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ORIGINAL CONTRIBUTIONS

Weight Loss After RYGB Is Associated with an Increase in Serum Vitamin D in a Population with Low Prevalence of Hypovitaminosis D at Low Latitude

Sônia Lopes Pinto [1,2,3] · Leidjaira Lopes Juvanhol [3] · Josefina Bressan [3]

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Abstract

Purpose In Brazil and worldwide, few studies have investigated vitamin D deficiency in patients with severe obesity who underwent bariatric surgery associated with latitude and level of solar radiation**.** The objective of this study was to investigate the prevalence of vitamin D deficiency and the predictive factors of serum level changes after 12 months of RYGB in a low latitude region.

Materials and Methods This study included 50 patients from a low-latitude city (10° 10′ 8″ S) in the north of Brazil. We collected data before surgery and after 3 and 12 months of surgery. The level of vitamin D was classified as deficiency (< 20 ng/ml), insufficiency (20–30 ng/ml), and sufficiency (≥ 30 ng/ml).

Results The mean age of the patients was 38.7 ± 8.9 years, 69% were women, and percent excess weight loss (% EWL) was 83% after 1 year of surgery. The prevalence of vitamin D deficiency in the preoperative period was 14%, and after 3 and 12 months of surgery, it decreased to 4% and 6%, respectively. The variation in vitamin D after 12 months of surgery was positively associated with changes in BMI, body fat, and % EWL.

Conclusions The prevalence of vitamin D deficiency is low in patients undergoing bariatric surgery in the northern region of Brazil, which is possibly related to low latitude. Weight loss was positively associated with an increase in serum vitamin D after surgery.

Keywords Bariatric surgery · Vitamin D · Brazil · Latitude and weight loss

Introduction

Obesity is a serious public health problem affecting millions worldwide [1]. A 2018 data show that 19.5% of adults in Brazil are with obesity (body mass index—BMI ≥ 30 kg/m^2) [2]. Bariatric surgery is the most recommended treatment for severe obesity (BMI ≥ 40 kg/m^2) because it results in greater weight loss and maintenance of the same, as well as improvement in comorbidities [2]. Roux-en-Y gastric bypass (RYGB), which combines restrictive and malabsorptive components, is the most popular procedure in Brazil [3] and is regarded as a gold standard according to efficiency and safety [2].

Micronutrient deficiency is an expected outcome after RYGB since food consumption is reduced; concomitantly, vitamin and mineral absorption is drastically reduced, requiring supplementation [4]. Among micronutrient deficiencies before and after the surgery, vitamin D deficiency stands out for being higher in the preoperative period [5].

A systematic review showed that the prevalence of hypovitaminosis D among individuals with obesity is about 35% higher than eutrophic individuals [6] and surpasses 90% for bariatric surgery candidates [7, 8]. In Brazil, few studies

✉ Sônia Lopes Pinto
sonialopes@uft.edu.br

Leidjaira Lopes Juvanhol
leidjaira@ufv.br

Josefina Bressan
jbrm@ufv.br

1 Nutrition Course, Federal University of Tocantins, Quadra 109 North, NS-15 Avenue, ALCNO-14, Block Bala2, North Director Plan, Palmas, Tocantins 77001-090, Brazil

2 Federal University of Viçosa, Viçosa, Minas Gerais, Brazil

3 Department of Nutrition and Health, Federal University of Viçosa, University Campus, Viçosa, Minas Gerais, Brazil

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have investigated vitamin D deficiency in patients with severe obesity before [9] and after [10] RYGB. To our knowledge, the prevalence of hypovitaminosis D has not been investigated in this profile of patients in the northern region of Brazil, where solar radiation is high all year due to low latitude. High-latitude regions have lower solar radiation levels and, therefore, a higher prevalence of vitamin D deficiency.

Also, little is known about predictive factors of serum vitamin D changes after bariatric surgery. Thus, we investigated the prevalence of vitamin D deficiency and the predictive factors of serum level changes in vitamin D after 12 months of RYGB in a low-latitude region.

Methods

Study Design and Population

This study is a longitudinal study in which patients who underwent RYGB were followed up for 12 months. We invited volunteers based on the following inclusion criteria: adult (> 19 years and < 60 years), first RYGB surgery, and non-smoker. The study was approved by the Ethics and Research Committee of the Federal University of Viçosa, Minas Gerais (protocol: 1.852.365). Informed consent was obtained from all individual participants included in the study.

We collected data between February 2017 and September 2018 in the city of Palmas, Tocantins state, northern region of Brazil, and in 3 phases: preoperative and after 3 and 12 months of surgery. Before the surgery, no patients were on vitamin D supplement or multivitamin. After 1 month of the surgery, all patients consumed 1 to 2 tablets of daily multivitamin supplement containing vitamin A (400 mcg), B1 (1.2 mg), B2 (1.3 mg), B3 (16mg), B5 (5.0 mg), B6 (1.3 mg), B9 (240 mg), B12 (2.4 mcg), C (45 mg), D (5.0 mcg), E (6.7 mg), biotin (30 mcg), vitamin K (65 mcg), calcium (150 mg), chlorine (320 mcg), copper (450 mcg), chromium (18 mcg), iron (8.1 mg), phosphorus (125 mg), iodine (33 mcg), magnesium (100 mg), manganese (23 mcg), potassium (10 mcg), selenium (20 mcg), and zinc (7.0 mg).

Anthropometric and Biochemical Assessment

We collected anthropometric data such as weight (kg), height (m), and waist circumference (cm). Subsequently, we calculated BMI considering the formula: weight (kg)/height (m)^2. Weight loss was assessed as a percent excess weight loss (% EWL). Considering a BMI of 25 kg/m^2 as ideal, we calculated excess weight (EW) in kilograms: preoperative weight (kg) − ideal weight (kg). We calculated EWL as absolute weight loss (kg)/EP × 100. Using tetrapolar electrical bioimpedance with a Biodynamics® BIA 310 instrument, we assessed body fat (BF) as a percentage.

We determined and classified serum vitamin D concentration (25-hydroxyvitamin D or 25(OH)D) by chemiluminescence: deficiency < 20 ng/ml; insufficiency 20–29, 9 ng/ml; and sufficiency ≥30 ng/ml [11]. We referred patients who presented nutritional vitamin D deficiency for medical care aimed at adequate supplementation. We also analyzed serum concentrations of total cholesterol (TC), HDL cholesterol, LDL cholesterol, triglycerides (TG), glucose, and fasting insulin.

Statistical Analysis

To assess the difference among the 3 phases (before, 3, and 12 months after surgery), we conducted the repeated measures ANOVA test followed by Bonferroni, or the Friedman test followed by Wilcoxon, according to the normality of the data. For categorical variables, we performed the McNemar test. Using multiple linear regression, we verified whether changes in weight (Δ) and other cardiometabolic risk measures (independent variables) were associated with changes (Δ) in serum vitamin D level (dependent variable) after 12 months of surgery. Adjustment was made for vitamin D in the preoperative period and for the value of the independent variable in the preoperative period. We utilized Stata® 13.3 with a 5% significance level (α) for all analyses.

Results

This study included 50 patients who underwent RYGB, with a mean age of 38.7 ± 8.9 years and 69% were women. Mean BMI, waist circumference, and BF decreased after 3 and 12 months of surgery. After 1 year, %EWL was 83.7%. In the preoperative period, we observed 52% of hypovitaminosis D (14% deficiency and 38% insufficiency). However, after 3 and 12 months of surgery, we observed a significant reduction in the prevalence of deficiency and an increase in vitamin D sufficiency (Table 1).

Multiple linear regression analysis showed that Δ vitamin D was positively associated with changes in BMI and BF after 12 months, and % EWL at 1-year post-surgery. A unit reduction of BMI after 12 months of RYGB was associated with a 1.12 ng/ml increase in serum 25-hydroxyvitamin D levels (Table 2). Other cardiometabolic risk factors (blood glucose, HDL, LDL, TC, TG, and insulin) were not associated with changes in serum vitamin D levels (not shown in table).

Discussion

We observed a low prevalence of vitamin D deficiency before and after 3 and 12 months of RYGB compared with studies conducted with patients with severe obesity who underwent

Table 1 Anthropometric, biochemical characteristics, and classification of vitamin D in patients before and after 3 and 12 months of RYGB ($n = 50$)

Variables	Baseline	3 months	12 months	p value*
Anthropometry		Mean ± SD		
BMI (kg/m^2)	42.3 ± 4.9^a	34.7 ± 4.1^b	28.2 ± 3.8^c	< 0.001
Waist circumference (cm)	122.4 ± 11.7^a	106.4 ± 11.0^b	92.5 ± 11.3^c	< 0.001
BF (%)	42.4 ± 4.6^a	37.7 ± 5.4^b	29.4 ± 7.4^c	< 0.001
% EWL	-	48.5 ± 11.0^a	84.3 ± 19.4^b	< 0.001
% TWL	-	18.5 ± 2.6^a	33.2 ± 6.3^b	< 0.001
Biochemistry	Median (IQR)			
Vitamin D (ng/ml)	28.2 (22.6–36.5)	30.0 (27.0–33.4)	30.9 (24.6–34.8)	0.781
Classification of vitamin D		% (n)		
Sufficiency	48 (24)^a	50 (25)^b	54 (27)^c	-
Insufficiency	38 (19)^a	46 (23)^b	40 (20)^c	-
Deficiency	14 (7)^a	4 (2)^b	6 (3)^c	-

*Different letters indicate a statistically significant difference ($p < 0.05$)

Continuous variables: ANOVA test of repeated measures followed by Bonferroni for variables with normality and, for the others, Friedman test followed by Wilcoxon. Categorical variables: McNemar test followed by Bonferroni

RYGB, Roux-en-Y gastric bypass; *SD*, standard deviation; *BMI*, body mass index; *EWL*, loss of excess weight; *TWL*, total weight loss; *BF*, body fat; *IQR*, interquartile range

bariatric surgery in other locations in Brazil [9, 10] and around the world [5, 8, 12]. To the best of our knowledge, the present study is the first to assess the prevalence of vitamin D deficiency in patients who underwent RYGB in a low-latitude area, such as the northern region of Brazil.

Previous studies on serum vitamin D levels of patients in the preoperative period of bariatric surgery report a range from 68 to 96% for hypovitaminosis D (defined as 25-hydroxyvitamin D < 30 ng/ml) [8, 9, 12] and 21 to 80% for vitamin D deficiency (defined as 25-hydroxyvitamin D < 20 ng/ml) [9, 13].

We observed a 52% prevalence of hypovitaminosis D before surgery, 50% at 3 months, and 46% after 12 months. Nutritional vitamin D deficiency decreased from 14 to 6% with 1 year of RYGB. This finding contradicts studies from other parts of the world because such low prevalence of vitamin D deficiency was not found among pre- and post-bariatric surgery patients.

The low prevalence of vitamin D deficiency observed may be related to the low latitude of Palmas city (10° 10′ 8″ S), which allows more intense solar radiation all year round (2026 kWh/m^2) [14]. A study conducted in the southern region of Brazil, with candidates for bariatric surgery, showed a 92.4% prevalence of hypovitaminosis D and 55.3% deficiency [9]. The city in question (Porto Alegre/RS) has a high latitude (30° 1′ 40″ S). Studies in Europe, Asia, and the USA at high-latitude places present higher hypovitaminosis D prevalence before bariatric surgery compared with the present study population: 96% Paris/France [13], 91.5% Beirut/Lebanon [8], and 88% Orono/USA [15].

The predictive factors of vitamin D changes after 12 months of surgery showed a more significant reduction in BMI and body fat associated with greater variation in vitamin D. This result is consistent with the literature, which shows that weight loss occurs with an increase in serum vitamin D [16, 17].

In individuals with obesity, the prevalence of vitamin D deficiency and insufficiency is higher than eutrophic individuals [6], which can be explained by several hypotheses. Possible causes can be lower ingestion of vitamin D food sources and less exposure to sunlight or impaired skin synthesis. Also, changes in protein binding or faster metabolic clearance–related obesity can lead to lower serum levels of 25(OH)D [18]. Another hypothesis could be that 1.25D acts to limit the production of its precursor, 25(OH)D. Early

Table 2 Association of Δ vitamin D* (dependent variable) with Δ cardiometabolic risk factors** (independent variables) in patients undergoing RYGB

Variables	β	p value***
Δ BMI	1.12	0.001
Δ BF	0.42	0.018
%EWL 12 months	0.13	0.004

*Δ vitamin D = value at 12 months − value at baseline

**Δ of cardiometabolic risk factors = baseline value − value at 12 months

***Adjustment was made for vitamin D in the preoperative period and for the value of the independent variable in the preoperative period

RYGB, Roux-en-Y gastric bypass; *BMI*, body mass index; *BF*, body fat; *EWL*, loss of excess weight studies found high concentrations of 1.25D in individuals with obesity and therefore it was thought to decrease serum 25(OH)D levels [19]. However, these hypotheses are controversial, especially because they have not been able to explain lower serum levels of vitamin D observed in recent studies [20, 21]. Volumetric dilution, on the other hand, is perhaps the most important explanation for nutritional deficiency, as it relates the quantity of vitamin D with body size [20, 21]. The distribution of vitamin D in a larger volume of body tissue may explain the lower serum vitamin D concentration, and thus when adjusted to body size, no difference is observed between individuals with obesity and eutrophic individuals [22].

Weight loss and body fat, in turn, can increase vitamin D levels due to reduced volume dilution [23]. Furthermore, stimulation of body fat oxidation and increased loss of fecal energy are mechanisms by which vitamin D alters energy balance and weight loss [24]. Patients who presented improved pathologies that interfere with vitamin D metabolism may increase its concentration, as in the case of non-alcoholic fatty liver disease (NAFLD). In addition, the reduction of inflammation caused by weight loss after RYGB is related to increase in vitamin D [16]. Studies indicate that the serum levels of 25(OH)D is inversely proportional to interleukin 6 (IL-6), a pro-inflammatory cytokine [25, 26].

In this study, patients used a multivitamin supplement in the dosage of 200 to 400 IU of vitamin D after RYGB. These values are well below the recommendation, which suggests 800 IU vitamin D supplementation to prevent serum 25(OH)D deficiency in the postoperative period of bariatric surgery [2, 27]. However, some studies show that this dosage is also not adequate to attain the recommended 25(OH)D serum level [28, 29], and a dosage above 800 IU would be effective for the prevention and treatment of 25(OH)D deficiency [30]. Considering this information, we assume that the geographical location of our study has a strong influence on the nutritional status of vitamin D, as our patients used supplementation of 25(OH)D with a dosage well below the recommended level and even so, they had a low prevalence of vitamin D deficiency.

Some limitations of the study include the impossibility to adjust for the period of sun exposure of each individual during the study period, an important factor for the cutaneous synthesis of 25-hydroxyvitamin D. In addition, before surgery, none of the patients were on vitamin D supplement; however, after surgery, all patients commenced supplementation as a mandatory protocol after RYGB. Despite the limitations, we believe that our findings are relevant due to the continuous increase of obesity in Brazil and worldwide, which impacts cardiometabolic changes and nutritional deficiencies.

Conclusion

The prevalence of vitamin D deficiency at baseline and after 3 and 12 months of RYGB was low, being affected by the low latitude and high annual solar radiation of the northern region of Brazil. Variations in serum vitamin D levels after 1 year of surgery were positively associated with weight loss and body fat. Nutritional assessment of vitamin D in individuals with obesity must consider the geographic location because regions close to the equator have higher solar radiation and possibly lower prevalence of vitamin D deficiency.

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Authors' Contributions Sônia L Pinto contributed in the design of the study, data collection, analysis and interpretation, manuscript writing, and final version approval.

Leidjaira L Juvanhol and Josefina Bressan contributed in the design of the study, analysis and interpretation of the data, critical revision of the manuscript, and approval of the final version.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical Approval Statement 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.

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