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Food intake in women two years or more after bariatric surgery meets adequate intake requirements

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ABSTRACT

Restricted food intake after bariatric surgery can be an important factor both in the long-term control of body weight and in the onset of nutritional deficiencies. The objective of this study was to assess the adequacy of food intake in women two or more years after bariatric surgery according to the excess weight lost. A group of 141 women who underwent banded Roux-en-Y gastric bypass (RYGB) was divided according to the percentage of excess weight they lost (%EWL)<50; 50┤75; = 75. The habitual energy and nutrient intakes were determined by a 24-hour recall over two days and the probability of adequate intake was based on the Dietary Reference Intake. The mean total estimated energy requirement (EER) as well as energy, macronutrient and cholesterol intakes did not differ among the groups. Only the %EWL<50 group had an intake equal to their EER, but they presented a higher number of inadequacies, such as low levels of magnesium, folic acid and vitamins C and E. Calcium and dietary fiber intakes were extremely low in all three groups. In conclusion, weight loss after surgery is associated with food habits that favor energy intake over micronutrient intake.

1. Introduction

Previous studies show how bariatric surgery successfully promotes weight loss and improves quality of life and obesity-associated comorbidities [1,2], especially Roux-en-Y gastric bypass (RYGP) since weight loss appears to be longer-lasting [3]. However, it may lead to nutritional deficiencies and clinical complications in the short and long terms that require micronutrient supplementation, and sometimes even macronutrient supplementation, in addition to multidisciplinary care before and after surgery [4,5].

Energy restriction is extremely necessary for weight loss but can be associated with certain side effects, such as food aversions, unbalanced diet, protein malnutrition, and specific

Abbreviations: %EWL, excess weight they lost; DRI, Dietary References Intakes; EAR, Estimated Average Requirement; EER, Estimated Energy Requirement; EW, Excess weight; PAF, physical activity factor; PAL, Physical Activity Level; PC-SIDE, Software for Intake Distribution Estimation; RYGB, Roux-en-Y gastric bypass; SUS, Unified Healthcare System; TER, total energy requirement.

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nutrient deficiencies [6,7]. However, in the long run, the degree to which obesity surgery impacts nutrient intake or how nutrient intake impacts surgery outcome is not yet fully understood [8].

Malnutrition in this population may stem from mal-absorption, in addition to inadequate food intake. A recent consensus suggested that micronutrient supplementation once a day that meets two-thirds to 100% of the recommended daily intake may not be enough, and it even recommended that American and Canadian individuals who underwent mal-absorptive procedures, such as RYGB, double the daily dose [9].

The Dietary References Intakes (DRI) values are a reference based on quantitative estimates of nutrient intake. They were established for planning and assessing the diets of healthy individuals, according to their life stage and gender. The establishment of these reference values considers the role that diet plays in promoting or protecting against chronic diseases. However, these values must be used with caution when the adequacy of food and nutrient intakes of populations with specific nutritional requirements are assessed, for example, when estimating the nutritional needs of bariatric surgery patients [10,11].

Micronutrient intake after surgery should meet the DRI and this can be achieved by daily supplementation of vitamins and minerals [5,9]. As for energy intake, only a scale can determine if energy intake and requirements are balanced.

It is essential to assess not only the weight lost after bariatric surgery but also the changes in dietary habits imposed by surgery, since there are still many questions to be answered. Thus, the present study aimed to assess the adequacy of food intake in women two or more years after bariatric surgery in relation to the amount of weight they lost.

2. Methods and materials

2.1. *Casuistic*

A total of 141 women who received an operation at the Bariatric Clinic of the *Hospital dos Fornecedores de Cana de Piracicaba* – São Paulo between 1998 and 2005 participated in the study. Women were included in the study if they met the following criteria: 21 years of age at the time of procedure or older, underwent laparoscopic or laparotomic banded Roux-en-Y gastric bypass between 1998 and 2005, attended the follow-up visits after the surgical procedure and had the procedure at least two years prior to the study (2 to 7 years).

A total of 1500 individuals underwent bariatric surgery during the study period and were potential candidates. Those who met the inclusion criteria were called in a random order. The sample was then formed by the individuals who were at home when the call was made and by those who were not home but returned the telephone call and agreed to participate in the study. Thirteen men agreed to participate in the study but since the number was too small they were excluded. The women who agreed to participate in the study signed a free and informed consent form after the study was explained to them. The study was approved by the local Research Ethics Committee, protocol number 16/2006.

2.2. *Weight history*

Body weight at surgery was collected from the electronic medical records of the patients. Weight after surgery was measured during the follow-up visits and, for this study, two years after the procedure, with a tolerance margin of approximately one month. Other data collected from the medical records included height, ideal weight, age, skin color, marital status, and surgical technique (laparotomic or laparoscopic RYGB). The following were then calculated: body mass index (BMI) was attained by dividing body weight in kilograms by the square of the height in meters (kg/m^2); excess weight (EW) at time of surgery was obtained by subtracting the ideal weight recommended by the Metropolitan Life table [12] from the weight at time of surgery; and percentage of excess weight lost (%EWL) was determined by multiplying excess weight lost by 100 and dividing by the excess weight, which was then used to determine the degree of surgical success [1,13,14].

2.3. *Food intake*

Since there would be only one meeting with the participants and knowing the importance of having at least two intake measurements to estimate the prevalence of adequacy, we proposed to investigate the quantitative habitual food intake during a weekday and during a weekend day in the same interview. In order to validate this method of assessing food intake (habitual week day and weekend day) the first 25 participants were instructed to fill out forms detailing their food intake during three nonconsecutive days, including a weekend day. The results in terms of energy and nutrient amounts were analyzed by the interclass correlation coefficient [$P=2\ \Sigma$ (a1-Xm) (a2-Xm) / Σ (a1-Xm)2+Σ (a2 - Xm)^2]. The agreement between the two methods (r=0,91 to 0,98) evidenced low variabilityof the meals consumed by the group.

2.4. *Estimate of the habitual food intake*

During the interview, the participants were asked to report what they usually ate during a weekday and a weekend day. All food consumed during every meal of each day were included, as well as the foods consumed most often. The amounts of each item used for preparing the meals that were consumed by the entire family, such as salt and oil, were divided by the number of people who consumed the meal and resulted in the mean intake per person per meal.

The amounts of the foods consumed were recorded in cooking units (spoons, cups, etc.) using the *RegistroFotográficoparaInquéritosDietéticos* (Photographic Record for Dietary Investigations) [15] and the utensils available in the experimental kitchen of the study site to aid the interviewee. The micronutrients obtained from dietary supplements were also included.

The habitual food intake during a day was expressed in cooking units, converted to grams using an appropriate table [16],and then entered in the Nutwin® software [17] to estimate the macro and micronutrient intakes. The Nutwin software databank was constructed with data from the Brazilian Table of Food Composition [18].

2.5. Estimate of the energy requirement

The specific equations for calculating the Estimated Energy Requirement (EER) in individuals with BMI>25kg/m^2 were used for estimating the total energy requirement according to the Dietary Reference Intakes (DRI) of the Institute of Medicine (2005) [10], taking into account the gender, weight, height, physical activity level, and age of the participants.

The mean Physical Activity Level (PAL), determined by the 3-day physical activity record, was used to determine a physical activity coefficient (PA) for each participant. PAL was characterized according to the DRI criteria [11].

2.6. Assessment of the adequacy of the estimated energy and nutrient intakes

The DRI was used to analyze energy and macronutrient and micronutrient intakes [10,19–23]. The dietary values from the Estimated Average Requirement (EAR) were used for assessing the adequacy of micronutrient and protein intakes. The Adequate Intake (AI) was used in place of the EAR for the micronutrients without EAR values. The percentage distribution of the macronutrients with respect to the total energy intake was assessed according to the Acceptable Macronutrient Distribution Ranges (AMDR).

The AI was established when it was not possible to determine the EAR, and thus, the RDA (Recommended Dietary Allowances). It is hoped that the AI is enough to meet or exceed the micronutrient requirement and ensure a healthy nutritional status. However, one cannot use the AI values to estimate the requirements; it is only a recommended intake.

Analysis of the habitual nutrient intake distribution among the groups with regard to the reference values was done by the PC-SIDE - Software for Intake Distribution Estimation- Version 1.02, 1999, taking the EAR as the cut-off point (or AI when an EAR value was not available). The software uses the methodology proposed by Verret (2006) [24] who used mathematical transformations to reduce the distortion that is typically observed in daily intake distribution. Transformations are also used to normalize daily intake data and analyze the variance. It then establishes the mean habitual intake, the percentile intake distribution and the proportion of the population that is above or below a given limit (in this case, the EAR and AI). The result is the probability of adequate or inadequate intake of a given nutrient expressed in percentages. A probability equal to or above 70% is considered adequate. Dietary cholesterol intake was based on the World Health Organization - WHO [25] recommendations, which states that an intake of 300mg or less per day is appropriate.

2.7. Statistical analyses

The demographic and anthropometric data were analyzed after dividing the participants of the study into three groups according to their %EWL (<50; 50┤75 and=75). The statistical analysis and data representation were done by Excel for Windows 2007, BioEstat 3 [26], PC-SIDE, 1999 and SAS, 2004. All of the recorded continuous variables were tabled as means± standard deviation or median, accompanied by the maximum and minimum values. The nominal variables were expressed in percentages. The nutrient data were mathematically transformed until normality was achieved [27]. The Student's t-test and the Mann Whitney test were used to analyze the relationship between the means and the medians, respectively, of continuous and categorical variables when the distribution was normal. When there were more than two sets of data, the means were compared by analysis of variance (ANOVA) and followed by the Tukeytest and by the Kruskal-Wallis and Dunn tests when the data did not present a normal distribution under the curve. The significance level was set at 5% ($P \leq .05$) for all calculations.

3. Results

The criterion adopted to determine surgical success (%EWL=50) showed that 84% of the women achieved a successful outcome. Of the 141 women who participated in the study, most were white (89%), married (72%), and had a mean age of 44±9 years. The group with the lowest %EWL was slightly older, with a mean age of 48±10years. Most women (90%) underwent the laparotomic banded RYGB surgical technique. More than half the surgeries (54%) were performed by the Unified Healthcare System (SUS).

Before the surgery, the participants presented similar anthropometric measurements when divided into three groups according to %EWL. Anthropometric data from the participants is included in Table 1. There was a statistical difference among the groups regarding the highest and lowest weights achieved and BMI. The values were inversely proportional to the %EWL. The highest mean current weights (92.0±10.1) and BMI (35.4±3.2) were found in the %EWL<50 group. The group that achieved the greatest weight loss (%EWL=75) had a significantly shorter time since surgery than the other groups (Table 1).

Surgery outcome in terms of %EWL was not associated with energy and macronutrient intakes. As Table 2 shows, there was no difference among the groups with regard to the mean estimated energy requirement and energy, macronutrient and cholesterol intakes. However, the energy requirement and total energy intake of both groups with %EWL>50 differed significantly.

Table 3 shows the median values and the probability of adequate micronutrient, the amount of protein in grams per kilogram of weight (g/kg) and the fiber intakes in relation to the EAR values, with AI values included when the EAR values were not available. The intakes of thiamin, riboflavin, niacin, vitamin B_6, vitamin B_{12}, iron, vitamin A, protein and zinc were adequate in all studied groups. Folic acid presented the lowest probability of adequate intake in the %EWL<50 group. Vitamin C and E intakes were adequate only in the %EWL=75 group (Table 3). The probability of adequate magnesium intake was very low in the %EWL<50 and %ELW=75 groups, while the probabilities of adequate calcium and fiber intakes were extremely low in all three groups

Table 1 – Anthropometric variables of the studied population according to the percentage of excess weight lost (%EWL)

Variables	%EWL				ANOVA
	< 50	50 ┤75	= 75	All	
	n=22	n=68	n=51	n=141	ρ
Before surgery					
Weight at surgery (kg)	116.3±16.0	120.3±16.6	113.2±15.9	117.1±16.4	P=,061
BMI at surgery (kg/m²)	45.0±5.6	46.9±6.6	45.2±7.3	45.9±16.4	P=,292
Time since surgery (years)	4.2±1.4[a]	4.1±1.4[a]	3.4±1.4b	3.9±1.4	P=P=.006
After surgery (= 2 years)					
Current weight (kg)	92.0±10.1 [a]	80.5±8.1 [b]	65.1±6.6 [c]	76.5±12.2	< .05
Current BMI (kg/m²)	35.5±3.2 [a]	31.4±3.2 [b]	25.9±2.8 [c]	30.0±4.5	< .05
%EWL *	45.3 (32.4-49.3)[a]	64.3 (50.1-74.8)[b]	86.8 (75.7-121.3)[c]	68.5 (32.3-121.3)	< .05

BMI=Body mass index (kg/m²).
Same letters in the same roll accompanying the values indicate that the values do not differ according to the Tukey test, after ANOVA ($P \leq .05$).
* Data were expressed as median (maximum and minimum). Same letters in the same roll accompanying the values indicate that the values do not differ according to the Dunn test after the Kruskal Wallis test ($P \leq .05$).

(Table 3). Most of the study women (75.2%) took dietary supplements, and the three groups did not differ in this respect (P=.80).

4. Discussion

Weight loss is usually maximal in the first year after surgery, especially in the first six months. From 3 to 12 months after surgery, energy intake according to the literature varies from 500 to 1000 kcal per day [28–30], while some authors found values of 1500 to 1700 kcal per day after 12 months [30,31]. Despite the inter-study variability, nutrient intake during the first year after surgery is expected to be considerably below the recommendations, since this period involves mechanical, and consequently, dietary adaptations [28]. The adaptation process should be complete two years after bariatric surgery with a stable intake of food and, thus, considered habitual food intake.

Habitual food intake will determine if weight will stabilize or continue to decline, even though other variables such as side effects, food aversions and mal-absorption also influence this process [7,32]. The present study observed that 16% of the women were in the %EWL<50 group, which means they had an unsuccessful surgery outcome according to the criterion adopted for this assessment. This group was the only group whose energy intake did not fall behind the estimated requirement according to current equations. Another study reported a similar finding: the group with %EWL<50 presented a considerably greater energy intake 8 years after surgery. Curiously, the group that presented the lowest weight loss (%EWL<50) and highest energy intake in the present study, also presented the lowest likelihood of meeting micronutrient requirements, hence denoting the worst dietary patterns.

Conceptually, food habits represent a general picture of food and nutrient intakes characterized by habitual food intake. The changes made to the gastrointestinal tract by bariatric surgery change food habits and eating patterns, which then need to adjust to the new gastric volume and to the characteristics of the macro and micronutrient sources ingested [33]. Nutrient intake adequacy is highly dependent on food choices and adoption of dietary practices that favor more nutritious foods.

The differences in food habits can be identified by the percentage of energy coming from the different macronutrients. Both the present study and Gomes' study [34] did not find differences among the groups regarding the AMDR. However, the group that lost the least amount of weight (%EWL<50) presented a percentage of fat intake of 37.7±4.7, while the AMDR recommends a maximum fat intake of 35% in relation to the total energy intake (20%-35%) [10]. Kruseman et al (2010) [32] did not observe a similar finding.

The high adequacy of nutrient intakes, that is, intakes higher than 70% of the EAR for the nutrients with EAR values, is probably due to the regular use of dietary supplements, which were taken by most of the participants.

Table 2 – Estimated energy intake, total energy requirement, macronutrients (%) and cholesterol of the studied population according to percentage of excess weight lost (%EWL), Eastern São Paulo State, Brazil, 2007, n=141

Variables	< 50% EWL	50 ┤75% EWL	= 75% EWL	ANOVA
	n=22	n=68	n=51	ρ
EER (kcal)	1800±123	1836±134	1838±121	0.1017
TEI (kcal)	1613±372	1457±554 *	1449±417 *	0.2570
Carbohydrates (%)	47.2±7.1	49.6±8.9	49.8±9.4	0.5280
Proteins (%)	15.0±4.8	15.8±4.9	16.0±5.8	0.7577
Fats (%)	37.7±4.7	34.5±7.3	34.1±6.5	0.0906
Cholesterol (mg)	132±76	126±70	126±60	0.9278

EEI=Estimated energy intake.
EER=Estimated energy requirement according to the INSTITUTE OF MEDICINE, 2005.
Data expressed as means±standard deviation.
* Differs from the EER of the respective group according to the Student's t-test ($P \leq .05$).

Table 3 – Adequacy of the estimated micronutrient, protein (g/kg) and fiber intakes by the studied population according to the percentage of excess weight lost (%EWL), Eastern São Paulo State, Brazil, 2007, n = 141

Variables	EAR/AI	< 50% EWL (n = 22)	50 ┤75% EWL (n = 68)	= 75% EWL (n = 51)	PA (%)	Med (min - max)	AP (%)
		Med (min - max)	AP (%)	Med (min - max)			
Thiamin (mg) [b]	0.9	2.2 (0.5 - 4.2)	99.9	2.2 (0.2 - 12.6)	83.1	2.4 (0.3 - 4.0)	99.5
Riboflavin (mg) [b]	0.9	2.4 (0.4 - 4.1)	89.4	2.6 (0.5 - 13.1)	86.9	2.6 (0.3 - 4.4)	89.5
Niacin (mg) [b]	11.0	28.9 (7.4 - 49.2)	99.1	30.9 (2.4 - 61.0)	100.0	28.3 (4.0 - 73.2)	98.1
Vit B6 (mg) [b]	1.14 [a]	2.5 (0.4 -7.5)	81.4	3.1 (0.1 - 21.7	86.6	2.8 (0.3 - 21.5)	88.7
Vit B12 (μg) [b]	2.0	7.4 (1.5 - 61.1)	100.0	8.2 (0.1 - 178.6)	99.9	7.5 (0.2 - 177.0)	99.1
Folic acid (μg) [b]	320	427 (27 - 789)	56.2	540 (34 - 5720)	70.8	498 (32.7 -5559)	71.6
Iron (mg) [b]	7.5 [a]	15.4 (5.7 - 30.4)	96.2	24.2 (2.4 - 66.5)	84.3	22.3 (2.18 - 66.7)	84.3
Vit A (UI) [b]	1667	5425 (13 - 17542)	86.7	6151 (59 - 25452)	88.9	6015 (202 - 26174)	89.8
Vit C (mg) [b]	12.0	75.1 (2 - 312.8)	68.0	74.1 (0.2 - 416.5)	65.8	99.8 (2.6 - 425.3)	76.4
Vit E (mg) [b]	60.0	16.7 (3.5 - 37.7)	63.4	25.6 (2.4 - 274.3)	65.8	23.1 (1.3 - 272.8)	75.9
Protein (g/kg) [b]	0.66	0.7 (0.2 - 2.0)	89.3	1.0 (0.1 - 2.3)	99.6	1.0 (0.3 - 3.9)	94.8
Zinc (mg) [b]	6.8 [a]	14.8 (3.1 - 30.4)	96.3	24.0 (2.4 - 39.7)	99.7	21.9 (2.2 - 34.3)	85.5
Magnesium (mg) [b]	264 [a]	264 (175 - 484)	49	310 (132 - 639)	70.0	293 (72 - 591)	62.0
Calcium (mg) [c]	1041 [a]	575 (191 - 2214)	1.7	643 (81.9 - 2191)	4.7	751 (101 - 2225)	19.8
Fiber (g) [c]	24.0 [a]	11.2 (3.8 - 35.7)	4.0	10.6 (1.5 - 35.5)	1.3	10.4 (1.6 - 23.3)	0.0

AP = Adequacy Probability; MED = median; MIN = minimum; MAX = maximum.
[a] Weighted mean requirements by age.
[b] Estimated Average Requirement (EAR).
[c] Adequate Intake (AI).

The nutrients that presented the highest probabilities of inadequate intake were folic acid, vitamin E, vitamin C and magnesium. This inadequacy may be due to the fact that 25% of the participants do not take dietary supplements, which end up being the main source of micronutrients for this population [35,36]. Another important factor that may justify this inadequacy is the low consumption of foods that provide these nutrients, such as organ meats and leafy greens which provide folic acid, whole grains which provide magnesium, and non-starchy vegetables and fruits, especially citrus fruits, which provide vitamin C [37,35].

Reports of iron, vitamin B_{12}, vitamin A and thiamin deficiencies are quite common in the literature [5,38–40]. The present study found that their intakes were adequate, probably because of the regular use of dietary supplements. However, only bioavailability studies or more studies with blood tests can determine for sure if the intake of these nutrients is adequate since RYGB induces anatomic and physiological changes in the gastrointestinal tract that may affect the absorption of these nutrients [33,41]. Bear in mind that the absorption of iron is limited and highly dependent on physiological environment, and the absorption of vitamin B_{12} is mediated by molecules present in the gastric juices.

According to Dalcanale et al [7], 2 years prior to undergoing gastric bypass surgery, even patients who were taking micronutrient supplements had low levels of serum magnesium, zinc, vitamin B_{12}, vitamin D_3 and beta-carotene. Patients at greater risk of nutritional deficiencies were those who lost the greatest amount of weight, vomited more frequently, presented dumping syndrome, and were females of childbearing age. Other studies have shown that higher incidences of digestive tract intercurrences [42] and food aversions [43] were associated with greater weight loss after surgery.

The estimated protein intake of all three groups was also considered adequate. This fact may be associated with the nutrition education process that the participants underwent, which promoted the consumption of protein-rich foods. It may also be due to the frequent consumption of legumes, especially beans, which is one of the staple foods of Brazil.

Calcium and fiber were the nutrients that presented the lowest levels of adequate intake according to the AI. However, one cannot ignore the fact that the AI values were established arbitrarily. They do not represent a requirement, but a recommendation. Nevertheless, the calcium and fiber intakes of the studied population were extremely low. The proportion of women who ingested enough calcium to meet the AI was less than 20% in all groups. It was already found that individuals who undergo bariatric surgery are at increased risk of developing bone abnormalities, secondary to inadequate intake of good dietary sources of calcium [38] or to the anatomic changes imposed on the intestinal tract (duodenal bypass and bypass of some of the proximal jejunum) which impair the absorption of this nutrient [37]. Furthermore, this study involved women with a mean age greater than 40 years, meaning that they are already at risk of developing bone diseases [37,39]. It must be emphasized that the calcium levels of these women should be monitored and supplementation should be provided when necessary, preferably in the form of calcium citrate since this salt does not depend on acid secretion to be absorbed [37,39]. The patient should also receive some nutrition education to promote his or her adherence to the proposed supplementation protocol.

The adequacy of fiber intake was even lower than that of calcium. The probability that the fiber intake of the studied population met the AI was less than 5%. Low fiber intake is likely associated with low intake of non-starchy vegetables and fruits after the surgery, which is quite common because of the mechanical restriction imposed by surgery [44,45]. Another factor that may contribute to low fiber intake is the contemporary dietary trends, which are heavily influenced by the ease of consuming processed foods because of their low cost and widespread availability [46].

The results of this work once more confirm the deleterious effects of the modern western diet, consisting mostly of energy-dense foods. The women with the worst surgery outcomes were those who reported energy intakes similar to their energy requirements two or more years after surgery. The most successful surgery outcomes (%EWL>50) were found in women who reported consuming significantly less energy than their requirement. Note that the estimated energy requirement was not corrected for possible metabolic adaptations to the food restrictions imposed by surgery or to over reporting the level of physical activity, which is common in this population. Food restrictions are usually blamed for the low nutrient intakes observed in bariatric surgery patients. However, among the participants of this study, the problem was more of a qualitative nature than of a quantitative nature since food choices are associated with surgery outcome. The women in the group considered unsuccessful consumed foods that contained more fat and less essential nutrients, such as vitamins C and E, folate and magnesium.

Finally, dietary assessments depend on accurate information to produce accurate results. There are innumerous difficulties associated with dietary assessments, regardless of the method used. Underreporting intake could be a factor associated with unsuccessful surgery outcome, but even though this could have occurred, the method used was sensitive enough to detect intake variations that often go unnoticed.

Assessment of the adequacy of energy and nutrient intakes, according to the DRI criteria for women, indicated that, two years or more after surgery, the probabilities of consuming adequate amounts of most nutrients were satisfactory for all three groups. In contrast the %EWL<50 group presented a higher number of inadequate intakes, which leads to a possible association between poor surgery outcome and poor food choices, such as a preference for non-nutritious, energy-dense foods. The calcium and fiber intakes of the studied population were extremely low. Furthermore, bioavailability studies would be necessary to help determine if most of the nutrient intakes were indeed adequate.

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