OBES SURG (2010) 20:1372–1379
DOI 10.1007/s11695-010-0121-3

ALLIED CARE

Bone Mineral Density and Nutritional Profile in Morbidly Obese Women

Daniela Schaan Casagrande · Giuseppe Repetto · Claudio Corá Mottin · Rodolfo Schneider · Jacqueline Rizzolli · Myriam Moretto · Alexandre Vontobel Padoin · Beatriz D'Agord Schaan

Published online: 22 April 2010

Abstract
Background Morbid obesity may be associated with malnutrition. Because it is important to assess the preoperative nutritional/metabolic status and bone mineral density of these patients, this study was designed aiming to evaluate bone metabolism/mineral density and nutritional profile in morbidly obese women.
Methods Thirty-three morbidly obese women in preoperative care for obesity surgery were enrolled. Blood samples were drawn to determine nutritional and metabolic status, and dual-energy X-ray absorptiometry (DXA) was performed to evaluate bone mineral density; 24-h recall and food frequency questionnaire (FFQ) were also evaluated.
Results Twenty-seven (81.8%) women were premenopausal and six (18.2%) were postmenopausal. The mean body mass index was 43.2±4.8 kg/m^2, and 91% were Caucasian. Insulin-resistant subjects comprised 81.8% of the sample. The median (25–75 percentile) of the total intake of 24-h recall was 3,081 (2,718–3,737) and for FFQ 2,685 (2,284–4,400) calories. FFQ underestimated total energy value intake. The median of calcium was higher when evaluated by the FFQ as compared with the 24-h recall. Protein and lipid intakes were lower if evaluated by the FFQ as compared to the 24-h recall. Vitamin D levels were low in 18 (81.8%) patients. In one premenopausal woman, bone mineral density was low in the lumbar spine (L1–L4), and in one postmenopausal woman it was low in L1–L4, femoral neck and 1/3 proximal radius.
Conclusions In this study, the nutritional status of morbidly obese women was good, except for markers of bone metabolism, with no detectable differences between pre- and postmenopausal women.

Keywords Morbid obesity · Metabolic bone disease · Malnutrition · Bone turnover · Vitamin D deficiency · Nutritional assessment

D. S. Casagrande · B. D. Schaan (✉)
Programa de Pós-graduação em Ciências Médicas: Endocrinologia e Metabologia, Universidade Federal do Rio Grande do Sul, Serviço de Endocrinologia do Hospital de Clínicas de Porto Alegre,
Rua Ramiro Barcelos 2350, prédio 12, 4º andar,
90035-003 Porto Alegre, Rio Grande do Sul, Brazil
e-mail: beatrizschaan@gmail.com

D. S. Casagrande · C. C. Mottin · J. Rizzolli · M. Moretto · A. V. Padoin
Centro da Obesidade e Síndrome Metabólica do Hospital São Lucas da Pontifica Universidade Católica do Rio Grande do Sul (COM HSL-PUCRS),
Porto Alegre, Brazil

D. S. Casagrande · G. Repetto · J. Rizzolli
Serviço de Endocrinologia do Hospital São Lucas,
Pontificia Universidade Católica do Rio Grande do Sul,
Porto Alegre, Rio Grande do Sul, Brazil

R. Schneider
Programa de Pós-Graduação em Gerontologia Biomédica,
Pontificia Universidade Católica do Rio Grande do Sul,
Porto Alegre, Rio Grande do Sul, Brazil

C. C. Mottin
Faculdade de Medicina e Curso de Pós-graduação da Pontificia,
Universidade Católica do Rio Grande do Sul,
Porto Alegre, Brazil

Introduction

Obesity is usually associated with a reduced risk of osteoporosis [1], but weight loss has been reported to reduce bone mineral density and increase fracture risk [2], especially when it occurs rapidly, as expected after gastric bypass surgery [3]. In this situation, bone mineral mass reduction, metabolic bone disease, and delayed fracture healing occur [4].

Since the development of bariatric surgery, several surgical methods for the treatment of severe obesity have

been developed. Roux-en-Y gastric bypass (RYGB) surgery is considered to be the ideal alternative treatment for severe obesity, because it is effective in reducing weight and complications/mortality associated with obesity [5, 6] and results in less severe malabsorption than with other malabsorptive procedures (e.g., jejuno-ileal bypass) [7] However, these procedures result in some degree of bone reabsorption and mineral metabolism abnormalities [3, 8]. Although postoperative malabsorption is thought to be the cause of these abnormalities, vitamin D deficiency with secondary hyperparathyroidism has been described in morbidly obese subjects before bariatric surgery [9–11].

There is some disagreement among experts about the best sites to measure bone mineral density. In general, bone mass at peripheral sites correlates with measurements at more central sites, such as the hip and the spine [12]. However, the evaluation of bone mineral density only at peripheral sites will miss a substantial number of individuals with osteopenia and osteoporosis. In fact, measurement at the site in question gives the best predictive value of the risk of fracture at that site. Since the sites more prone to fracture are the spine, femur, and distal radius, they are usually chosen to detect osteoporosis [12, 13]. Forearm bone mineral density should be measured especially when hip and/or spine cannot be measured or interpreted, in cases of hyperparathyroidism or in very obese patients [12]. However, reports on bone density described for morbidly obese subjects do not represent the actual bone density of these subjects because of selection biases [8]. There are no data documenting bone density in a large group of morbidly obese subjects measured by dual-energy X-ray absorptiometry, and there is little information on the evaluation of bone metabolism in these patients.

Because morbid obesity and surgical treatment of obesity may cause vitamin D deficiency and hyperparathyroidism [11, 14], it is important to understand the preoperative nutritional/metabolic status and bone mineral density of these patients. Considering the above observations, a cross-sectional study was designed aiming to evaluate bone metabolism/mineral density and nutritional profile in morbidly obese women before surgery.

Patients and Methods

We prospectively evaluated 33 class III obese women (body mass index—BMI—43.2±4.8 kg/m^2), 18 to 58 years old, between January 2007 and July 2008. Subjects were recruited from the outpatient of Centro da Obesidade e Síndrome Metabólica do Hospital São Lucas da Pontifica Universidade Católica do Rio Grande do Sul (COM HSL-PUCRS) in Porto Alegre, Brazil. Individuals were excluded if they had previous diseases such as gut malabsorption, any gastric disease, or kidney or liver disease, or were taking medications known to affect bone or mineral metabolism (glucocorticoids, calcium supplements, vitamin D derivatives, diuretics, and anti-epileptic drugs). The study was approved by the Internal Review Board of the Hospital São Lucas da PUCRS, and all subjects gave written informed consent before entering the study (protocol 06/02985).

Medical history and physical examination were performed for each subject by an endocrinologist. The dietitian enrolled the patients in the study, carried out anthropometric measurements (body weight and height), performed an evaluation of history of eating habits (intake of 24-h recall) and a validated food frequency questionnaire (FFQ) for obesity [15, 16]. The FFQ contains questions on the frequency of consumption of a usual portion size of food items [15] in the period prior to completion of the questionnaire. Frequency is reported as the number of times the food is consumed per day, per week, or per month or none at all. To calculate the nutritional composition of the FFQ, the frequencies of food intake are converted into numerical possibilities in order to analyze the variables. Composition of diet is calculated by the sum of all the food items listed in the questionnaire. The investigation of food intake in 24 h was obtained by a 24-h recall. All foods and beverages and their portion sizes consumed during a week day were recorded, excluding the weekend. It is true that, although dietary intakes estimated by the FFQ are correlated with true usual intake, such estimates are often based on systematic errors: underreporting or overreporting at the level of the individual [17]. Therefore, for proper interpretation of the results of epidemiological studies that use FFQ, it is necessary to know the relationship between reported intakes from the FFQ and true usual intake by the 24-h recall [18]. Nutrient analysis of FFQ and 24-h recall were performed using the food analysis software Dietwin® Professional 2.0 of Brubins and Dataweb Tecnologia, Porto Alegre, Brazil.

Blood samples were drawn after the above evaluations for laboratory analysis parameters using commercial kits as follows. Ferritin, folic acid, vitamin B12, insulin, and intact parathyroid hormone (iPTH) were measured by a chemiluminescence method (Advia Centaur, Bayer Corporation, Tarrytown, NY). Serum and urinary calcium, alkaline phosphatase, liver enzymes, plasma glucose, creatinine, albumin, cholesterol, high-density lipoprotein cholesterol (HDL-cholesterol), triglycerides, uric acid, and iron were measured by the dry chemical system (Fusion FS 5.1, Johnson & Johnson, Buckinghamshire, United Kingdom). Serum thyroxine (T4), thyrotropin (TSH), and 17β-estradiol were measured using a chemiluminescence immunoassay (Vitros ECi Immunodiagnostic System, Ortho-Clinical Diagnostics, Rochester, NY). Hemoglobin was analyzed with a Roche

Sysmex XT-2000i (Roche Diagnostic Corporation, Indianapolis, IN). Low-density lipoprotein cholesterol (LDL-cholesterol) was calculated by Friedewald's formula: [(triglycerides / 5) + (HDL-cholesterol) − total cholesterol]. Insulin resistance was assessed by the HOMA-IR (homeostasis model assessment of insulin resistance) in individuals who were not on hypoglycemic agents or insulin, as described [25]. The HOMA-IR index was calculated by the formula: $\mathrm{HOMA1\text{-}IR} = \text{fasting plasma insulin}(\mu\mathrm{U/ml}) \times \text{fasting plasma glucose}(\mathrm{mM}/22.5)$ [25]. Serum vitamin D levels (25-hydroxyvitamin D) were determined by radioimmunoassay based on an antibody with specificity for 25-OH-D (DiaSorin, Stillwater, MN). Serum collagen-type I N-telopeptide (NTX-s) was measured by means of the enzyme-linked immunosorbent assay (ELISA) using the Osteomark NTx® serum test (Whampole Laboratories Inc., Princeton, NJ). The manufacturer's recommendation of reference values for women ranges from 6.2 to 19.0 nM bone collagen equivalents (nM BCE). Some tests were used only as a criterion of exclusion and were not shown in results. Because of technical problems (loss of samples), not all variables had the same *n*, as follows: iPTH (n=29), NTX-s (n=22), 25-OH-vitamin D (n=22) and 24-h urinary calcium (n=26).

High iPTH was defined as iPTH of more than 65 pg/mL [19]. High NTX-s was defined as values above 16.5 nM BCE [20]. High 24-h urinary calcium was defined as values higher than 200 mg in 24 h [21]. Low serum calcium was defined as values lower than 8.5 mg/dL [22, 23]. Low serum 25-OH-vitamin D was defined as values lower than 20 ng/dL [19, 23].

Bone mass density was evaluated using dual-energy X-ray absorptiometry (DXA) at the lumbar spine (L1–L4), femoral neck, forearm (one-third distal radius), and leg (one-third distal tibia). It was measured in all subjects using the Hologic QDR-4500 Acclaim (Boston, MA). Low bone density was defined as a *Z* score lower than −2.0 for premenopausal and T-score lower than −1.0 for postmenopausal women for any of the sites of bone mineral density studied [24].

Statistical Analysis

Data are expressed as absolute and relative frequency or mean and standard deviation or median and interquartile range (P25–75). The Wilcoxon nonparametric test was used to compare the values of the nutritional composition of the diet obtained by 24-h recall and food frequency questionnaire. Fisher's exact test or Student's *t* test was used for categorical or continuous variables, respectively. Probability values below 0.05 were considered significant. Spearman correlation analyses were performed to test associations between variables. All analyses were performed with SPSS statistical software (SPSS 17.0).

Results

The general clinical characteristics of the subjects studied are summarized in Table 1. Twenty-seven (81.8%) premenopausal and six (18.2%) postmenopausal women were evaluated. The sample enrolled was typical of the population of patients presenting for bariatric surgery at our institution. Subjects were morbidly obese (BMI of 43.2±4.8 kg/m^2), and the ethnicity was 91% Caucasian and 9% black. There were few patients with diabetes mellitus or dyslipidemia. However, there was a high rate of insulin-resistant subjects (81.8%), considering the patients whose HOMA-IR was above the 90th percentile as insulin-resistant subjects (threshold value for insulin resistance of 2.71) [25].

Nutritional composition of the diet, obtained by the 24-h recall in comparison with the composition evaluated by the food frequency questionnaire is shown in Table 2. The table also shows the dietary reference intake [44, 45] of the macronutrients ingested. In the 24-h recall, the median and percentile (P25–75) of total intake was 3,081 (2,718–3,737) calories. The diet reported by the subjects studied had the usual content of proteins, carbohydrates, lipids, calcium, and magnesium, but had a high content of cholesterol, phosphorus, and sodium and low content of

Table 1 Clinical and metabolic characteristics of the subjects studied

Characteristic	
Age (years)	35.9±10.3
Weight (kg)	111.1±13.0
BMI (kg/m^2)	43.2±5.0
Waist circumference (cm)	121.2±9.0
Hip (cm)	131.0±8.0
Waist/hip	0.93±0.07
Menopause	6 (18.2)
Systemic arterial hypertension	23 (69.7)
Systolic blood pressure (mm Hg)	135.7±18.1
Diastolic blood pressure (mm Hg)	86.5±11.9
Diabetes mellitus	2 (6)
Use of oral contraceptive	12 (36)
Hormone replacement therapy	1 (3)
Smoking	2 (6)
Antiobesity drug use	4 (9.8)
Hemoglobin (g/dL)	13.9±4.3
Cholesterol (mg/dL)	205.6±37
HDL-c (mg/dL)	50.8±14.0
Triglycerides (mg/dL)	133 (101–179)
HOMA-IR	4.2 (2.7–4.6)

Results are expressed as mean ± SD, number of patients (percent of patients), or median (25/75 percentile). *BMI* body mass index; *HDL-c* high-density lipoprotein cholesterol; *HOMA-IR* homeostasis model assessment insulin resistant

Table 2 Nutritional composition of the diet (n=33)

Variable	DRIs	24-h recall	Food frequency questionnaire	p
Total energy value (kcal)	1,800–2,000	3,081 (2,718–3,737)	2,685 (2,284–4,400)	0.950
Protein (%)	10–35	19.1 (12.5–30.2)	11.9 (7.6–13.4)	<0.001
Carbohydrate (%)	45–65	51.4 (31.8–79.8)	57.3 (50.9–62.6)	0.728
Lipid (%)	20–35	36.8 (25.0–61.3)	32.0 (28.9–40.5)	0.110
Cholesterol (mg)	<300	471 (334–625)	241 (181–367)	0.008
Iron (mg)	18	20.3 (15.0–28.0)	11.3 (7.7–17.2)	<0.001
Vitamin D intake (μg)	5	2.0 (1.0–4.4)	2.0 (0.7–4.5)	0.357
Magnesium (mg)	320	287 (233–398)	185 (145–412)	0.201
Phosphorus (mg)	700	1,587 (1,222–2,077)	1,076 (784–1,507)	0.008
Calcium (mg)	1,000	912 (630–1,516)	1,141 (885–1,238)	0.654
Potassium (mg)	4,700	2,981 (2,424–4,468)	1,896 (1,092–3,442)	0.036
Sodium (mg)	1,500	5,379 (3,308–7,202)	2,014 (1,429–3,746)	<0.001

Results are expressed as median (25/75 percentile). *DRIs* dietary reference intake. 24-h recall quantifies the consumption of food throughout the 24 h preceding the interview or during the previous day. The value of p is the minimum level of significance of the nonparametric Wilcoxon test for the comparison between nutritional composition evaluated by 24-h recall vs. the food frequency questionnaire

potassium, as compared to the dietary reference intake [26]. Although the median calcium intake was that usually recommended, there were 13 (49.6%) subjects who had an intake of less than 800 mg calcium/day. Calcium intake was higher when evaluated by the food frequency questionnaire as compared with the 24-h recall. Vitamin D, magnesium, and potassium intakes were lower than recommended [26]. The food frequency questionnaire underestimated total energy value intake as compared with the 24-h recall. Protein and lipid intakes were lower if evaluated by the food frequency questionnaire as compared to the 24-h recall.

Table 3 depicts the characterization of the subjects studied according to their bone metabolism markers (iPTH, NTX-s, 24-h urinary calcium, and serum calcium and vitamin D). Concerning other laboratory tests, all subjects had normal levels of albumin, as well as ferritin and folic acid. Vitamin D levels (upper normal limit 20 ng/mL) were low in 18 of the 22 (81.8%) patients.

Table 3 Characterization of the subjects studied according to their bone metabolism markers

Variable	n	n (%)
High iPTH	29	4 (13.8)
High serum collagen-type I N-telopeptide	22	6 (27.2)
High 24-h urinary calcium	26	8 (30.8)
Low serum calcium	33	1 (3.0)
Low serum 25-OH-vitamin D	22	18 (81.8)
Low bone density by DXA	33	2 (6.0)

The results are expressed in number of patients (percent of patients). *DXA* dual-energy X-ray absorptiometry

The comparison of the individuals according to their vitamin D levels is presented in Table 4. Subjects with low serum vitamin D levels had lower NTX-s, but there were no other differences as compared to those with normal serum levels.

Bone mineral density was low in the lumbar spine (L1–L4) in one premenopausal woman, and bone mineral density was low in the lumbar spine (L1–L4), femoral neck, and 1/3 proximal radius in one postmenopausal woman.

There was a positive correlation between NTX-s and body mass index (r_s=0.51, p=0.015) and between vitamin D and NTX-s (r_s=0.42, p=0.054).

The comparison of the individuals according to the presence or absence of menopause is presented in Table 5. As expected, postmenopausal women were older. No other difference was observed between pre- and postmenopausal women.

Discussion

The main findings of the present study, evaluating 33 morbidly obese women candidates for bariatric surgery, were that general nutrition status was very good, except for biochemical markers of bone metabolism, especially vitamin D, which was found to be low in 81.8% of them. These patients had low levels of NTX-s and high (although not significantly) iPTH levels, as compared to those with normal vitamin D levels but with no impact upon bone mineral density. Also, no differences were observed between pre- and postmenopausal women.

Subjects of our study reported a high caloric intake demonstrated by the 24-h recall and food frequency

Table 4 Characterization of the subjects studied according to their vitamin D status

Variable	Low serum vitamin D (n=18)	Normal serum vitamin D (n=4)	p
Hormone replacement therapy	1 (5.6%)	0	1.000
Menopause	3 (16.7%)	0	1.000
Age (years)	36.7±7.9	31.0±5.1	0.226
Body mass index (kg/m^2)	43.1±1.4	44.4±1.3	0.678
Alkaline phosphatase (U/L)	87.8±5.1	77.5±10	0.396
Serum calcium (mg/dL)	9.4±0.1	9.2±0.1	0.415
24-h urinary calcium (mg/24 h)	184.8±51.1	194.3±82.5	0.886
iPTH (pg/mL)	47.1±5.3	37.2±5.9	0.402
Vitamin D intake (μg)	5.1±1.5	1.7±5.0	0.343
Calcium intake (mg/day)	1,020±96	1,040±388	0.940
NTX-s (nM BCE)	14.6±1.2	18.2±0.4	0.015
Low bone density in lumbar spine, femoral neck, and 1/3 distal radius	0	1 (25%)	0.182
HOMA-IR	5.2±0.6	4.9±1.1	0.862
Vitamin B12 (pg/mL)	421±33	554±114	0.144
BMD of neck (g/cm^2)	1.03±0.04	0.90±0.02	0.210
BMD of lumbar spine (g/cm^2)	1.15±0.02	1.04±0.01	0.051
BMD of radius (g/cm^2)	0.58±0.01	0.60±0.01	0.526
BMD of tibia (g/cm^2)	0.96±0.11	0.93±0.02	0.913

Results are expressed as mean and standard error (SE) of mean or in number of patients (percent of patients). Low serum vitamin D values<20 ng/mL. *iPTH* parathyroid hormone. *NTX-s* serum collagen-type I N-telopeptide. *nM BCE* nM bone collagen equivalents. *HOMA-IR* homeostasis model assessment insulin resistant. *BMD* bone mineral density. The value of p is the minimum level of significance of Student's t test (continuous variables) or of Fisher's exact test (categorical variables)

Table 5 Characterization of the subjects studied according to their menopause status

Variable	Premenopause (n=27)	Postmenopause (n=6)	p
Hormone replacement therapy	0 (0.0%)	1 (16.7%)	0.182
Age (years)	31.9±1.3	52.3±1.5	<0.001
Body mass index (kg/m^2)	43.6±1.0	41.5±1.0	0.373
Alkaline phosphatase (U/L)	97.4±8.2	98.1±11.7	0.968
Serum calcium (mg/dL)	9.4±0.1	9.2±0.3	0.337
24-h urinary calcium (mg/24 h)	205.0±40.7	146.7±22.8	0.452
iPTH (pg/mL)	45.2±4.2	45.5±6.5	0.968
Vitamin D intake (μg)	2.8±0.6	8.5±4.2	0.234
Calcium intake (mg/day)	968±92	1,203±155	0.670
NTX-s (nM BCE)	15.4±0.9	14.4±5.9	0.876
Low bone density in lumbar spine, femoral neck, and 1/3 distal radius	1 (3.7%)	1 (16.7%)	0.335
HOMA-IR	5.4±0.5	5.0±1.1	0.762
Vitamin B12 (pg/mL)	423±31	493±69	0.343
BMD of neck (g/cm^2)	1.00±0.02	1.02±0.09	0.821
BMD of lumbar spine (g/cm^2)	1.11±0.01	1.13±0.07	0.798
BMD of radius (g/cm^2)	0.59±0.01	0.53±0.03	0.056
BMD of tibia (g/cm^2)	0.96±0.07	1.13±0.07	0.301

Results are expressed in mean and standard error of mean or in number of patients (percent of patients). *iPTH* parathyroid hormone. *NTX-s* serum collagen-type I N-telopeptide. *nM BCE* nM bone collagen equivalents. *HOMA-IR* homeostasis model assessment insulin resistant. *BMD* bone mineral density. The value of p is the minimum level of significance of Student's t test (continuous variables) or of Fisher's exact test (categorical variables)

questionnaires, although lower than expected by their dietary reference intake. Several studies in industrialized countries have documented a high prevalence of underreporting energy intakes from 24-h recalls, food records, and food frequency questionnaires [18, 27, 28]. It was shown that underreporting is not random, but is related to characteristics such as obesity, smoking, dieting, and psychological factors [28], leading to the conclusion that food consumption evaluation still needs improvement. Jain et al. [18] suggest that the food frequency method gives acceptable estimates of nutrients or food components as assessed by their calibration study against diet recalls. Serious bias reporting habitual energy intake was observed in data obtained from 24-h recalls, as compared with the food frequency method [29], as was also observed in the present study.

Here, we report that 81.8% of the patients studied had a high HOMA-IR (>2.7) (Table 1), which was an expected finding, because of their obesity state [25]. Although other authors reported that fasting insulin levels were positively associated with bone mineral density [41], we did not observe any association between these variables. This fact could be attributed to the small number of individuals with low bone density.

We did not observe any significant nutritional deficiencies in our sample. Clearly, because the sample was small, this may not represent the whole population of morbidly obese individuals. Also, we did not determine all serum vitamins like in other studies. Despite the excessive intake that causes obesity, obese patients can show nutritional deficiencies as a consequence of inadequate dietary intake related to poor education or social factors, eating disorders, unbalanced weight-reducing diets, or comorbidities [30]. Other authors evaluated morbidly obese subjects and described low albumin (1.1 to 12.5%), low ferritin (6.9 to 8.4%), low folate (3.4%), and low vitamin B12 levels (18.1%) [31, 32]. These data probably reflect reality more than ours, because of the high number of subjects that these authors studied and also because of the more diverse social classes to which those subjects pertained.

We observed a high prevalence of vitamin D deficiency (81.8%), hypercalciuria (30.8%), high NTX-s (27.2%), and high iPTH (13.8%). Other authors reported low 25-hydroxyvitamin D in 25.4 [31], 57.4 [33] and 68.1% [32] of their patients. The difference between the values could be explained by the differences in age, race, sex, smoking habit, and body fat percentage, factors that interfere with vitamin D metabolism [23]. It is important to point out that low serum vitamin D concentration in patients with systemic inflammation—as is the case with obese individuals—does not necessarily indicate that the body stores are depleted [34]. Decreased sun exposure, sequestration of vitamin D in fat, and a physiologic adaptation to the need for more bone mass to support increased weight are suggested mechanisms leading to vitamin D deficiency in morbidly obese individuals [22, 37]. Interestingly, vitamin D deficiency was recently associated with incident cardiovascular disease [35], and high iPTH levels were found to be predictive of mortality [36]. Consequently, chronic vitamin D deficiency, inadequate calcium intake, and secondary hyperparathyroidism would place these obese patients at risk for cardiovascular mortality, beyond the expected low bone mass.

We found a low prevalence (13.8%) of high levels of iPTH compared to some authors who observed a 25% prevalence [22, 38], but El-kadre et al. [14] reported 10% hyperparathyroidism in obese Brazilian women. The absence of a similar incidence of secondary hyperparathyroidism with deficiency of vitamin D in Brazilian women observed in the present study vs. that of El-Kadre [14] may be due to lifestyle or cultural differences in diet as well as genetics. Also, magnesium deficiency is a putative factor, but we did not evaluate this micronutrient. Low calcium intake and low albumin levels could not account for this discrepancy because they were evaluated and were within the expected ranges.

The high levels of this calcium reabsorption marker observed in almost one-third of our sample is a new finding. Markers of bone reabsorption are interesting to study in situations which could progress with high calcium reabsorption and bone loss, such as the postoperative period of morbidly obese patients. New bone reabsorption markers have been introduced in order to be more specific for metabolic breakdown of bone collagen, such as deoxypyridinoline and the cross-linked N-telopeptides and C-telopeptides of type I bone collagen (NTX and CTX, respectively) [39]. Serum-based markers of bone turnover tend to show less variability as compared with urine-based markers [39].

There was a positive correlation between NTX-s and body mass index, suggesting that patients with high BMI could experience higher bone reabsorption. This finding may explain the increased prevalence of low bone density in morbidly obese subjects [42]. This is not the case in non-obese subjects, as a Japanese study described an inverse correlation between these variables [40]. There are very few studies that have evaluated NTX-s in obese and morbidly obese individuals, and thus, our data is new, but needs further confirmation. We speculate that the trend toward a positive correlation between NTX-s and vitamin D represents an increased need for more calcium absorption, but no cause–effect can be established with these data. Alternatively, since weight loss can unfavorably alter bone turnover markers in overweight adults [43], NTX-s could be correlated to body mass index, because this is a variable that indirectly indicates that patient is on a diet.

Menopause had the effect of increasing the circulating concentrations of NTX-s and alkaline phosphatase activity by 15% ($p=0.001$) and 11% ($p=0.02$), respectively. However, serum levels of PTH were not different between these two groups of women [46].

We observed low bone mineral density in one premenopausal and one postmenopausal woman, a low prevalence, as compared to 31% of premenopausal obese women with osteopenia or osteoporosis as described before [43]. Probably the low prevalence of osteopenia could be explained by the fact that the subjects we evaluated were very young. Also, patients in the study of Bacon et al. [42] with a history of chronic dieting behavior had a higher occurrence of osteoporosis or osteopenia, and they observed a negative correlation between the number of times the women go on a diet to lose weight and bone mineral content values. Gomez et al. [42] observed an inverse correlation between body fat and bone mineral density, suggesting that extreme obesity may increase the risk of osteoporosis.

Comparing the pre- and postmenopausal group, we did not find any difference concerning the characteristics of the subjects, except for age and a trend toward lower bone mass density of the radius in postmenopausal women. El-Kadre et al. [14] described urinary NTX-s within the normal range in premenopausal and high levels in postmenopausal morbidly obese women after bariatric surgery, but they did not present comparative data between these two groups before surgery.

In conclusion, the nutritional status of morbidly obese women studied here was good, except for markers of bone metabolism, but no reduction in bone mineral density was observed.

Disclosure There are no external sources of funds supporting this work. There is no financial interest for any of the authors.

References

1. Rosen C, Klibanski A. Bone, fat, and body composition: evolving concepts in the pathogenesis of osteoporosis. Am J Med. 2009;122:409–14.
2. Langlois JA, Mussolino ME, Visser M, et al. Weight loss from maximum body weight among middle-aged and older white women and the risk of hip fracture: the NHANES I epidemiologic follow-up study. Osteoporosis Int. 2001;12:763–8.
3. Coates PS, Fernstrom JD, Fernstrom MH, et al. Gastric bypass surgery for morbid obesity leads to an increase in bone turnover and a decrease in bone mass. J Clin Endocrinol Metab. 2004;89:1061–5.
4. Bano G, Rodin DA, Pazianas M, et al. Reduced bone mineral density after surgical treatment for obesity. Int J Obes Relat Metab Disord. 1999;23:361–5.
5. Sjöström L, Lindroos AK, Peltonen M, et al. Lifestyle, diabetes, and cardiovascular risk factors 10 years after bariatric surgery. N Engl J Med. 2004;351:2683–93.
6. Sjöström L, Narbro K, Sjöström CD, et al. Effects of bariatric surgery on mortality in Swedish obese subjects. N Engl J Med. 2007;357:741–52.
7. Colossi FG, Casagrande DS, Chatkin R, et al. Need for multivitamin use in the postoperative period of gastric bypass. Obes Surg. 2008;17:1150–8.
8. Fleischer J, Stein EM, Bessler M, et al. The decline in hip bone density following gastric bypass surgery is associated with extent of weight loss. J Clin Endocrinol Metab. 2008;93:3735–40.
9. Hamoui N, Kim K, Anthone G, et al. The significance of elevated levels of parathyroid hormone in patients with morbid obesity before and after bariatric surgery. Arch Surg. 2003;138:891–7.
10. Carlin AM, Rao DS, Meslemani AM, et al. Prevalence of vitamin D depletion among morbidly obese patients seeking gastric bypass surgery. Surg Obes Relat Dis. 2006;2:98–103.
11. Goldner WS, Stoner JA, Thompson J, et al. Prevalence of vitamin D insufficiency and deficiency in morbidly obese patients: a comparison with non-obese controls. Obes Surg. 2008;18:145–50.
12. Lacativa PG, Farias MLF. Office practice of osteoporosis evaluation. Arq Bras Endocrinol Metab. 2006;50:674–84.
13. Miller PD, Zapalowski C, Kulak CAM, et al. Bone densitometry: the best way to detect osteoporosis and to monitor therapy. J Clin Endocrinol Metab. 1999;84:1867–71.
14. El-Kadre LJ, Rocha PR, Tinoco ACA, et al. Calcium metabolism in pre- and postmenopausal morbidly obese women at baseline and after laparoscopic Roux-en-Y gastric bypass. Obes Surg. 2004;14:1062–6.
15. Sichieri R. Epidemiologia da Obesidade. Rio de Janeiro. EDUERJ 1998.
16. Souza RAG, Rangel ACS, Rogério CM, et al. Confiabilidade de um questionário de consumo alimentar em mulheres. Cienc Cuid Saúde. 2007;6:103–9.
17. Carroll Rj, Pee D, Freedman LS, et al. Statistical design of calibration studies. Am J Clin Nutr. 1997;65:1187S–9S.
18. Jain MG, Rohan TE, et al. Calibration of the dietary questionnaire for the Canadian study of diet, lifestyle and health cohort. Public Health Nutr. 2003;6:79–86.
19. Ashraf A, Alvarez J, Saenz K, et al. Threshold for effects of vitamin D deficiency on glucose metabolism in obese female African American adolescents. J Clin Endocrinol Metab. 2009;94:3200–6.
20. Nishizawa Y, Nakamura T, Ohta H, et al. Guidelines for the use of biochemical markers of bone turnover in osteoporosis (2004). J Bone Metab. 2005;23:97–104.
21. Lam GS, Asplin JR, Halperin ML. Does a high concentration of calcium in the urine cause an important renal concentrating defect in human subjects? Clin Sci (Lond). 2000;98:313–9.
22. Hamoui N, Anthone G, Crookes PF. Calcium metabolism in the morbidly obese. Obes Surg. 2004;14:9–12.
23. Lee JH, O'Keefe JH, Bell D, et al. Vitamin D deficiency: an important, common, and easily treatable cardiovascular risk factor? J Am Coll Cardiol. 2008;52:1949–56.
24. Brandão CMA, Camargos BM, Zerbini CA, et al. 2008 official positions of the Brazilian society for clinical densitometry—SBDens. Arq Bras Endocrinol Metab. 2009;53:107–12.
25. Geloneze B, Vasques ACJ, Stabe CFC, et al. HOMA1-IR and HOMA2-IR indexes in identifying insulin resistance and metabolic syndrome—Brazilian Metabolic Syndrome Study (BRAMS). Arq Bras Endocrinol Metab. 2009;53:281–7.
26. US NATIONAL ACADEMY OF SCIENCES (USA). Dietary Reference Intakes for vitamin C, vitamin E, selenium and carotenoids. Washington DC : National Academy Press, 2000, 506p. (A report on the antioxidants and related compounds. Subcommittees on Upper Reference Intake Levels of Nutrients and Interpretation of Uses of Dietary Reference Intakes and the Standing Committee on the Scientific Evaluation of Dietary Reference Intakes. Food and Nutrition Board).

27. Krebs-Smith SM, Graubard BI, Kahle LL, et al. Low energy reporters vs others: a comparison of reported food intakes. Eur J Clin Nutr. 2000;54:281–7.
28. Johansson G, Wikman A, Ahrén AM, et al. Underreporting of energy intake in repeated 24-hour recalls related to gender, age, weight status, day of interview, educational level, reported food intake, smoking habits and area of living. Public Health Nutr. 2001;4:919–27.
29. Hernández-Avila M, Romieu I, Parra S, et al. Validity and reproducibility of a food frequency questionnaire to assess dietary intake of women living in Mexico City. Salud Publica Mex. 1998;40:133–40.
30. Allard J. Should nutritional status be routinely assessed and corrected before bariatric surgery? Nat Clin Pract Gastroenterol Hepatol. 2007;4:130–1.
31. Ernst B, Thurnheer M, Schmid SM, et al. Evidence for the necessity to systematically assess micronutrient status prior to bariatric surgery. Obes Surg. 2009;19:66–73.
32. Flancbaum L, Belsley S, Drake V, et al. Preoperative nutritional status of patients undergoing Roux-en-Y Gastric Bypass for morbid obesity. J Gastrointest Surg. 2006;10:1033–7.
33. Gemmel K, Santry HP, Prachand VN, et al. Vitamin D deficiency in preoperative bariatric surgery patients. Surg Obes Relat Dis. 2009;5:54–9.
34. Aasheim ET, Hofsø D, Hjelmesaeth J, et al. Vitamin status in morbidly obese patients: a cross-sectional study. Am J Clin Nutr. 2008;87:362–9.
35. Wang TJ, Pencina MJ, Booth SL, et al. Vitamin D deficiency and risk of cardiovascular disease. Circulation. 2008;117:503–11.
36. Hagström E, Hellman P, Larsson TE, et al. Plasma parathyroid hormone and the risk of cardiovascular mortality in the community. Circulation. 2009;119:2765–71.
37. Silva BC, Camargos BM, Fujii JB, et al. Prevalence of vitamin D deficiency and its correlation with iPTH, biochemical bone turnover markers and bone mineral density, among patients from ambulatories. Arq Bras Endocrinol Metab. 2008;52:482–8.
38. Avgerimos DV, Leitman MI, Martinez RE, et al. Evaluation of markers for calcium homeostasis in a population of obese adults undergoing gastric bypass operations. J Am Coll Surg. 2007;205:294–7.
39. Eastell R, Mallinak N, Weiss S, et al. Biological variability of serum and urinary N-Telopeptides of Type I collagen in postmenopausal women. J Bone Miner Res. 2000;15:594–8.
40. Nakamura K, Saito T, Yoshihara A, et al. Low calcium intake is associated with increased bone reabsorption in postmenopausal Japanese women: Yokogoshi Study. Public Health Nutr. 2009;12:1–5.
41. Barrett-Connor E, Kritz-Silverstein D. Does hiperinsulinemia preserve bone? Diabetes Care. 1996;19:1388–92.
42. Gómez JM, Vilarrasa N, Masdevall C, et al. Regulation of bone mineral density in morbidly obese women: a cross-sectional study in two cohorts before and after bypass surgery. Obes Surg. 2009; 19:345–50.
43. Bacon L, Stern JS, Keim NL, et al. Low bone mass in premenopausal chronic dieting obese women. Eur J Clin Nutr. 2004;58:966–71.
44. Institute of Medicine, Food and Nutrition Board. Dietary reference intakes (DRIs): recommended intakes for individuals, Vitamins. Washington: National Academy Press; 2001.
45. Institute of Medicine, Food and Nutrition Board. Dietary reference intakes (DRIs): recommended intakes for individuals, Elements. Washington: National Academic Press; 2001.
46. Baca EA, Ulibarri VA, Scariano JK, et al. Increased serum levels of N-telopeptides (NTx) of bone collagen in postmenopausal Nigerian women. Calcif Tissue Int. 1999;65:125–8.