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ORIGINAL CONTRIBUTIONS

Nutritional Status, Body Composition, and Bone Health in Women After Bariatric Surgery at a University Hospital in Rio de Janeiro

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Abstract
Introduction Calcium and/or vitamin D deficiency can occur after Roux-en-Y gastric bypass (RYGBP) because of impaired absorption, resulting in secondary hyperparathyroidism and increased risk of reduced bone mineral density (BMD).
Objective The objective of this study is to assess nutritional status, body composition, and bone health in women after RYGBP.
Method Twenty-five premenopausal women who had undergone RYGBP (test group) and 33 women matched for age and body mass index who had not undergone surgery (control group) participated. Test group received 250 mg of calcium for day. Anthropometric, dietary, laboratory, body composition, and BMD (X-ray absorptiometry) analyses were performed.
Results No differences were found between the groups in waist circumference, fat or lean mass, BMD, or dietary calcium intake, although calcium intake was low in both groups. The test group had better results for complete blood count, total cholesterol, low-density lipoprotein, and triglycerides. The mean parathyroid hormone was higher (p=0.005) in the test group, although still within normal limits. Plasma levels of 25-hydroxyvitamin D were low in groups but did not differ between them (p=0.075). Vitamin D concentrations were lower in women with longer time since surgery. The test group had lower intake of energy, protein, lipids, polyunsaturated fatty acids, fiber, phosphorus, and iron than the control group.
Conclusion Elevation of parathyroid hormone, low dietary calcium intake, and vitamin D plasma insufficiency without BMD reduction occurred after RYGBP. Patients who underwent RYGBP had adequate lipid profiles but inadequate intake protein, polyunsaturated fatty acids, fiber, and iron. Vitamin D deficiency may occur in the late postoperative period.

Keywords Bariatric surgery · Nutritional status · Body composition · Bone health

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Introduction

Bariatric surgery is considered to be the treatment with the best long-term results for severe obesity [1]. Santos et al. [2] reported a 255 % increase in cases of severe obesity between

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1974 and 2003 in Brazil, and more than 10,000 bariatric surgeries were performed in Brazil's Unified Health System from 1999 to 2006.

Despite satisfactory weight loss results, the inherent impaired absorption, food restriction, and digestive symptoms in the postoperative period after bariatric surgery contribute to decreased absorption of important nutrients and, in association with intense weight loss, can cause changes in bone metabolism [3, 4]. Calcium and vitamin D deficiencies are the main precursors of bone mineral density (BMD) reduction and increased risk of fracture in these patients [5]. Studies have also reported vitamin D deficiency during the presurgical period in this population [6–8].

Secondary hyperparathyroidism has been reported after bariatric surgery, with an associated increased risk of BMD reduction [9]. The mechanisms involved in the development of hyperparathyroidism after surgery need elucidation, and improved supplementation protocols are required to reduce the risk of long-term bone disease [10]. There is no consensus on the dose or route of administration of vitamin and mineral supplementation after bariatric surgery [11]. In view of the reported nutritional deficiencies, this issue should be addressed [12]. The aim of this study was to evaluate the nutritional status, body composition, and bone health of premenopausal women after Roux-en-Y gastric bypass (RYGBP) surgery.

Methods

Subjects

Adult women who had undergone RYGBP surgery at the Clementino Fraga Filho University Hospital (HUCFF), Rio de Janeiro, between 6 and 64 months (between the years 2006 and 2010) (test group) and obese women who had not undergone RYGBP surgery (control group) were included in the present study.

Women were excluded from participation in the study if they had malignant tumors or infectious diseases; were postmenopausal; were taking drugs that affect bone metabolism (bisphosphonates, estrogens, anticonvulsants, glucocorticoids); were pregnant; had malabsorption syndrome, primary hyperparathyroidism, renal, or liver failure; or weighed >120 kg because of safety limitations of the dual-energy X-ray absorptiometry (DXA) machine. Selected participants in the test group which remained ingesting a daily multivitamin containing 250 mg of calcium continuously after surgery.

Among the 59 patients who underwent RYGBP during the study period, 25 agreed to participate and met eligibility criteria. Thirty-three women matched for body mass index (BMI) and age, and who met the same eligibility criteria as the test group, were selected for the control group.

Ethical Considerations

The project was approved by the Research Ethics Committee of HUCFF (121/2010).

Study Design

This was a cross-sectional, case–control study. After a 12-h overnight fast, participants visited the Physical and Rehabilitation Medical Service at HUCFF to sign an informed consent form, complete a questionnaire with general data, and undergo an anthropometric and dietary assessment. Participants were then directed to the laboratory at HUCFF for blood collection. Blood tests included complete blood count (CBC), blood glucose, lipid profile, calcium, phosphorus, albumin, creatinine, parathyroid hormone (PTH), and 25(OH)D. After blood collection, participants underwent BMD assessment and DXA body composition analysis.

Dietary Assessment

A semi-quantitative food frequency questionnaire was used for dietary assessment [13, 14]. Dietary chemical composition analyses (energy, macronutrients, fiber, calcium, iron, and phosphorus) [15–18] were performed with DietPro Professional® software, version 5i (AS Sistemas, Viçosa, Brazil) [19].

Anthropometry

Participants were weighed without shoes and wearing light clothing on a Welmy® digital scale with a 300-kg capacity and 50-g precision. Height was measured in centimeters with the height rod of the same digital scale. Participants were barefoot, standing upright with heels together [20].

Waist circumference (cm) was measured at the midpoint between the last rib and the iliac crest [21] with a 2-m inelastic tape (Sanny®).

Body Composition and Bone Mineral Density

Body composition and BMD of the lumbar spine, femoral neck, and total femur were assessed by DXA with a GE Lunar Prodigy bone densitometer (software version 9.15). *Z*-scores were considered for all segments analyzed. *Z*-scores compare the patient's bone mass with that of healthy women grouped by age, ethnicity, and BMI from the NHANES III database. *Z*-scores less than or equal to −2 standard deviations (SD) were classified as "below expected BMD" [22].

Biochemical Examination

Blood sampling was performed at the Biochemistry Laboratory of HUCFF. CBC was determined with automated counting using impedance and laser [23]. Glycemia [24] and lipid profile (serum concentrations of triglycerides, high-density lipoprotein (HDL), and total cholesterol) [25–27] were determined with the enzymatic-colorimetric method (CELM® and KATAL® commercial kits). Low-density lipoprotein (LDL) levels were calculated with the Frieddwald formula [28].

We also assessed serum calcium (O-cresolphthalein) [29], phosphorus (UV-Molybdate) [30], creatinine (Jaffé, modified) [31], albumin (bromocresol purple) [32], and PTH (chemiluminescent immunoassay) [33]. Levels of calcium, phosphorus, creatinine, and albumin were determined with the Siemens Dimension RXL analyzer. Serum specimens for 25(OH)D analysis by high-performance liquid chromatography were protected from light and stored at −80 °C [34].

Reference values for CBC, glucose, total cholesterol and fractions, triglycerides, albumin, calcium, phosphorus, creatinine, and PTH were those used by the Biochemistry Laboratory of HUCFF. Reference values for 25(OH)D were as follows: adequate, 30–100 ng/mL; inadequate, 21–29 ng/mL; and deficient, below 20 ng/mL [35].

Statistical Analysis

Quantitative variables were analyzed as means and 95 % confidence intervals (CI). The Kolmogorov–Smirnov test showed that the data were not normally distributed; nonparametric tests and the Mann–Whitney test were used to compare differences between the groups. Multiple regression analyses and Spearman's correlation were used to assess the influence of time since surgery and weight loss on variables related to bone health. Values of $p<0.05$ were considered significant. The Statistical Package for the Social Sciences (SPSS, version 16) software was used for analyses [36].

Results

No differences were found between test and control groups in age, body weight, BMI, waist circumference, or fat and lean mass (%). Medical records showed that the average BMI during the preoperative period was 52.2 kg/m^2 (40.1–73.3 kg/m^2). Mean BMI after surgery was 34.6 kg/m^2 (32.7–36.5 kg/m^2), with 65.1 % of excess body weight lost, which is considered successful surgery. The patients in both groups had grade I obesity, excess body fat, and increased risk of metabolic complications resulting from increased central adiposity [20, 21] (Table 1).

The control group had a higher intake of energy, lipids, polyunsaturated fatty acids (PUFA), fiber, phosphorus, and iron than the test group. Calcium intake was low in both groups, with no significant difference between them. Protein intake per kilogram of body weight was lower in the test group (Table 2).

The test group had better results for CBC, total cholesterol, LDL, and triglycerides than the control group. No differences were found between the groups for serum glucose, HDL, albumin, calcium, phosphorous, or creatinine. The test group had a higher mean PTH concentration than the control group, although still within normal values. Twelve women (48 %) in the test group and five (15 %) in the control group had elevated PTH levels, with values greater than or equal to 65 pg/mL. Levels of 25(OH)D were not different between the groups, but both groups included women with insufficient levels: in the test group, 13 (52 %) women had vitamin D insufficiency and 3 (12 %) had deficiency, whereas 17 (51.5 %) had insufficiency and 9 (27.3 %) had deficiency in the control group (Table 3).

In the test group, 9 women (36 %) reported bone pain compared with 22 (66 %) in the control group. Neither group had BMD reduction in the lumbar spine, femoral neck, or total femur (Table 4).

Only vitamin D levels correlated with time since surgery and weight loss ($r=0.51$; $p=0.036$), showing an inverse correlation ($r=-0.54$; $p=0.005$) with time since surgery. No correlations were found between BMD, PTH, calcium, or phosphorus and time since surgery or weight loss.

Discussion

Several studies have reported an increased risk of changes in bone structure with increased PTH after bariatric surgery [9, 10, 37, 38]. Valderas et al. [39] compared 26 women after RYGBP with women of matching age and BMI who had not undergone surgery and found higher PTH levels in the RYGBP group. Another study of 44 women who had undergone RYGBP and 65 who had not also found higher PTH levels after surgery [37]. In the present study, PTH levels were higher in the test group than in the control group, although the mean value remained within the normal range. Approximately half of the women in the test group (48 %) had PTH levels greater than or equal to 65 pg/mL. Elevated PTH, in association with low calcium intake, may increase the risk of bone health impairment.

Both groups in this study had vitamin D insufficiency, suggesting that the increased PTH seen after RYGBP may result from low calcium absorption [40]. Poor calcium absorption increases PTH secretion, stimulating resorption of calcium from bone to maintain normal blood concentrations of this mineral [41]. Inadequate calcium intake after RYGBP has also

Table 1 Anthropometric variables and body composition (mean [CI 95 %]) of test and control groups

Variables	Test (n=25)	Control (n=33)	p value*
Age (years)	38.9 (35.8–41.9)	39.8 (37.6–42.0)	0.683
PO weight (kg)	139.5 (130.3–148.7)		
Height (cm^2)	1.63 (1.60–1.65)	1.60 (1.58–1.62)	0.099
PO weight excess (kg)	73.1 (64.1–82.2)		
PO BMI (kg/m^2)	52.2 (40.1–73.3)		
Current weight (kg)	92.5 (86.4–98.4)	87.5 (83.3–91.7)	0.201
Current BMI (kg/m^2)	34.6 (32.7–36.5)	33.9 (32.4–35.4)	0.437
Weight loss (kg)	47.0 (40.4–53.7)		
Excess weight loss (%)	65.1 (59.4–70.7)		
Waist circumference (cm)	95.8 (85.4–106.1)	97.0 (93.4–100.5)	0.771
Fat mass (%)	46.6 (43.4–49.7)	48.8 (47.6–50.1)	0.615
Lean mass (%)	50.7 (47.8–53.7)	48.6 (47.3–49.9)	0.470

BMI body mass index, *PO* preoperative

*Means were compared between groups with the Mann–Whitney test at 5 % probability

been reported [38, 42]. In our study, we observed that calcium intake was low in both groups, suggesting that low intake combined with low absorption may have contributed to the increased PTH levels [40]. The test group received multivitamin supplementation with 250 mg of calcium. However, this amount of calcium intake may not be sufficient to maintain appropriate PTH levels in this population.

Vitamin D insufficiency is associated with systemic inflammation, low dietary intake, limited sun exposure, liver failure, and vitamin sequestration by adipose tissue [6–8]. Vitamin D can reduce levels of proinflammatory cytokines and hence can improve the characteristic inflammatory state observed in obesity [43]. Bellia et al. [44] observed an inverse association between vitamin D levels and inflammatory markers in individuals with severe obesity. Every woman in the test group received multivitamin supplementation, but the dose of vitamin D may not have been adequate and its administration in the preoperative period needs to be reviewed. According to Wimalawansa et al., [45] adults require between 600 and 2000 IU of vitamin D per day to maintain physiologic levels of serum vitamin D. Vulnerable populations should receive 50, 000 IU once or twice per month over the long term. Carlin et al. [46] studied 60 women with vitamin D depletion: 30 received 50,000 IU of vitamin D weekly after RYGBP and 30 did not. Both groups received 800 IU of vitamin D and 1500 mg of calcium daily. The group receiving weekly vitamin D supplementation showed improvement in vitamin D status at 1-year follow-up. The negative correlation observed in the present study between time since surgery and vitamin D levels indicates the need for early supplementation in these individuals. Severity of deficiency should be considered, as well as individualization of doses to achieve target vitamin D levels [47].

Table 2 Dietary intake (mean [CI 95 %]) of the test and control groups

Variables	Test (n=25)	Control (n=33)	p value*
Energy (kcal)	1208.8 (1030.5–1387.0)	2195.5 (1861.7–2529.3)	0.000*
Carbohydrate (%)	52.3 (48.2–52.4)	48.7 (46.2–51.1)	0.094
Protein (%)	22.3 (19.3–25.4)	20.2 (18.4–22.1)	0.230
(g/kg)	0.71 (0.58–0.54)	1.22 (1.05–1.39)	0.000*
Lipid (%)	25.4 (22.6–28.2)	30.9 (29.0–32.8)	0.002*
PUFA (%)	4.3 (3.4–5.2)	6.0 (5.4–6.7)	0.000*
MUFA (%)	8.7 (7.5–9.9)	9.9 (8.1–11.2)	0.319
SFA (%)	8.5 (7.4–9.7)	9.6 (8.6–10.7)	0.242
Fibers (g)	17.1 (12.4–21.9)	24.4 (19.4–29.4)	0.011*
Calcium (mg)	808.9 (628.0–989.8)	664.5 (612.5–816.5)	0.169
Phosphorus (mg)	966.3 (813.2–1119.4)	1285.6 (1101.6–1469.6)	0.011*
Iron (mg)	6.7 (5.3–8.1)	10.1 (8.6–11.6)	0.002*

PUFA polyunsaturated fatty acids, *MUFA* monounsaturated fatty acids, *SFA* saturated fatty acids

*Means were compared between groups with the Mann–Whitney test at 5% probability

Table 3 Laboratory findings (mean [CI 95 %]) of the test and control groups

Variables	Test (n=25)	Control (n=33)	p value*
Erythrocytes (million/mm^3)	4.6 (4.4–4.7)	4.2 (3.9–4.5)	0.027*
Hemoglobin (g/dL)	13.1 (12.4–13.6)	11.9 (10.9–12.8)	0.011*
Hematocrits (%)	39.3 (37.6–40.9)	35.8 (33.1–38.5)	0.027*
Glucose (mg/dL)	82.8 (80.9–84.7)	86.5 (83.3–89.7)	0.184
Total cholesterol (mg/dL)	169.9 (157.5–182.3)	201.6 (189.2–213.9)	0.001*
LDL (mg/dL)	104.7 (94.4–114.9)	128.8 (117.8–139.7)	0.002*
HDL (mg/dL)	51.5 (46.0–56.8)	48.5 (42.3–54.6)	0.322
TG (mg/dL)	69.1 (58.9–79.1)	112.1 (97.5–126.5)	0.000*
Albumin (g/dL)	3.8 (3.6–3.9)	3.8 (3.7–3.9)	0.893
Calcium (mg/dL)	8.6 (8.4–8.7)	8.8 (8.6–9.0)	0.095
Phosphorous (mg/dL)	4.0 (3.7–4.2)	3.7 (3.5–3.9)	0.113
Creatinine (mg/dL)	0.7 (0.6–0.8)	0.7 (0.6–0.7)	0.553
PTH (pg/mL)	63.6 (53.6–73.6)	45.7 (38.4–52.9)	0.005*
25(OH)D (ng/mL)	28.2 (24.7–31.6)	24.3 (21.7–26.9)	0.075

LDL low-density lipoprotein, *HDL* high-density lipoprotein, *TG* triglycerides, *PTH* parathyroid hormone, *25(OH)D* 25-hydroxyvitamin D

*Means were compared between groups with the Mann–Whitney test at 5 % probability

Lamohamed et al. [48] found that bariatric surgery was not associated with increased risk of fracture, but that risk increased 3–5 years after surgery in individuals with a large BMI reduction. BMD reduction has been described in the first year after surgery [49] and is related to significant weight loss. In our study, although the percentage of excess weight lost was considerable (65.1 %), we did not observe changes in BMD or a correlation between time since surgery or weight loss and BMD. Goode et al. [37] reported lower bone mineral content in the femurs of postmenopausal women who had undergone gastric bypass, a change that had not been observed during the premenopausal period. The selection of premenopausal women in the present study may have contributed to the absence of BMD changes. However, increased PTH levels after RYGBP may raise the risk of bone health impairment after menopause in this population.

Table 4 Bone mineral density in the lumbar spine, femoral neck, and total femur (mean [CI 95 %]) of the test and control groups

Variables	Test (n=25)	Control (n=33)	p value*
BMD LS (g/cm^2)	1.300 (1.233–1.367)	1.234 (1.178–1.287)	0.093
BMD FN (g/cm^2)	1.166 (1.112–1.221)	1.137 (1.077–1.197)	0.545
BMD FT (g/cm^2)	1.169 (1.113–1.225)	1.114 (1.059–1.168)	0.132
z-score LS (SD)	−0.2 (−0.7–0.4)	−0.4 (−0.9–0.1)	0.479
z-score FN (SD)	0.5 (0.1–0.9)	0.3 (−0.1–0.7)	0.197
z-score FT (SD)	0.6 (0.2–1.0)	0.5 (0.0–1.0)	0.666

BMD bone mineral density, *LS* lumbar spine, *FN* femoral neck, *FT* femur total

*Means were compared between groups with the Mann–Whitney test at 5 % probability

Changes in body composition contribute to changes in bone structure after bariatric surgery [50]. In our study, fat and lean mass did not differ between the two groups. The reduction in lean mass after RYGBP seems to be higher than with other surgical approaches and is related to severe weight loss [51]. Maintaining lean mass after surgery is critical for bone health in these individuals because of its important role in skeletal support [52].

Calcium levels remained within the normal range in this study probably because higher PTH levels enhance intestinal absorption of calcium by stimulating the production of vitamin D, calcium resorption in the renal tubules, and osteoclastic activity [41].

The test group had better lipemia indices than the control group, as described in other studies [53, 54]. The test group had lower hemoglobin and hematocrit levels than the control group. De Luis et al. [55] assessed 115 morbidly obese individuals and found that 2.6 % had low hemoglobin. Iron deficiency after surgery may result from reduced gastric acid secretion, low intake of iron-rich foods, and intestinal bypass, which impairs nutrient absorption [11]. While patients have a greater susceptibility to nutritional deficiencies after surgery, multivitamin supplements can have a positive effect on CBC by assuring adequate iron intake. However, Gasteyger et al. [56] reported that multivitamin supplementation alone is not enough to avoid deficiencies. In that study, women were clinically followed up after surgery and immediately supplemented in case of iron deficiency. Blume et al. [53] reported that 60 premenopausal women had low hemoglobin and hematocrit levels in the pre- and postsurgical periods. Although these studies have confirmed iron deficiency in this population, the results of our study were favorable, showing adequate iron status after RYGBP.

In addition to iron, we also observed lower intake of energy, lipids, PUFAs, phosphorus, and fiber after surgery. However, it is possible that individuals under- or over-reported intake on the food frequency questionnaire [57]. Lower intake of fiber-rich food may result from volume restriction imposed by the RYGBP and the discomfort caused by insufficient chewing [58]. Although the test group received a higher percentage of calories from protein than the control group, they had lower protein intake per kilogram of body weight [15], which is associated with obesity in women. Low protein intake can affect bone structure because adequate intake of protein, calcium, and vitamin D is essential for bone formation and maintenance and is important for preventing osteoporosis [59]. However, excess protein is related to higher renal calcium loss. Protein-rich foods are sources of phosphorus, which, in excess, can form calcium phosphate in the intestine and increase calcium loss, especially when calcium intake is inadequate [60]. Phosphorus intake was lower in the test group than in the control group but was above the recommended levels in both groups [17].

This study had limitations, including the low number of participants who met eligibility criteria and the difficulty of using detailed dietary surveys. The number of surgeries performed in the study period was small, and many participants did not return for follow-up because of personal problems, mostly financial, because HUCFF is a public hospital that serves primarily patients of low socioeconomic class. This factor influenced the selection of participants with periods of nearest postoperatively. The effect of seasonal variation in vitamin D status was also not assessed; however, data from both groups were collected during the same period of the year (March to September).

Conclusions

Higher PTH levels, low calcium intake, and vitamin D plasma insufficiency were seen after RYGBP; however, these changes occurred without BMD impairment. Vitamin D concentrations were lower with increasing time since surgery.

Bariatric surgery was effective for weight loss, with more than 50 % of excess body weight lost. The test group had adequate results on tests of iron nutritional status and lipid profiles. However, the intake of protein, PUFAs, fiber, and iron was inadequate.

Long-term longitudinal studies are needed, as well as determination of specific guidelines for calcium and vitamin D supplementation, including the dose and route of administration suitable for this population. These studies will provide important information on preventing and/or treating bone disease after bariatric surgery and maintaining adequate nutritional status and body composition.

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Compliance with Ethics Guidelines

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Conflict of Interest Gigliane Cosendey Menegati received research grants from Foundation Capes. All the other authors declare that they have no competing interests.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study

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