the recommended intake (<70 g/d) for 88.88% of the patients. Laboratory analyses demonstrated an average decrease in total protein ($P < .05$), prealbumin ($P = .002$), and PTH ($P = .008$) between pre- and postsurgery, and a decrease in the percentage of deficiencies for Mg ($P < .05$), CaI ($P < .05$), and Fe ($P = .021$).

Conclusion: Despite improvements in the autonomic nervous system balance, stiffness index markers and insulin resistance, we found a high prevalence of hypozincemia at 6 months post-RYGB. Furthermore, protein supplements were needed to maintain an adequate protein intake up to 6 months postsurgery. (Surg Obes Relat Dis 2014;10:944–951.) © 2014 American Society for Metabolic and Bariatric Surgery. All rights reserved.

Keywords: Bariatric surgery; Roux-en-Y gastric bypass surgery; micronutrient deficiency; food intake; autonomic nervous system balance; stiffness index; insulin resistance; obesity

Recent statistics indicate that excess weight and obesity have become an increasingly severe global socio-economic clinical problem. Moreover, these individuals have a higher risk of developing associated diseases, such as type 2 diabetes mellitus, hypertension, sleep apnea, and other

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disorders negatively affecting their quality of life, as well as their life expectancy [1]. Currently, bariatric surgery is considered an effective method for sustained weight loss among patients with severe obesity who have not achieved weight loss using other treatment methods [2]. The Roux-en-Y gastric bypass surgery (RYGB) is the most commonly used surgical procedure in Brazil. Although studies have shown % excess weight loss of 48–85% of initial weight, the surgery may lead to nutritional complications because of significant changes in gastrointestinal anatomy and physiology [3–5]. For many patients, the benefits of weight loss, such as decreased blood glucose, lipids, and improvements in autonomic nervous system function and blood pressure, exceed the risks of surgical complications and help in the prevention of chronic diseases [2,6,7]. As such, it is important to monitor related risk factors after surgery.

The presence of macronutrient and micronutrient deficiencies may lead to severe complications that will be discussed later in this article. Dietetic counseling, monitoring, and supplementation are ways to prevent these deficiencies [3,8]. Data regarding postoperative deficiencies remain scarce, and the amount of each nutrient that needs to be supplemented is still a matter of debate [9,10]. The primary aim of this study was to evaluate the nutritional status of minerals and vitamins and the food consumption in patients with obesity before and at 6 months after RYGB. As a secondary aim, monitoring additional risk factors of related chronic diseases was considered to evaluate the overall effect of RYGB.

Methods

Patients

Patients were accompanied at the Hospital de Clínicas at Universidade Estadual de Campinas (HC-UNICAMP) Bariatric Surgery Outpatient Clinic, according to a list of patients that had been enrolled to undertake RYGB. They were selected according to chronologic order of enrollment in the program and were followed up for 6 months after the surgical procedure in a prospective study. One hundred patients were assessed before starting follow-up in the preoperative group by a multidisciplinary team composed of surgeons, nurses, nutritionists, a physical education teacher, and a psychologist, who provided weekly recommendations to the patients. It was requested to the patients participating on this survey to consume a hypocaloric diet containing: 1.279 kcal, 198 grams of carbohydrate (53% of total energy intake), 92 grams of protein (25% of total energy intake), 36 grams of lipid (22% of total energy intake), and 24 grams of fibers in 6 meals per day; and nutrition guidelines were individualized when necessary.

The patients were followed up from 7–14 months before the surgery until they achieved weight loss of 10% or more of their initial weight. Patients who did not achieve this result, did not undergo the surgery and, therefore, were excluded from the study. Two patients decided not to undergo surgery during the preoperative follow-up. Thirty-six patients completed the protocol and underwent RYGB, and thus were included in this study. Patients were assessed at baseline (presurgery) and 6 months after the RYGB.

All surgical procedures were performed at the HC-UNICAMP (Brazil). The procedures were approved by the Ethics Committee of the Faculty of Medical Sciences, with number of acceptance 288/2010, Universidade Estadual de Campinas, in accordance with the Declaration of Helsinki.

Clinical protocol

Demographic, anthropometric, ES Complex (Electro Sensor Complex, LD Technology, USA), and laboratory data were collected at baseline and at 6 months after surgery. Data collected were; gender, age, weight, height, body mass index (BMI), food consumption, and total protein serum levels, albumin, prealbumin, parathyroid hormone (PTH), zinc (Zn), B12 vitamin (VitB12), iron (Fe), ferritin, copper (Cu), ionic calcium (CaI), magnesium (Mg), and folic acid.

The inclusion criteria were: ages ranging from 18–65, obesity for a period exceeding 2 years, and BMI over 40 kg/m² or above 35 kg/m² associated with chronic diseases such as diabetes, hypertension, arthropathy, herniated disc, and sleep apnea. All patients received nutritional and exercise counseling during their weekly appointment throughout the period before the surgery to lose at least 10% of their weight before the day of surgery. If the patients failed to achieve this weight loss they were not permitted to undergo the surgery.

Patients with medical conditions, such as endocrine disorders, mental illnesses, drug or alcohol addiction, liver cirrhosis, heart disease, lung disease, chronic renal failure and others were also excluded.

Before surgery, 26 patients received vitamin and mineral supplements (Centrum®) for a period of 3 months, and 35 patients took the same commercial supplement daily 30 days after surgery.

The patients contributing to this survey had to participate in weekly meetings, which could last 5 hours, until the week before their surgery. In these meetings, the patients would receive orientations from the team conducting this survey, composed of doctor, nurse, nutritionist, physical education teacher, and psychologist. The exercises were individually recommended, according to the availability of specific location and time for each participant. In general, it was recommended aerobic exercises such as walking.

After achieving the weight loss target of 10%, the participants received postoperative instructions from the multidisciplinary team, including postsurgery diet and its progression.

Surgical procedure

The RYGB procedure consists of the transection of the upper portion of the stomach, creating a proximal gastric pouch measuring 30–50 mL. The gastric pouch is anastomosed end-to-side to the Roux-en-Y retro-gastric transmesocolic limb. A 1.2-cm diameter silastic ring is placed around the pouch 2–3 cm above the jejunum-gastric anastomosis.

The standard Roux (alimentary) limb length is about 150 cm, the biliopancreatic limb is 100 cm, and the common channel is approximately 500 cm, all measured by a tape-measure. Surgery was performed using the open technique (laparotomy). All surgical procedures were performed by the same surgeon.

Anthropometry

The anthropometric data collected were; weight, measured by a Filizola® digital scale (scale-capacity 300 kg and precision of .1 kg) and height, measured by a Seca® wall stadiometer with a capacity of 2 meters and accuracy of .1 cm. The BMI (kg/m²) classification for adults adopted for this study was that proposed by the World Health Organization [11].

ES Complex data [12]

The ES complex software manages and integrates data from a medical device with the Electro Sensor Oxymeter (ESO) and Electro Sensor Galvanic Skin (ES-GS) sensors. ESO is a spectrophotometric pulse oximeter while ES-GS uses galvanic skin response and bioimpedance to measure body composition.

All data measured are stored and presented by the ES Complex software. The latter also provides a heart rate variability analysis based on the vascular wave data from the pulse oxymeter and the calculation of an algorithm for insulin resistance.

The ES Complex data collected were autonomic nervous system level activity by Heart rate variability analysis, arterial stiffness by photoelectrical plethysmography and Insulin resistance by ES Complex Algorithm for Insulin Resistance (ESC-IR) algorithm. The ESC-IR incorporates the following parameters; heart rate, low frequency spectral analysis of the heart rate variability (LF), fat mass, and stiffness index. [12]

Laboratory analysis

Blood samples were collected from a peripheral vein in the morning, after a 12- hour overnight fast, and analyzed by the Clinical Analysis Laboratory of the Hospital de Clínicas, Unicamp. The following parameters were measured; total serum protein, albumin, prealbumin, PTH, Zn, VitB12, Fe, ferritin, Cu, CaI, Mg, and folic acid. The procedures used for these measurements were; colorimetric for total protein and albumin; nephelometry for prealbumin; immunoassay/ electrochemiluminescence for PTH, B12 and folic acid; atomic absorption spectrophotometry for Zn, Cu and Mg; colorimetric (ferrozine, without deproteinization) for Fe; immunoassay/chemiluminescence for ferritin and ion selective electrode for CaI.

The parameters measured are described in Table 2.

Dietary intake

The dietary intake was assessed using a 24-hour recall survey before and after surgery. The recall was performed only by the first author (R.C.G.), who is a registered dietician. Food intake was converted to nutrient intake using the Nutwin® software [13] for calories and the amount of micronutrients. The daily micronutrient recommendations were evaluated according to the daily intake of micronutrients (DRI) [14].

Statistical analysis

Differences between groups were compared by Student's paired t test and correlation analysis was used to evaluate the association between nutrients intake and serum levels nutrients before and after surgery. P values $< .05$ were considered significant. Data are presented as means and standard deviation. Statistical analyses were performed using the SAS System for Windows (Statistical Analysis System), SAS 9.2.

Results

Patients' characteristics are shown in Table 1. Principal biochemical levels are described in Table 2 and main ES Complex data depicted in Table 3. The majority of patients were female (75%) and the mean weight loss from baseline to 6 months after surgery was 35.34 ± 4.82% of weight. Markers of autonomic nervous system balance were improved ($P < .01$), as well as the markers of the stiffness index ($P < .01$) and insulin resistance as shown by ES Complex data ($P < .001$).

Thirty-four patients demonstrated deficiencies for some of the micronutrients measured. Twenty-three presented preoperative micronutrient deficiencies, 27 presented postsurgery micronutrient deficiencies, and 18 presented pre- and postsurgery micronutrient deficiencies. The highest prevalence of micronutrient deficiency was found for zinc for both pre- (55.5%) and postsurgery (61.1%) values.

Table 1
Characteristics of the study population pre- and postsurgery

	Pre-surgery	Post-surgery 6 months
Number of patients	36	36
Gender (% female)	75	75
Age (years)	37.66 ± 9.67	37.66 ± 9.67
Weight (kg)	118.85 ± 19.80	76.51 ± 11.60
Body mass index (kg/m²)	44.20 ± 4.71	28.49 ± 2.84
% weight loss		35.34 ± 4.82

Table 2
Pre- and postoperative deficiency and high levels of selected nutritional markers

Nutritional markers	Pre-surgery	Post-surgery 6 months	*p* value
Total protein (6.4–8.3 g/dl)	7.37±0.44	7.02±0.37	0.0000*
Albumin (3.4–4.8 g/dl)	4.52±0.24	4.48±0.18	0.3241
Prealbumin (20–40 mg/dl)	28.03±11.25	21.59±3.93	0.0020*
Parathyroid hormone (15–65 pg/ml)	51.63±16.15	45.53±12.73	0.0083*
% of zinc deficiency patients (<80 mcg/dl)	55.55	61.11	0.5478
% of iron deficiency patients (men < 45; women < 30 mcg/dl)*	2.77	0	0.0211*
% of ferritin deficiency patients (men < 30; women < 13 ng/ml)*	2.77	8.33	0.2623
% of copper deficiency patients (men < 70; women < 80 mcg/dl)*	0	8.33	0.0035*
% of ionic calcium deficiency patients (<1.15 mmol/L)	13.88	2.77	0.0001*
% of magnesium deficiency patients (<1.3 mEq/l)	2.77	0	0.0004*
% of folic acid deficiency patients (<4.6 ng/ml)	0	2.77	0.0597
High levels % of B12 vitamin (>900 pg/ml)	11.11	27.77	
High levels % of iron (>160; mcg/dl)	2.77	0	
High levels % of ferritin (men > 400; women > 150 ng/ml)*	16.66	11.11	
High levels % of copper (men > 140; women >155 mcg/dl)*	22.22	11.11	
High levels % of folic acid (18.7ng/ml)	13.88	11.11	

*Student's paired t test

High levels of VitB12, ferritin, Cu, and folic acid deficiency were found at presurgery as well as for postsurgery.

Patients did not present with low levels of total protein, albumin or prealbumin in the preoperative stage; however, 33.33% of the patients presented with low levels of prealbumin 6 months postsurgery. However, as prealbumin is an acute phase reactant, lower levels in the immediate and preoperative period among RYGB patients may not be reflective of true protein status but rather a marker of postoperative stress. High levels of PTH (>65 pg/mL) and ferritin (men > 400 and women > 150 ng/mL) were found in 16.66% of the patients for both parameters before surgery, and in 2.77% and 11.11%, respectively, at postsurgery. Table 4 depicts the prevalence of micronutrient deficiencies reported in the literature.

Twenty-four hour recalls demonstrated that the average number of daily meals were 5 and 6 for pre- and postsurgery, respectively; none of the patients were vegetarians.

Table 3
Main monitoring ES Complex data results

Parameters	Values +/− SD			*P* value
	Start	Presurgery	Postsurgery	
HF HRV#	33 ± 11	33.4 ± 9	36.7 ± 10	<.05
LF HRV*	43 ± 10	41 ± 11	36.9 ± 10	<.01
LF/HF†	1.34 ± .7	1.28 ± 04	1.1 ± .4	<.01
SDNN‡§	50 ± 19	52.4 ± 15	59.3 ± 17	<.01
Stress Index	132 ± 100	121 ± 90	106 ± 79	<.05
SI‡‖	5.9 ± 1	5.6 ± 1.1	5.2 ± 1.1	<.05
RI§	45 ± 13	41 ± 12	36 ± 11	<.01
Systolic P	131.7 ± 29	120 ± 20	120 ± 19	<.01
Diastolic P	80 ± 15	74 ± 13	72 ± 9	<.01
ESC-IR	639 ± 201	525 ± 120	399 ± 160	<.001

Diastolic P = diastolic pressure; ES = Electro Sensor; ESC-IR = Electro Sensor complex algorithm for insulin resistance; HF HRV = high frequency of heart rate variability; LF/HF = low frequency / high frequency; LF HRV = low frequency of heart rate variability; SDNN = standard deviation of normal-to-normal intervals; RI = reflection index; SI = stiffness index; Systolic P = systolic pressure.

#HF HRV is an indicator of parasympathetic activity

*LF HRV is an indicator of sympathetic activity;

†LF/HF ratio is an indicator of the balance of the 2 components of autonomic nervous system

‡SDNN and SI are indicators of the sympathetic system activity

§RI is an indicator of the small and medium artery stiffness

‖SI an indicator of the large artery stiffness

The intake of selected nutrients is shown in Table 5. During caloric restriction to lose weight, some experts recommend the consumption of 70 g/d of protein and many bariatric surgery programs recommend 60 to 80 g/d of protein [24,25]. As the exact requirements have not yet been established, 70 g/d was considered as the ideal consumption. Therefore, 9 patients out of 36 did not demonstrate the required protein intake preoperatively, while 32 (88%) patients presented a low intake postsurgery. Table 6 presents the nutrient intake adequacy, according to DRI [14]. An adequacy of ≤85% was considered an inadequate intake.

Discussion

Nutrition plays an important role in the development and course of chronic diseases. The Western diet contains refined products, such as sugar, alcohol and fat, and is usually low in essential nutrients, potentially resulting in obesity, atherosclerosis, immune disorders, infections, allergies, cancer, and other chronic diseases [26,27]. Because of such diets, patients with obesity sometimes display micronutrient deficiencies because of an unbalanced and hypercaloric diet that is usually low in vitamins and minerals [26–28]. The imbalance or lack of ingested essential nutrients can have a major effect on daily performance, interfering in behavior, as well as intellectual and physical activities [29,30]. In addition, the bioavailability of these micronutrients may be altered in individuals with obesity. One explanation for this imbalance is that the body composition

Table 4
Prevalence of micronutrient deficiency after RYGB according to the literature presurgery and up to 8 years after surgery

	% of deficiency	Presurgery	Postsurgery
Ernst et al. [10], Madan et al. [15], Gong et al. [16], Sallé et al. [17], Balsa et al. [18], Gehrer et al. [19], Dalcanale et al. [20]	% of zinc deficiency	8.1–28	1.92–40.7
Toh et al. [3], Ernst et al. [10], Madan et al. [15], Gehrer et al. [19], Dalcanale et al. [20], Donadelli et al. [21], Skroubis et al. [22], Flancbaum et al. [23]	% of B12 vitamin deficiency	0–18.1	0–61.8
Toh et al. [3], Madan et al. [15], Sallé et al. [17], Gehrer et al. [19], Dalcanale et al. [20], Skroubis et al. [22], Flancbaum et al. [23]	% of iron deficiency	14–50.2	6–37.7
Toh et al. [3], Ernst et al. [10], Madan et al. [15], Dalcanale et al. [20], Skroubis et al. [22], Flancbaum et al. [23]	% of ferritin deficiency	2–16.4	15–36
Balsa et al. [18]	% of copper deficiency	0	1.92
Ernst et al. [10], Dalcanale et al. [20]	% of magnesium deficiency	4.7	32.1
Toh et al. [3], Ernst et al. [10], Madan et al. [15], Gehrer et al. [19], Dalcanale et al. [20], Donadelli et al. [21]	% of folic acid deficiency	0–7	0–12
Toh et al. [3], Ernst et al. [10], Gehrer et al. [19]	% of parathyroid hormone > 65pg/ml	20–36.6	33
Gehrer et al. [19], Dalcanale et al. [20], Flancbaum et al. [23]	% of calcium deficiency	3.2	0–2.2
Toh et al. [3], Ernst et al. [10], Dalcanale et al. [20], Donadelli et al. [21], Flancbaum et al. [23]	% of albumin deficiency	1–15.5	7

may influence the vitamin status by causing dilution effects of extracellular concentrations because of the elevated quantities of total body water in individuals with obesity, as the extracellular compartment is relatively larger than the intracellular compartment [26,27,31,32].

The prevalence of micronutrient deficiencies in patients was low, with the exception of zinc deficiency (Table 2). Iron and ferritin deficiencies were lower than those previously reported in the literature, suggesting that iron and ferritin deficiencies may be approximately 49% for iron and 16% for ferritin in patients undergoing RYGB. Iron deficiency is common among postsurgical menstruating women; therefore, supplementation is recommended for all menstruating RYGB patients [3,8,10,27]. Low serum calcium levels lead to increased PTH release by parathyroid glands [33]; our data show that 16.66% of patients had high preoperative PTH levels, decreasing to 2.77% after RYGB, consistent with previous studies that have found a prevalence of high PTH levels of up to 36.6% [10] during the presurgical period and up to 14% [3] at postsurgery.

There is a paucity of data regarding Mg and folate deficiency post-RYGB surgery. Ernst, et al. [10] reported a prevalence of <5% of Mg and folate deficiencies in postsurgical patients. In contrast, other studies [34–36] have reported an incidence of 6–65% folic-acid deficiency after RYGB. Moreover, Balsa [18], in a cohort study, found that hypocupremia is rare after RYGB, which is compatible with the results found in this study. Furthermore, our study did not find any evidence of VitB12 deficiency either at pre- or postsurgery, probably because of the intramuscular

Table 5
Pre- and postoperative intake of selected nutrients

	Pre-surgery	Post-surgery	*p value
Energy (Kcal/day)	1812.21 ± 767.52	1060.34 ± 322.25	<0.0001
Protein (g/day)	96.22 ± 36.13	47.11 ± 17.70	<0.0001
Zinc intake (mg/day)	10.09 ± 4.10	6.97 ± 3.25	0.0015
B12 vitamin intake (mcg)	4.47 ± 1.71	3.40 ± 1.82	0.0112
Iron intake (mg)	11.98 ± 5.06	7.36 ± 2.96	<0.0001
Copper intake (mg)	0.89 ± 0.32	0.56 ± 0.19	<0.0001
Calcium intake (mg)	661.67 ± 312.76	597.03 ± 289.55	0.3723
Magnesium intake (mg)	246.26 ± 67.13	156.64 ± 63.19	<0.0001
Folic acid intake (mcg)	255.15 ± 100.94	182.48 ± 101.98	0.0049

Food intake was converted to nutrient intake using the Nutwin® software [13].
*Student's paired t test.

Table 6
Nutrients intake adequacy according to Dietary Reference Intakes

	Pre-surgery			Post-surgery		
Nutrients intake adequacy	≤85%	86 to 99%	≥100%	≤85%	86 to 99%	≥100%
Zinc intake adequacy	22.22	27.78	50	61.11	19.45	19.44
B12 vitamin intake adequacy	0	8.34	91.66	25	5.56	69.44
Iron intake adequacy	61.11	2.78	36.11	80.56	0	19.44
Copper intake adequacy	36.11	25.01	38.88	86.11	11.12	2.77
Calcium intake adequacy	77.77	5.57	16.66	83.33	8.34	8.33
Magnesium intake adequacy	88.88	11.12	0	97.22	2.78	0
Folic acid intake adequacy	91.66	8.34	0	94.44	5.56	0

VitB12 supplementation provided throughout the 6-month postsurgical period. It is also possible that VitB12 body stores may last from 2–5 years, therefore, longer periods might be necessary to detect deficiency. Flancbaum et al. [23] did not relate VitB12 deficiency in any of the patients preoperatively. The principal deficiency found in the present study was low serum levels of Zn, which is the second most prevalent trace element found in the human body and essential for normal cell function and metabolism. Zinc has an antioxidant and immune function and regulates taste and appetite [37]. Several factors may lead to Zn deficiency after surgery, such as the reduction in digestive enzymes and a reduction in the consumption of zinc sources, such as beef, chicken, fish, liver, wheat germ, and whole grains, either because of intolerance or to a decrease in the amount of protein intake [37], which was found to be below recommended levels in the present study.

Zinc deficiency is usually defined as serum concentrations of lower than 70 mcg/dL, but in this study <80 mcg/dL was used as a parameter since the standard cut-off utilized by the laboratory employed for analysis was <80 mcg/dL. Zinc status was evaluated by determining serum zinc concentration, which is the most widely used parameter for indicating zinc status and the only indicator for which adequate reference data is available. Serum zinc content is well regulated by body homeostasis and a reduction in this parameter reflects an increased risk of development of clinical and metabolic signs of zinc deficiency [38]. Previous studies have suggested that Zn deficiency occurs in up to 28% of patients preoperatively and in up to 32.9% of patients [10,16,17,18,27] at 6 months after RYGB; as such, this study demonstrated higher levels of deficiency of 55.5% and 61.1%, respectively.

Zinc intake recommendations are 8 mg/d for women and 11 mg/d for men [14]. All patients took a multivitamin and mineral supplement after surgery; supplements contained 7 mg/d of zinc oxide in addition to the Zn ingested during food consumption. Despite the fact that the patients studied had a Zn consumption of 100% or more of the recommended intake, over 50% of the participants were deficient at pre- and postsurgery. The high prevalence of zinc deficiency may be explained by the fact that zinc is mainly absorbed in the small intestine, primarily in the jejunum [37]. As the RYGB is a restrictive procedure that bypasses these segments of the gastrointestinal tract, the absorptive surface area for this micronutrient may be significantly decreased [2]. Another hypothesis is that zinc oxide, the zinc chemical form present in the vitamin and mineral supplement offered, has low bioavailability [39–41]. The study by Balsa et al. [18] suggested that Zn deficiency is common in patients who undergo biliopancreatic diversion**,** but it is rare after RYGB when the patients receive a multivitamin containing 8 mg of Zn chelate/d; however, this Zn chemical form differs from the chemical form offered in the present study (zinc oxide), and some reports indicate low relative bioavailability of zinc and copper oxide mineral salts [39–41].

The average preoperative calorie intake in this study was 1812 ± 767 kcal/d, whereas other studies have documented an intake of 2401 ± 97 kcal/d and 2307 ± 107 kcal/d [42,43]. Food intake was probably underestimated because patients with obesity may understate their consumption. For the calorie intake at 6 months after surgery, data demonstrate a 1060 ± 322 kcal intake/d, which is higher than those reported by Ribeiro et al. [44] and Moizé et al. [45] (677 ± 314 kcal/d and 866 ± 320 kcal/d, respectively), but it is consistent with the related study by Bobbioni-Harsch et al. [43] study (1142 ± 57 kcal/d).

The protein intake in this study was similar to that reported in the literature, both at pre- and postsurgery [42,45] (above 90 g/d and below 70 g/d, respectively). The consumption at 6 months after surgery was <70 g/d, suggesting that protein supplements are needed to maintain an adequate protein intake up to 6 months after RYGB. As mentioned previously, the patients had an average of 6 meals/day, and there were no vegetarians among the participants. The protein intake recorded probably occurred due to patients' inappropriate consumption of protein sources, as patients could not achieve the daily recommendations independently of the kind or the quality of protein.

There was no correlation between nutrient intake and serum levels of nutrients before and after surgery (Supplementary figure) and this may have occurred for several reasons: 1) the fact that the amount of nutrients in food varies according to geographic region and food processing, including methods of preparation, not necessarily reflecting the amount described in food composition tables available to estimate food consumption, and 2) because of the surgical technique of RYGB, which causes nutrient malabsorption, possibly increasing the nutritional requirements and the risk of micronutrient deficiencies.

A second finding of the present study was that surgically induced weight loss had a favorable effect on all the cardiovascular and metabolic risk factors, as well as on autonomic function. According to Table 4, the gradual weight loss before and after the bariatric surgery reduced the reflection index, stiffness index, and systolic and diastolic pressure. All the Heart Rate Variability parameters for autonomic function showed a significant improvement, reflecting a better sympathetic and parasympathetic balance. SDNN increased and the ESC-IR algorithm decreased substantially, showing a reversed procedure of metabolic deterioration [7,46]. Although the ESC-IR algorithm demonstrated a good correlation with the homeostatic model assessment index to identify insulin resistance (HOMA2-IR) [12], further studies are needed to compare with data for the euglycemic-hyperinsulinemic clamp. As such, the SDNN indicator was included in the measurements as an additional diabetes risk factor [47]. Despite the small numbers of patients in the study, the findings indicate that the predictive risk factors measured by the ES Complex in the dynamic analysis had an overall improvement in severely obese individuals at 6 months after surgery. This result confirms the previous studies about the cardiovascular risk factors measured [6,7,46,47].

The number of patients included in the study is small, due to patients' difficulty in following the presurgery protocol, which requires a 10% weight loss in initial weight. It was considered that requiring preoperative weight loss before bariatric surgery could help to identify patients who would comply better with their dietary restrictions after surgery, what could lead to an improvement of their total postoperative weight loss and decrease their recovery time [48]. As such, this may be considered as a limitation to this study.

Other limitations include the measurement of zinc with just the serum zinc exam; it would be ideal to use other examinations in association with this dosage. The 24-hr food record employed also has the disadvantage of not reflecting the habitual food intake of individuals and a 4-day evaluation of the dietary intake would be more accurate to estimate the diet adequacy compared with the DRIs. However, in the postsurgery period, mainly up to 6 months, the patient´s food intake does not vary significantly, so we opted to use the 24-hr recall.

Conclusion

This study showed that patients demonstrate improvement in the autonomic nervous system balance, as well as improvements in the stiffness index and insulin resistance, in association with a high frequency of hypozincemia at 6 months after RYGB. Furthermore, the amount and type of zinc supplementation requires further experimental investigation, since the applied amount of zinc oxide in this survey, 7 mg/d, was not enough to prevent low serum levels of Zn and that protein supplements are needed to maintain an adequate protein intake for up to a 6-month period after surgery. After RYGB, good adherence to a high-quality vitamin and mineral supplement and frequent monitoring is needed to prevent nutritional disorders.

Disclosures

The authors have no commercial associations that might be a conflict of interest in relation to this article.

Appendix

Supplementary data

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.soard.2014.05.011.

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