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CLINICAL RESEARCH

Energy Expenditure and Weight Regain in Patients Submitted to Roux-en-Y Gastric Bypass

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Abstract
Background Although Roux-en-Y gastric bypass (RYGBP) is a highly effective treatment for clinically severe obesity, not all patients achieve desirable weight loss and maintenance. There is some evidence that weight loss can induce a disproportionate reduction in resting metabolic rate (RMR). This reduction in RMR can be related to fat-free mass (FFM) loss, as FFM is the greatest responsible for variations in energy expenditure at rest. Abnormally low basal metabolic rate may predispose surgical patients to weight regain.
Method Thirty-six individuals were divided into two groups: patients who have kept a healthy weight 2 years after surgery and patients who showed weight regain of at least 2 kg 2 years after the surgery. Selected patients have signed a consent form. Body mass index and excess weight loss were evaluated. RMR and body fat percentage were measured. FFM is a heterogeneous component that can be partitioned into muscle mass and no-muscle mass. The FFM was calculated as the result of subtracting total fat weight from total body weight in kilogram. We also wanted to know if the predictive formulas to assess RMR overestimate energy expenditure in these patients. Statistical tests were used to analyze the two groups.
Results We found out that the RMR of the weight regain group was statistically inferior to the mean of the healthy weight group—the difference between the two groups was about 260 kcal/day. We also found out that the predictive formulas overestimate the RMR in the weight regain group.
Conclusion This study suggests that a lower RMR may contribute to weight regain in patients who undergo RYGBP. It is important to ensure ways to elevate energy expenditure in the patient, such as increasing the percentage of fat-free mass in the body and the practice of physical activities.

Keywords Energy expenditure · Weight regain · Bariatric surgery · Morbid obesity · Indirect calorimetry · Resting energy expenditure · Fat-free mass

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Introduction

Obesity, which has become a major public health problem, has an exceedingly complex etiology, with contributions from both hereditary and environmental factors. Obese people have a history of repeated failures with traditional weight loss methods, such as diet, exercise, and the use of medication [1]. Bariatric surgery is the best treatment available for morbidly obese patients, resulting in long-term weight loss. Roux-en-Y gastric bypass (RYGBP) is currently the weight loss surgery most frequently performed in Brazil and is considered the gold standard procedure for weight loss surgery [2].

Although RYGBP is a highly effective treatment for clinically severe obesity, not all patients achieve a desirable weight loss or maintain it [3]. Several studies have investigated the occurrence of weight regain in patients 2 years after the procedure [4].

There is some evidence that weight loss induces a disproportionate reduction in the resting metabolic rate (RMR). RMR can be defined as the energy expended for maintaining the body's integrated systems and the homeothermic temperature by an individual who is resting but awake and fasted in comfortable ambient conditions. The reduction in RMR after weight loss can be related to a high-fat-free mass (FFM) lost during the period that the patient is losing weight. When in a program to lose weight, many patients do not follow their body composition and they usually worry about weight loss and not about knowing if they are losing fat mass (FM) or FFM. An abnormally low RMR may predispose surgical patients to weight regain [5].

Since few studies have investigated the effects of RMR on weight control after RYGBP, we investigated in this study whether RYGBP patients with weight regain have lower RMR than bariatric patients with a healthy weight. We also investigated whether RYGBP patients have lower RMR values than those calculated by predictive formulas (which are most frequently used and accessible in clinical practice), and whether there is a correlation between fat-free mass and RMR in these patients.

Methods

This was a cross-sectional study. Patients who participated in the study were those operated in the Gastrocirurgia Clinic of Brasília. We carried out a random selection of patients who had had the surgery at least 2 years before, thus dividing them into two groups:

1. Patients who have kept a healthy weight 2 years after the surgery

To keep a healthy weight, the patient is supposed to maintain the same weight during at least 6 months after 1 year and 6 months of surgery. We accept the variation in weight assessed from 0.1 to 1.9 kg as metabolic normal variation of weight.

2. Patients who showed weight regain of at least 2 kg 2 years after the surgery

Selected patients were invited to participate in the research and have signed a consent form.

Body mass index (BMI) and excess weight loss (EWL) were assessed.

The patients' RMR were assessed in the supine position with indirect calorimetry (Cosmed®) after a 12-h fasting. The room had air conditioning kept at 22°C.

The RMR values obtained were compared to those calculated with two predictive equations: the Harris–Benedict equation and the equation obtained by Bobbioni-Harsch et al. [6] from a linear regression analysis linking RMR and FFM.

$$\mathrm{RMR} = 64.5 + 29.5 \times \mathrm{FFM}$$

Body composition was assessed using bioelectrical multifrequency bioimpedance (Inbody 520®). The percentage of patients' FFM was assessed since lean mass is most responsible for variations in RMR. FFM is a heterogeneous component that can be partitioned into muscle mass and no-muscle mass. FFM was calculated as the result of subtracting total fat weight from total body weight in kilogram.

Patients with thyroid disorders were excluded.

This study was approved by the Santa Luzia Hospital's Scientific Ethics Committee.

All patients in the study filled out the informed consent form.

Statistical Analyses

In order to compare genders between the two groups, the exact chi-squared test was used. In order to compare mean time of surgery, age, and weight regain between both groups, Student's *t* test was used. In order to compare assessments of weight, BMI, percentage of excess weight loss (PEWL), percentage of fat, and RMR between the two groups (healthy weight and weight regain), Student's *t* test was used. A level of significance of 5% was used for analysis purposes.

In order to assess the RMR and lean mass in kilogram (LM-kg), a multiple linear regression model was used in both groups (healthy weight and weight regain).

In order to compare the effects of the three methods (RMR assessed by indirect calorimetry, predicted by Harris–Benedict, predicted by Bobbioni-Harsh) in both groups, analysis of variance was used for repeated measurements with interaction between factors, employing a mixed-effects model.

Results

Of the 36 individuals included in our study, 21 were allocated to the weight regain (WR) group and 15 to the healthy weight (HW) group. The demographic data for the whole sample are shown in Tables 1 and 2.

From the chi-squared test and Student's *t* test, we found that there is no difference between the two groups related to

Table 1 Sample's demographic characteristics

Variable	Weight regain group (WR)	Healthy weight group (HW)	*P* value
Age (years)	40.29 (±9.46)	42.47 (±12.71)	0.558
Time after surgery (months)	63.50 (±18.94)	32.00 (±8.38)	0.014
Weight regain (kg)	9.39 (±9.37)	0.27 (±0.46)	0.047

Table 2 Sample's gender distribution

Variable	Weight regain group (WR)	Healthy weight group (HW)
Female (number, %population)	17 (80.95%)	12 (80%)
Men (number, %population)	4 (19.05%)	3 (20%)

gender (p=1.000) and related to age (p=0.558). The WR group has higher values of time of surgery and of weight regain in comparison with the HW (p=0.014 and p=0.047, respectively).

We also analyzed differences in the assessments of weight, BMI, PEWL, percentage of fat, and RMR between the two groups. Student's t test was used. Tables 3 and 4 show these data.

From the statistical analyses, we found, using Student's t test, that weight and BMI were higher in the WR group (p< 0.05). On the other hand, we found no differences in EWL and percentage of fat (p>0.05).

The linear multiple regressions showed that the HW group expends 260.09 kcal/day more than the WR group. For each increase of one FFM kilogram, we found one increase of 10.78 kcal (p=0.015) in RMR. This increase was not different between both groups (p=0.754).

After comparing measured and predicted values for RMR, we found that the WR group's measured RMR was significantly lower than the values calculated with both predictive equations, 282.62 kcal lower than Harris–Benedict formula (p<0.001) and 349.76 kcal lower than the Bobbioni-Hasch formula. The Harris–Benedict and Bobbioni-Hasch formulas had no difference between them (p=0.759). In the HW group, the assessed RMR and the two formulas presented no difference among them (p>0.05).

Analysis using Pearson's correlation coefficient indicated a statistically significant linear relation between measured RMR and FFM (kg) for both the WR group (0.508; p=0.02) and the HW group (0.776; p=0.002).

Table 3 Assessments of weight, BMI, PEWL, fat percent, and RMR in the WR group

Variable	Mean	SD	Minimum	Maximum
Weight (kg)	86.26	86.26	52.00	116.00
BMI (kg/m^2)	32.49	32.49	22.80	46.00
PEWL (%EWL)	60.92	60.92	26.10	104.40
Fat%	34.51	34.51	19.60	43.00
BMR (kcal/day)	1,369.33	1,369.33	985.00	1,862.00

Table 4 Assessments of weight, BMI, PEWL, fat percent, and RMR in the HW group

Variable	Mean	SD	Minimum	Maximum
Weight (kg)	74.86	10.08	54.00	89.00
BMI (kg/m^2)	27.90	3.76	20.50	33.50
PEWL (%EWL)	65.45	21.95	23.60	110.40
Fat%	30.59	6.72	20.70	41.30
BMR (kcal/day)	1,582.73	238.60	1,093.00	1,983.00

Discussion

Many factors contribute to weight regain, including abnormal eating habits [7], noncompliance with postoperative treatments [8], and anatomical and physiological adaptations that occur over time after surgery [9]. A low RMR after RYGBP may be another factor contributing to weight regain. We verified in our study that patients with WR had the lowest RMR. Since these patients also had a higher absolute weight and RMR is related to body weight, this result was not expected.

There is growing evidence to suggest that weight loss may be accompanied by metabolic adjustments that promote weight regain. Whereas it is generally accepted that weight loss is accompanied by reduced RMR, the controversial issues are (1) whether this reduction is simply attributable to the reduction in mass that would have been expending energy or whether there is a reduction in the basal metabolic rate in one or more of the metabolically active tissues and (2) whether this adjustment persists during weight maintenance and contributes to the metabolic propensity to regain weight after weight loss [10]. In our study, we found great individual variability in the modifications of RMR within a group of patients undertaking the same caloric restriction, and this result is in accordance with the currently available literature [3].

Observing the analyses of demographic data, we noticed that the WR group had more time after surgery than the HW group. It is important to have others studies that can have groups with the same time after surgery because, as time goes on, we can have weight regain in the HW group.

Comparing the measured and predicted values for RMR, we found that in the WR group the predicted values were significantly higher than expected. This means that if we only use predictive equations to evaluate this group, we may overestimate their energy requirements. The predictive equations may have overestimated energy requirements because they were developed to determine the RMR of a healthy population but not specifically for obese individuals. We suggest that centers without access to indirect calorimetry that work with obese population, mainly bariatric population, should use predictive formulas as a parameter and subtract at least 260 kcal from the obtained value to estimate the RMR in patients with weight regain. Indirect calorimetry should be used when possible to assess RMR.

Not all patients developed a low RMR after RYGBP, suggesting that the metabolic adaptation capacity may vary from individual to individual. The reasons for this must be clarified in future research [6]. One important factor that seems to explain the variation in RMR between individuals is FFM [11]. We verified this by identifying a positive linear correlation between FFM and RMR. Therefore, a patient's quality of weight loss should be evaluated during follow-up, with emphasis on the reduction of fat percentage and on maintenance of FFM.

To promote weight loss and prevent weight gain, mechanisms that enhance the patient's total energy expenditure should be encouraged by all health care professionals. Total energy expenditure has three components: RMR, thermic effect of food (TEF), and thermic effect of exercise (TEE).

RMR is the minimum energy expenditure necessary for an organism to sustain basic life processes, such as respiration, heartbeat, and renal function, and normally constitutes about two thirds of the total daily energy expenditure. According to our study and others [5, 11], an increase in RMR can be achieved by reducing the fat percentage and elevating FFM.

TEF, which is the amount of energy consumed by eating and digestion, is responsible for approximately 5–10% of energy expenditure. It can be increased with a higher consumption of protein- and fiber-rich foods together with a reduced intake of high-fat foods.

TEE is the most variable component of total energy expenditure. It is the result of volitional mechanical work, such as exercise and daily activities, and nonvolitional activity, such as fidgeting, spontaneous muscle contractions, and maintaining posture, which account for 15–30% of TEE. To increase energy expenditure, an increase in the frequency, duration, and intensity of physical activity should be promoted [12].

Conclusion

In our study, we found that:

1. The WR group had a lower RMR than that of the HW group. A lower RMR may contribute to weight regain in patients after RYGBP.
2. The predictive equations overestimated the RMR of the WR group. Therefore, we should, when possible, use indirect calorimetry to estimate the energy requirements of patients with WR. If this is not possible, we can use predictive equations and subtract at least 260 kcal/day to estimate the RMR. Nutritional support is very important to follow up on these patients.
3. FFM has a significant positive correlation with RMR.

These data show the importance of nutritional follow-up, so we can help the patient to maintain lean mass and lose fat mass, which is an important factor in weight maintenance.

In patients with weight regain, it is important to encourage ways to elevate energy expenditure, such as increasing the percentage of FFM, physical activity, and an increase in the consumption of fiber- and protein-rich foods.

It is also important to undertake studies that follow up on the RMR and FFM of patients after RYGBP for longer periods of time.

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