Original Research Communications

Energy and macronutrient intake after gastric bypass for morbid obesity: a 3-y observational study focused on protein consumption[1]

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ABSTRACT

Background: The effect of a Roux-en-Y gastric bypass (RYGB) on body weight has been amply documented, but few studies have simultaneously assessed the evolution of energy and macronutrient intakes, energy expenditure, and changes in body composition over time after an RYGB.

Objective: We evaluated energy and macronutrient intakes, body composition, and the basal metabolic rate (BMR) in obese female patients during the initial 3 y after an RYGB.

Methods: Sixteen women with a mean ± SEM body mass index (in kg/m^2) of 44.1 ± 1.6 were included in this prospective observational study. The women were studied on 6 different occasions as follows: before and 1, 3, 6, 12 (n = 16), and 36 (n = 8) mo after surgery. On each occasion, food intake was evaluated from 4- or 7-d dietary records, body composition was assessed with the use of bioimpedancemetry, and energy expenditure was measured with the use of indirect calorimetry.

Results: Body weight evolution showed the typical pattern reported after an RYGB. Total energy intake was 2072 ± 108 kcal/d at baseline and decreased to 681 ± 58 kcal/d at 1 mo after surgery ($P < 0.05$ compared with at baseline). Total energy intake progressively increased to reach 1240 ± 87 kcal/d at 12 mo after surgery ($P < 0.05$ compared with at 1 mo after surgery) and 1448 ± 57 kcal/d at 36 mo after surgery ($P < 0.05$ compared with at 12 mo after surgery). Protein intake was 87 ± 4 g/d at baseline and ± 2 g/d 1 mo after surgery ($P < 0.05$ compared with at baseline) and increased progressively thereafter to reach 57 ± 3 g/d at 36 mo after surgery ($P < 0.05$ compared with at 1 mo after surgery). Carbohydrate and fat intakes over time showed similar patterns. Protein intake from meat and cheese were significantly reduced early at 1 mo after surgery but increased thereafter ($P < 0.05$). The BMR decreased from 1.12 ± 0.04 kcal/min at baseline to 0.93 ± 0.03, 0.86 ± 0.03, and 0.85 ± 0.04 kcal/min at 3, 12, and 36 mo after surgery, respectively (all $P < 0.05$ compared with at baseline).

Conclusions: Total energy, carbohydrate, fat, and protein intakes decreased markedly during the initial 1–3 mo after an RYGB, whereas the BMR moderately decreased. The reduction in protein intake was particularly severe at 1 mo after surgery, and protein intake increased gradually after 3–6 mo after surgery. This trial was registered at clinicaltrials.gov as NCT01891591. *Am J Clin Nutr* 2016;103:18–24.

Keywords: body composition, energy intake, gastric bypass, protein intake, weight loss

INTRODUCTION

Bariatric surgery is currently considered to be the most-effective treatment of severe obesity when lifestyle interventions and pharmacologic treatments have failed (1, 2). Of bariatric surgical procedures, a Roux-en-Y gastric bypass (RYGB) is particularly efficient in inducing sustained weight loss, reverting comorbidities associated with obesity, and improving the quality of life and life span (1). The weight loss induced by an RYGB can be explained by several factors including a decreased capacity to ingest large amounts of foods, a decreased appetite, early satiation secondary to alterations of postprandial gut peptide secretion and a moderate malabsorption secondary to the bypass of the proximal short-bowel segments (3). An RYGB also alters postprandial blood bile acid kinetics, and increased bile acid concentrations may exert metabolic effects through alterations of gut peptide secretion and the activation of liver farnesoid X receptors (4–6).

Gross carbohydrate malabsorption is usually not observed after a standard RYGB (7, 8). In contrast, the incidence of vitamin and micronutrient deficiencies is very high and requires a tight postsurgical nutritional follow-up (9). Because of the current worldwide epidemic of obesity and metabolic disorders, the number of bariatric surgery interventions has increased dramatically over the past decades and is likely to further increase in the future (10). As a consequence, an ever increasing number

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of RYGB patients require immediate and long-term postsurgery nutritional monitoring and counseling.

Several previous studies reported that rapid weight loss almost invariably occurred during the first 3 mo after an RYGB and was associated with low total energy and protein intakes together with low intake of animal protein after surgery (11–17). Energy expenditure decreased concomitantly mainly because of lean body mass loss (18). However, few studies have included a follow-up >18 mo. To gain additional insights into the effects of RYGB on energy and macronutrient metabolism, we studied a small group of obese female patients over 1 to 3 y after an RYGB. The follow-up of subjects over a 3-y period, although possible only in a small number of participants, allowed for the evaluation of the short- and longer-term effects of an RYGB on total food energy and protein intakes. In addition, the simultaneous monitoring of food intake, body composition, urinary urea nitrogen excretion, and basal metabolic rate (BMR) provided a comprehensive assessment of energy and macronutrient balances.

METHODS

Subjects

Sixteen female patients, who had their presurgical evaluations at the obesity clinic of Lausanne University Hospital March and December 2008, were included in a prospective longitudinal study. Inclusion criteria were as follows: BMI (in kg/m^2) ≥40 and the failure of previous lifestyle interventions (19). Exclusion criteria were as follows: having hepatic, gastrointestinal, or endocrine diseases; malignancy; pregnancy; uncorrected nutritional deficiencies; and an inability to understand instructions. Participants followed our standard preparation program for bariatric surgery, which included medical and psychological evaluations, and s dietary assessment and instructions (20). Presurgical energy-restricted diets were not advocated when the study was initiated (2008). All participants were evaluated once during the 3 mo before the RYGB and on 4 or 5 different occasions until 36 mo after surgery. The experimental protocol was approved by the Ethical Committee for Human Research of the Canton de Vaud, and every participant provided an informed written consent. The study was run between March 2008 and December 2011.

Surgical technique

The RYGB was performed in a retrocolic-retrogastric fashion with a small 10–15-mL gastric pouch, short biliopancreatic limb, and a 100-cm Roux limb (21).

Presurgical and postsurgery management

Patients included in this study followed the standard program for preparation to bariatric surgery and postsurgical follow-up in use in our obesity clinics by the time the study was performed. The preparation program started with information classes (3 periods of 150 min) that were delivered 12–24 mo before surgery and focused on medical aspects of bariatric surgery, associated changes in food tolerance, and potential adverse psychological outcomes (20). During the same period of time, the patients also underwent a psychological evaluation. In the second part of the program, which corresponded to the 3 mo before surgery, participants attended preoperative classes (3 periods of 150 min) that were focused on practical aspects of perioperative nutrition and long-term diet adaptation to an RYGB. After the intervention and ≤1 mo after surgery, patients were instructed to follow a semiliquid diet. Thereafter, they were instructed to switch to solid foods. Finally, patients attended 3 classes of 150 min on long-term nutritional risks associated with an RYGB 3 mo after surgery.

Study outcomes

The following set of evaluations was obtained in each participant before surgery and 1, 3, 6, and 12 mo post-surgery: *1*) Daily protein intake (primary outcome) and carbohydrate, fat, and energy intakes were calculated from 7-d food records (except for the 1-mo postsurgery evaluation for which information was collected for 4 d only). Qualitative and quantitative analyses of data were performed with the use of validated food photographs (SU.VI.MAX) and artificial food items. The computation of nutrient intake was done with the Prodi 5.3 Expert Nutrition Software Program (WVG). Dietary sources for protein intake were evaluated by specifically calculating meat, fish, cheese, noncheese dairy products, and egg-protein intake. 2) A 24-h urine collection was done for the measurement of daily urea production. Daily nitrogen excretion was calculated with the assumption that the urea nitrogen accounted for 90% of the total nitrogen excretion (22). *3*) The participant's spontaneous physical activity was recorded with a podometer (Electronic Step Counter Podometer; ReducTip.ch). *4*) The BMR was recorded (n = 14). For this measurement, subjects came to the Clinical research Centre in the morning after an overnight fast; at their arrival, they were transferred into beds where they remained in a semi-recumbent position for the next 90–120 min. Respiratory gas exchanges were monitored with the use of open-circuit indirect calorimetry (Deltatrak II; Datex Instrument) for ≥60 min or until adequate measurements were recorded. Energy expenditure and net substrate-oxidation rates were calculated with the use of the equations of Livesey and Elia (23). This measurement was done at all time points except at 1 mo after surgery. Measurements could not be obtained for at least one time point in 2 participants, and the statistical analysis was done with the group of 14 participants who completed all measurements. *5*) Body composition was assessed with the use of a bioelectrical impedance analysis (BIA 101; Akern Srl). Results were analyzed with the Bodygram program (1.31 version, 1998; Akern Srl). These evaluations were also repeated 36 mo after surgery in a subset of 10 patients (of whom only 8 subjects had indirect calorimetry measurements).

Statistical analysis

All values are expressed as means ± SEMs. Data normality was checked with the use of Shapiro-Wilk tests. Nonnormally distributed data (carbohydrate and fat intakes, energy expenditure, fat and protein oxidation, and urinary nitrogen excretion) were log transformed before the statistical analysis. All normally distributed raw and transformed variables were analyzed with the use of a 1-factor ANOVA and post hoc Bonferroni tests. Respiratory quotients remained nonnormally distributed even after transformation and were compared with the use of a nonparametric signed rank test with Bonferroni correction. The software used was STATA version 10 (StataCorp LP). This software eliminated observations that had one or more missing values (LISTWISE deletion).

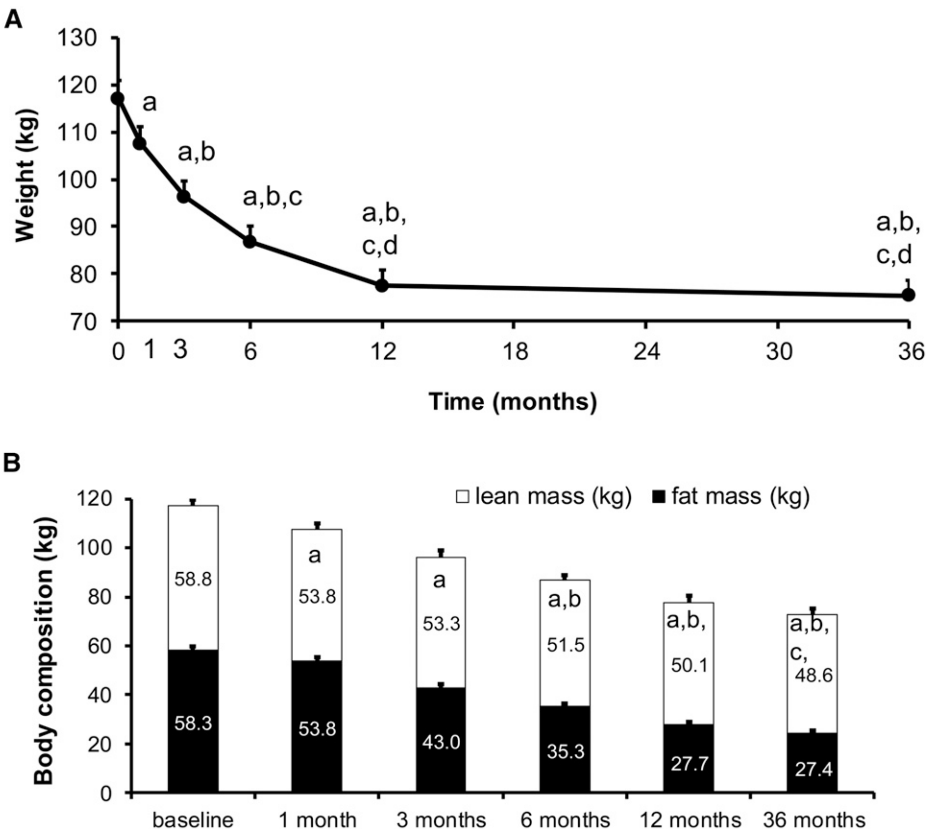

FIGURE 1 Mean ± SEM changes in body weight and body composition after a Roux-en-Y gastric bypass. Changes in body weight (A) and body composition (B) in participants before surgery (baseline; *n* = 16) and 1 (*n* = 16), 3 (*n* = 16), 6 (*n* = 16), 12 (*n* = 16), and 36 (*n* = 10) mo after surgery. Values for fat mass are reported in Results. The statistical analysis was done with the use of a 1-factor ANOVA and post hoc Bonferroni tests. *P* values were considered significant at <0.05. [a–d]Significance is indicated for total body weight (A) and lean body mass (B) as follows: [a]different from baseline, [b]different from 1 mo after surgery, [c]different from 3 mo after surgery, and [d]different from 6 mo after surgery.

RESULTS

Body composition

A total of 16 female patients were included in the study. Before surgery, their mean age was 39.4 ± 2.4 y, mean BMI was 44.1 ± 1.6 kg/m^2, and mean body weight was 117.1 ± 3.7 kg. One patient had impaired glucose tolerance, 3 patients had dyslipidemia, 3 patients had high blood pressure, and 10 patients had no comorbidity. None of the patients had type 2 diabetes mellitus. All participants were studied before and 1, 3, 6, and 12 mo after surgery, and 10 of the subjects were studied again after 36 mo. The main reasons why participants were not evaluated at 36 mo were a lack of time because of professional activities and having moved outside the area.

All participants were advised to take a standard multivitamin supplement daily and were administered bimonthly intramuscular injections of vitamin B-12 after surgery. In addition, supplementary folic acid, thiamin, calcium, vitamin D, and iron were given as required. The changes in body weight and lean body mass over time are shown in **Figure 1**. As expected, body weight and lean body mass loss decreased rapidly during the initial 3 mo after surgery, further declined until 12 mo after surgery, and remained stable thereafter. The RYGB led to a mean total weight loss of 39.7 ± 1.0 kg (34.2% ± 1.0% of initial body weight; $P < 0.001$) at 12 mo after surgery and to a mean lean body mass loss of 8.9 ± 1.0 kg (14.9% ± 1.3% of initial lean body mass; $P < 0.01$). One-half of the total lean body mass loss occurred during the initial 1 mo after surgery. During this initial

TABLE 1
Total energy, protein, carbohydrate, and fat intakes at baseline and 1, 3, 6, 12, and 36 mo after an RYGB[1]

	Baseline (*n* = 16)	1 mo (*n* = 16)	3 mo (*n* = 16)	6 mo (*n* = 16)	12 mo (*n* = 16)	36 mo (*n* = (10)	*P* (1-factor ANOVA)
Total energy intake, kcal/d	2072 ± 108	681 ± 58[a]	1047 ± 62[a,b]	1270 ± 77[a,b]	1240 ± 87[a,b]	1448 ± 57[a–c]	<0.001
Protein, g/d	87 ± 4	29 ± 2[a]	45 ± 3[a,b]	50 ± 3[a,b]	46 ± 3[a,b]	57 ± 3[a,b]	<0.001
Carbohydrate, g/d	231 ± 11	76 ± 8[a]	111 ± 8[a]	137 ± 13[a,b]	138 ± 9[a,b]	144 ± 6[a,b]	<0.001
Fat, g/d	89 ± 7	29 ± 3[a]	47 ± 4[a]	58 ± 6[a,b]	56 ± 6[a,b]	76 ± 5[b,c]	<0.001

[1]All values are mean ± SEMs. The statistical analysis was done with the use of a 1-factor ANOVA and Bonferroni post hoc test. *P* values were considered significant at <0.05. [a–c]Significance is indicated as follows: [a]different from baseline, [b]different from 1 mo after surgery, and [c]different from 3 mo after surgery. RYGB, Roux-en-Y gastric bypass.

period, lean body mass loss accounted for 51.6% ± 8.8% of total weight loss. In contrast, lean body mass loss accounted for only 24.5% ± 11.1% of the weight lost between 1 and 12 mo after surgery. Participants who completed all visits had lost 45.6 ± 11.0 kg body weight and 13.6 ± 5.8 kg lean body mass at 36 mo after surgery.

Energy and macronutrient intakes

Before surgery, total energy intake was 2072 kcal/d, of which 45% was from total carbohydrates, 38% was from fat, and 17% was from protein. After surgery, energy intake decreased sharply by 67% during the first month. Energy intake increased gradually between 1 and 12 mo after surgery and showed no significant change between 12 and 36 mo after surgery (**Table 1**). Compared with baseline values, total carbohydrate, fat, and protein intakes all decreased at 1 mo after surgery ($P < 0.01$) and remained lower than presurgical values after 12 mo postsurgery ($P < 0.05$). Total carbohydrate and protein intakes remained significantly lower after 36 mo postsurgery ($P < 0.05$). Carbohydrates represented the main source of dietary energy until 12 mo after surgery but were replaced by dietary fat at 36 mo after surgery (Table 1).

RYGB surgery also had major consequences on the consumption of protein-containing foods (**Figure 2**). Protein intake from meat decreased significantly 1 mo after surgery ($P < 0.05$), which was essentially because of the consumption of a semiliquid diet. Protein intake from meat increased when the ingestion of solid foods was resumed and was significantly higher at 3 mo after surgery. Protein intake from meat was also significantly increased at 36 mo post-RYGB. Fish protein intake did not significantly vary during the study. Cheese-protein intake decreased significantly at 1 mo compared with baseline values ($P < 0.05$) and remained lower than baseline values after 3 mo. Other dairy protein intake did not change significantly over the first month after surgery but was decreased at 3, 6, and 12 mo after surgery compared with baseline values. Vegetal protein intake decreased at 1 mo after surgery compared with baseline values ($P < 0.05$) and increased significantly between 1 and 3 mo after surgery ($P < 0.05$).

Energy expenditure and substrate oxidation

The effects of an RYGB on the BMR, fasting respiratory quotient, net fasting substrate oxidation, and urinary nitrogen excretion are shown in **Table 2**. The BMR was decreased by 16.4% 3 mo postsurgery. The BMR expressed as the percentage of predicted values remained constant over time. The respiratory quotient decreased significantly at 3 mo and increased progressively until 12 mo after surgery. These results reflected the use of endogenous body fat as the major source of energy during this period of rapid weight loss. The 24-h urinary urea excretion rate, which corresponded tightly to the net protein oxidation, was ~50% lower 3 mo after surgery than at baseline. The calculated 24-h protein oxidation markedly exceeded protein intake. This result indicated that a large amount of endogenous protein was degraded was also reflected by an important lean body mass decrease during this period.

Physical activity

Physical activity monitored was 4473 ± 445 steps/d before surgery, 3837 ± 638 steps/d 1 mo after surgery ($n = 16$; NS), 5518 ± 698 steps/d 3 mo after surgery (NS), 5073 ± 730 steps/d 6 mo post-surgery (NS), and 6592 ± 620 steps/d 12 mo after surgery ($n = 16$; $P < 0.02$ compared with before surgery). At 36 mo after surgery, the number of steps per day amounted to 6032 ± 982 (NS; $n = 8$).

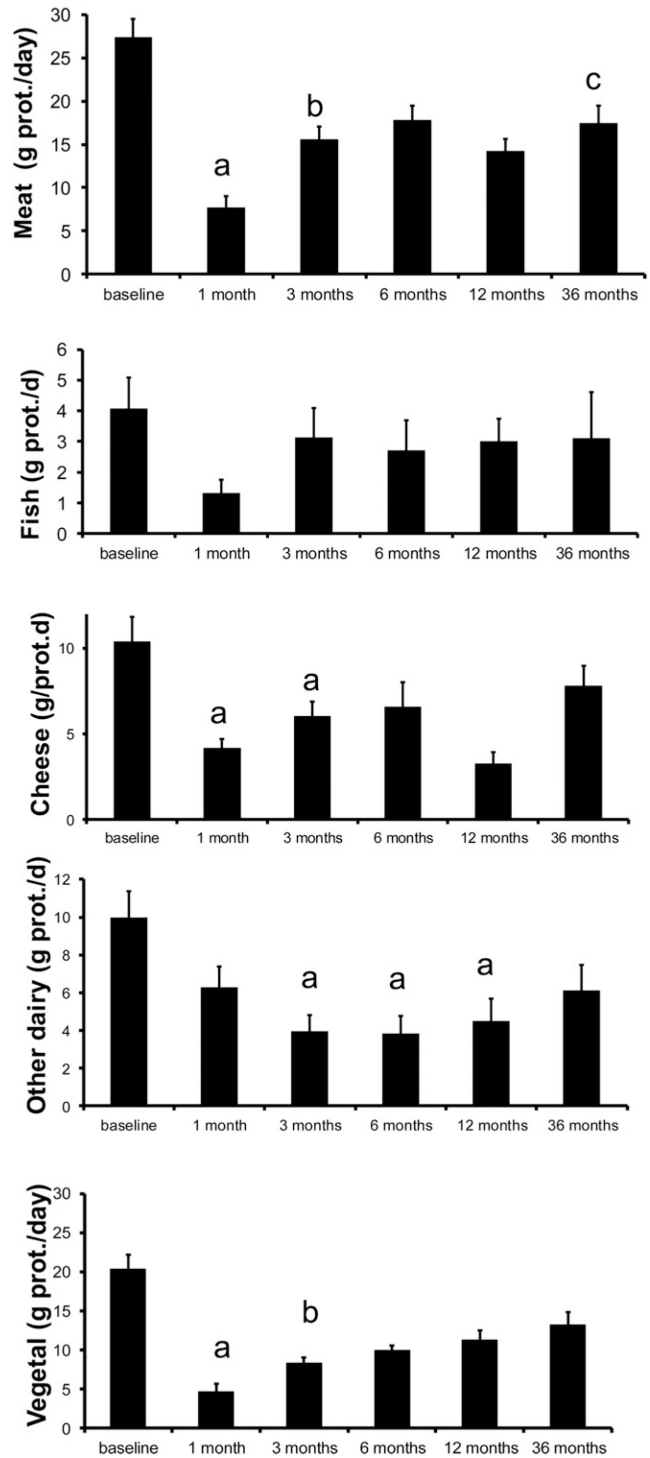

FIGURE 2 Mean ± SEM changes in dietary protein sources after a Roux-en-Y gastric bypass. Sources of dietary protein (partitioned into meat, fish, cheese, dairy products other than cheese, and protein of vegetarian origin) were assessed from an analysis of 4- or 7-d food records before surgery (baseline; n = 16) and 1, 3, 6, 12 (n = 16), and 36 (n = 10) mo after surgery. The statistical analysis was done with the use of 1-factor ANOVA and post hoc Bonferroni tests. P values were considered significant at <0.05. [a–c]Significance is indicated as follows: [a]different from baseline, [b]different from 1 mo after surgery, and [c]different from 12 mo after surgery. prot., protein.

TABLE 2
BMR expressed as the percentage of BMR/HB, respiratory quotient, net carbohydrate, fat, and urinary nitrogen excretion at baseline and 3, 6, 12, and 36 mo after an RYGB[1]

	Baseline (n = 14)	3 mo (n = 14)	6 mo (n = 14)	12 mo (n = 14)	36 mo (n = 8)	P (1-factor ANOVA)
BMR, kcal/min	1.12 ± 0.04	0.93 ± 0.03[a]	0.90 ± 0.03[a]	0.86 ± 0.03[a]	0.85 ± 0.04[a]	<0.001
BMR/HB, %	85 ± 2	83 ± 2	85 ± 2	83 ± 2	83 ± 2	NS
Respiratory quotient	0.83 ± 0.01	0.76 ± 0.01[a]	0.79 ± 0.01	0.81 ± 0.02[b]	0.85 ± 0.02	<0.001
Carbohydrate oxidation, $g \cdot kg^{-1} \cdot d^{-1}$	1.04 ± 0.12	0.38 ± 0.15	0.77 ± 0.19	1.06 ± 0.34	1.52 ± 0.44	<0.001
Fat oxidation, $g \cdot kg^{-1} \cdot d^{-1}$	0.73 ± 0.04	1.10 ± 0.05	0.97 ± 0.12	0.87 ± 0.16	0.57 ± 0.14[b]	<0.001
Protein oxidation, $g \cdot kg^{-1} \cdot d^{-1}$	0.75 ± 0.07	0.56 ± 0.05	0.77 ± 0.04	0.99 ± 0.08[b]	1.24 ± 0.11[a–c]	<0.001
Urinary urea nitrogen excretion, g/d	15.02 ± 1.66	8.52 ± 0.70[a]	10.74 ± 0.65	12.95 ± 0.94[b]	15.09 ± 1.31[b]	<0.001

[1]All values are means ± SEMs. The statistical analysis was done with the use of 1-factor ANOVA and Bonferroni post hoc tests. P values were considered significant at <0.05. [a–c]Significance is indicated as follows: [a]different from baseline, [b]different from 1 mo after surgery, and [c]different from 3 mo after surgery. BMR, basal metabolic rate; BMR/HB, basal metabolic rate predicted with the use of the Harris-Benedict equation; RYGB, Roux-en-Y gastric bypass.

DISCUSSION

This observational study provided a detailed report on energy and macronutrient intake and on energy expenditure over a 3-y period after an RYGB in a small cohort of formerly obese subjects. It further extends the previous report by Johnson et al. (24) on dietary changes observed during the initial 12 mo after surgery.

Our current study led to 2 main observations: first, a major decrease in protein intake was observed during the first month after an RYGB and was concomitant with an important lean body mass loss. The latter effect may have caused a decrease in total energy expenditure and, hence, may have limited weight loss to some extent. Second, meat and vegetarian protein intakes were significantly decreased at 1 mo and remained low until 1 y after surgery. These observations are consistent with those of several previous reports and appeared to be mainly related to the consumption of a semiliquid diet during the initial 2–4 wk after surgery. The consumption of a semiliquid diet aims to prevent the immediate post-surgical stress on gastric sutures but can be associated with low protein intake (25–27). Therefore, the addition of powdered milk protein to the semiliquid diet is advocated to alleviate a postsurgical net protein loss (27). In addition, changes in food-intake behavior and, more particularly, a taste aversion for meat are frequently observed after an RYGB (14, 28).

Total carbohydrate and fat intakes also severely decreased during the initial 3 mo after surgery and increased progressively thereafter. However, the contribution of carbohydrate to total energy intake significantly decreased by ∼15% after an RYGB, whereas that of fat increased. These changes in dietary macronutrient composition persisted 3 y after surgery.

It is well known that there is much uncertainty regarding food-intake evaluations and that underreporting has been frequently observed in subjects with overweigh and obesity (29). Therefore, we were concerned that our dietary intake data may have been grossly underestimated. The average protein intakes at 1 and 3 mo after surgery were largely inferior to the 0.8-$g \cdot kg^{-1} \cdot d^{-1}$ maintenance requirements (30). However, the 24-h urinary urea nitrogen excretion that was measured at the same time points was higher than dietary intakes, which was consistent with an important endogenous protein breakdown. Urinary nitrogen excretion 3 mo after surgery exceeded the estimated total nitrogen intake by 8 g/d. Again, this estimated protein deficit fitted well with our observation that subjects lost, on average, 15 g lean body mass/d between 1 and 6 mo after surgery.

A low energy or protein intake is a nutritional concern in surgical patients with cancer, multiple traumas, or multi-organ failure and in elderly subjects because it is associated with increased perioperative morbidity and mortality, impaired wound healing, and an increased length of stay in intensive care units (31, 32). Malnutrition, however, is not a major concern in bariatric surgery patients who are usually in fair physical health and do not display chronic inflammatory or wasting diseases. However, in these subjects, very low protein intake may be responsible for an excessive lean body mass loss, which may, in turn, induce a decrease in the BMR and total energy expenditure and, thus, limit weight loss or favor the recurrence of obesity in the long term (33). It has also been observed that inadequate protein intake may contribute to a rapid decrease in bone mass during the first year after an RYGB (34). An additional unexpected observation was that the proportion of dietary fat to total energy intake increased slightly but significantly after surgery. We have no obvious explanation for this change in dietary pattern. It may possibly be explained by lower intake of added sugars, mainly as sugar-sweetened beverages, because their consumption may favor unpleasant adverse effects after bariatric surgery. A change in food preferences has been observed after an RYGB and may play a role in this change in dietary macronutrient composition (35, 36).

This study had several important limitations: first, it included a small number of subjects, essentially because iterative metabolic and anthropometric measurements were costly and time consuming. Second, because of the large time interval between the 12- and 36-mo postsurgery evaluations, one-half of the patients could not be evaluated at 36 mo after surgery, which decreased the confidence in our late measurements; third, our study included only women who represented ∼80% of the population at our obesity clinics at this time, and we could not exclude that results may be different in men. Fourth, our primary endpoint rested on the evaluation of food intake, which is known to be frequently underreported, mainly in obese subjects. Daily energy intake at inclusion averaged 2000 kcal/d and fitted with a mean BMR of ∼1600 kcal/d, which corresponded to a 24-h energy expenditure of 2000–2400 kcal/d for a physical activity level from 1.3 to 1.5. Total daily protein intake estimated from food records (∼90 g/d) was also in close agreement with the calculated urinary nitrogen excretion (∼15 g/d, which corresponded to ∼94 g protein/d). This result suggested that, in this specific population of obese subjects who were preparing for bariatric surgery, there was no gross underreporting. Fifth, body composition was assessed with the use of bio-impedancemetry, which may have overestimated the lean body mass, to some extent, in obese subjects. However, several studies have shown that this method, when performed in well-standardized conditions, closely agrees with dual X-ray absorptiometry (37, 38).

In conclusion, this study confirms the importance of nutritional counseling and monitoring to increase dietary protein intake mainly during the first year after RYGB surgery.

The authors' responsibilities were as follows—VG: designed the study, analyzed the data, interpreted the results, and revised the manuscript; FT, MS, and LT: drafted and revised the manuscript; VDV: was responsible for participants' follow-ups and drafted and revised the manuscript; and MC: recruited patients and was responsible for participants' follow-ups. LT has received financial support from Nestlé SA, Switzerland; Ajinomoto Inc., Japan; and Ferrero, Italy, for studies unrelated to this report. None of the other authors reported conflicts of interest related to the study.

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