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Evaluation of nutrient status after laparoscopic sleeve gastrectomy 1, 3, and 5 years after surgery

Taha Saif, M.D.[a], **Gladys W. Strain, Ph.D.**[a,*], **Gregory Dakin, M.D.**[a], **Michel Gagner, M.D.**[b], **Ricardo Costa, B.S.**[a], and **Alfons Pomp, M.D.**[a]

[a]Department of Surgery, Weill Cornell College of Medicine, New York, New York

[b]Department of Surgery, Florida International University, Miami, Florida

Abstract

Background—Laparoscopic sleeve gastrectomy evolved as a primary bariatric procedure with little information on its nutritional effects. Our objective was to assess the longer term micronutrient and vitamin status after laparoscopic sleeve gastrectomy at a university hospital.

Methods—Measurements of ferritin, iron, total iron binding capacity, hemoglobin, hematocrit, parathyroid hormone, albumin, calcium, magnesium, phosphorus, zinc, folate, and vitamins A, B_1, B_{12}, and D were obtained at baseline and 1, 3, and 5 years after surgery. Two-sample *t* tests with multiple adjusted comparisons and Fisher's exact test were used to determine deficiency.

Results—A total of 82 patients (67% women), with a mean age of 46.4 years and a baseline body mass index 55.7 kg/m^2 were included in the present study (35 at 1, 27 at 3, and 30 at 5 years postoperatively). The percentage of excess body mass index loss was 58.5% at year 1 in 35 patients, 63.1% at year 3 in 27 patients, and 46.1% at year 5 in 30 patients. The parathyroid hormone level decreased from 75.0 to 49.6 ng/mL in year 1 to 40.7 ng/mL in year 3. The year 5 levels increased to 99.6 ng/mL. The mean vitamin D level increased from 23.6 ng/mL to 35.0, 32.1 and 34.8 at years 1, 3, and 5 (P= .05 for baseline to year 1). The vitamin D level was less than normal in 42% of the patients at year 5. After normalization from baseline, by year 5, parathyroid hormone had increased in 58.3% of patients. At year 5, vitamin B_1 was less than normal in 30.8% of patients, and hemoglobin and hematocrit were less than normal in for 28.6% and 25% of patients, respectively. Finally, 28.9% of patients reported taking supplements in year 1, 42.9% in year 3, and 63.3% in year 5. The other variables were not significantly different.

Conclusions—Laparoscopic sleeve gastrectomy resulted in health improvements through year 3. At year 5, the nutrient levels had reverted toward the baseline values. These observations provide focus for necessary clinical monitoring.

Keywords

Laparoscopic sleeve gastrectomy; Nutrient status after sleeve gastrectomy; Nutritional deficiency; Nutrition after bariatric surgery

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[*]Correspondence: Gladys W. Strain, Ph.D., Department of Surgery, Weill Cornell College of Medicine, Box 294, 525 East 68th Street, New York, NY 10065. Gls2010@med.cornell.edu.

Disclosures

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It has been clearly established that there is an association between the body mass index (BMI) and the prevalence of some low micronutrient levels among U.S. adults [1]. The National Health and Nutrition Examination Survey III provided nationally representative cross-sectional data for 16,191 participants, verifying this important finding. This has been substantiated by numerous studies of patients requesting weight loss surgery [2–6]. It is an important practice to obtain an assessment of micronutrient levels to assist with optimal surgical outcomes by nutrient status normalization before surgery. To date, most postoperative evaluations extend for 1–2 years, but little information extends beyond the 2-year observations.

The focus of our present research is laparoscopic sleeve gastrectomy (LSG), which has evolved as a primary standalone procedure. Originally, LSG was used as a part of a 2-stage procedure to assist with weight loss before a second definitive malabsorptive procedure for high-risk patients. During the past decade, after 3 international consensus summits and a careful meta-analysis of 2570 patients in 36 studies, LSG has been increasingly accepted as a primary procedure [7]. However, a paucity of data is available on longer term outcomes. In terms of nutrient deficiency, only 3 reports of studies completed within 1 year of LSG [4,8,9] were identified, and another report with 1-year data on iron deficiency anemia [10] was located. Guidelines have been published regarding nutrient supplementation after LSG; however, these have been developed from data obtained from other bariatric procedures and adjusted for LSG [11–13]. Most of the evaluations related to the nutritional effects of bariatric procedures suffer from documentation of vitamin and mineral supplements that were advised and any measure of compliance with those recommendations.

Admittedly, follow-up with bariatric patients is difficult and costly. With the major acceptance of LSG by the surgical and general communities, clinical tracking of these increasingly more diverse patients becomes a required necessity. The data collection resulting from intensive efforts to provide LSG follow-up provide the basis for the present report.

Methods

As a part of our investigation of the longer term outcomes after LSG, all patients who underwent LSG as a primary procedure from 2003 to 2009, who had not undergone operative revision, and who signed an institutional review board-approved consent form for measurements of height, weight, and body composition using bioimpedance [14], were included. The percentage of excess BMI loss (%EBMIL) was calculated by assigning a normalized BMI as 25 kg/m^2. The change in BMI divided by the preoperative BMI minus 25 was considered the %EBMIL. Those patients who had not scheduled a follow-up visit with their surgeon for the past 24 months were contacted by telephone to schedule a clinic visit. If insurance was available, a standard nutrient analysis was completed. Patients who had moved from the area served by the surgical center were asked by telephone for oral consent to telephone their primary care physician to obtain a recent professionally measured weight and obtain a blood sample for vitamin and micronutrient analyses, along with the form recording their current medications and dietary supplements.

Patients were excluded if they had undergone other weight loss-assisting procedures; if their procedure was not a first procedure performed by us; or if the LSG had been revised surgically.

Blood was drawn for the vitamin and micronutrient analyses, which are the subject of the present report. At the clinic visit, the patients were also requested to complete a form detailing their current medications and any vitamin, mineral, or other supplements they were taking regularly. Patients had been advised as a standard recommendation to take 1–2 adult multivitamins with minerals, including iron after surgery, and 1200 mg of calcium citrate daily. Additional vitamin D and iron were prescribed on an individual basis.

Patients were classified into 3 “follow-up” cohorts according to the interval that had elapsed from LSG. The 3 follow-up cohorts were defined as patients with approximately 1, 3, and 5 years of elapsed time from their LSG procedure. Cross-sectional comparisons were made between the cohorts for the purposes of the present study.

Statistical analysis

The primary objective of our study was to evaluate the long-term micronutrient and vitamin status after LSG. The correlation between supplement usage and nutrient levels postoperatively was also determined. The null hypothesis was that no nutrient differences or deficiencies would be found among the baseline and 1-, 3-, and 5-year measures. The micronutrients included hematocrit, hemoglobin, ferritin, iron, total iron binding capacity, total protein, albumin, parathyroid hormone (PTH), calcium, magnesium, phosphorus, zinc, and glycated hemoglobin (HbA1c). The vitamins included vitamins A, B_1, B_{12}, and D and folate. Each of these variables was also dichotomized as deficient or not according to its corresponding normal range. The descriptive statistics for continuous variables were summarized as the mean ± standard deviation, with percentages reported for deficiency rates for each measurement point. To evaluate the overall difference, 1-way analysis of variance was performed for each continuous variable, and pair wise comparisons adjusting the significance level using the Holm procedure were used. The chi-square test or Fisher’s exact test, as applicable, was performed to access the association between 2 categorical variables. All analyses used SAS, version 9.2 (SAS Institute, Cary, NC).

Results

A total of 82 patients were located who had preoperative baseline data and follow-up observations (35 at 1 year [median 14 mo, range 12–21], 27 at 3 years [median 36 mo, range 24–42], and 30 at 5 years [median 57 mo, range 48–84]; Table 1). The total number of yearly cohort observations exceeded the baseline observations, because some patients received more than 1 nutrient status evaluation after surgery and were therefore included in more than 1 timed cohort.

Of our 82 patients, 33% were men who chose LSG in contrast to other bariatric procedures, for which the percentage of men is usually 20–30% [15,16]. Also, 65.9% of our sample were superobese.

The baseline mean BMI was significantly different among the 3 cohorts: year 1, 60.5 ± 16 kg/m^2; year 3, 52.8 ± 12.4 kg/m^2; and year 5, 52.2 ± 10.2 kg/m (P = .04). The postoperative mean BMI tended to be slightly lower in the year 3 cohort than in other 2 cohorts (year 1, 41.2 ± 11.8 kg/m^2; year 3, 35.5 ± 7.6 kg/m^2; and year 5, 40.0 ± 8.1 kg/m^2; P = .12). Within each follow-up cohort, significant decreases occurred in the mean BMI from the preoperative levels (all cohorts, $P < .0001$). The 3 groups differed in the mean %EBMIL (P = .04), with a mean %EBMIL of 58.5% ± 21.8% at year 1, 65.7% ± 17.6% at year 3, and 48.0% ± 25.2% at year 5. In these cross-sectional data sets, the year 3 and 5 cohorts were significantly different from each other (P = .01), indicating the possibility of weight regain at the 5-year point.

An evaluation of the mean and standard deviations of the multiple metabolic, mineral, and vitamin measures as listed in Table 2. The 82 patients were generally within the accepted normal ranges for all variables, with the exception of the mean vitamin D level at baseline, which was low at 22.2 ng/mL, and the mean HbA1c (6.1%) and the mean PTH (75 ± 48 ng/mL), which were elevated outside of accepted ranges at baseline. These abnormalities were not present for those patients with 1- and 3-year observations but began to reappear in those patients observed 5 years after surgery. Albumin was not low at baseline but did increase at year 1 (P = .03).

To better understand the effects of sleeve gastrectomy on nutrient status, the percentage of abnormal values observed for the parameters measured are listed in Table 3. Before surgery about 20% of the patients had low hemoglobin and hematocrit measurements. These values had normalized in years 1 and 3 but had returned to preoperative levels at 5 years. In this limited data sample, ferritin, iron, and total iron binding capacity were not altered by surgery. No problems with calcium, magnesium, phosphorus, and zinc were identified, however magnesium increased significantly from baseline to year 1 (P = .0002) and year 5 (P = .0012). HbA1c was elevated in 30% of the sample at baseline. After surgery, the blood glucose levels normalized and HbA1c decreased to nondiabetic standards; however, by year 5, elevations had occurred. The differences between year 1 and year 5 were significant (P = .03) and between years 3 and 5 were significant (P = .01). No baseline values were available for vitamins A, B_{12}, and folate; however, the low incidence of abnormal values for the 3 timed cohorts is reassuring that the nutritional status of these vitamins is being maintained. Although the patient numbers were limited for vitamin B_1, we have an increase of low blood levels that merits close monitoring and possibly indicates the need for increased supplementation. Vitamin D improved by year 1, most probably related to the effects of both supplementation and surgery (P = .05) and the improvement in vitamin D status is maintained, yet by year 5, PTH increases were observed.

The effectiveness of supplement use has been difficult to quantify. The importance of supplement use was stressed to all patients, and the standard recommendations are included in the “Methods” section. All results were self-reported. With this approach, only 28.9% of the patients reported taking supplements at year 1, 42.9% at year 3, and 63.3% at year 5. When the nutrient blood values were related to supplement use, no correlation was found. The number of patients taking supplements and the blood values reported for a representative sample are listed in Table 4. It is apparent that supplementation as advised is inadequate to normalize blood levels for some and supplementation is not necessary for others.

Discussion

The evaluation of nutrient status is challenging after a surgical intervention. Adequate micronutrient, mineral, and vitamin levels are based on normative studies; however, with a nutrient such as vitamin D that is retained in the body fat and liver, the establishment of recommended levels remains an unsettled question. Synthesis with sun exposure adds to the complexity. A closer look at the 3 available studies related to nutrient levels after LSG highlight the difficulties involved. Toh et al. [4] shared their data on 46 sleeve patients, but observations reported at 1 year were available for only for 7 patients, 3 of whom had low vitamin D levels, with no elevations in PTH present in the 5 patients studied. Multivitamin and mineral supplements had been recommended. With the variables involved and the small sample sizes, it is not surprising that the PTH changes and vitamin D status had no correlation. Gehrer et al. [9] reported deficiencies in their sample of 50 patients who were advised calcium and vitamin D_3 supplements after surgery. The mean follow-up was 24 months. Low zinc was observed in 34% and increased PTH in 14%. Iron was low in 18%, as was vitamin B_{12}. They reported the normalization of all measures in 100% of the patients with treatment. They were also able to normalized the vitamin D levels (16 patients) and PTH (7 patients) in all patients using the protocol provided.

In our sample, we did not observe the multiple deficiencies reported by Gehrer et al. [9]. It could be questioned whether the environment and culture in the Swiss location contributed to the specific problems with zinc and folate. With our current therapeutic protocols, the patients from our surgical center have not yet been able to achieve 100% normalization for all values as reported by the Swiss.

Aarts et al. [8] expressed serious concerns about the development of nutrient deficiencies in their patients in The Netherlands just 1 year after LSG. The patients had been advised to take 150% of the recommended dietary allowances and additional calcium and vitamin D_3. At follow-up, iron was low for 43% of patients (23 of 54 patients). Vitamin D remained low for 39%, and PTH remained elevated for 39%. The high levels reported for vitamin A, B_1, and B_6 probably reflect intense compliance with the supplement recommendations.

The Dutch report with decreased iron levels in 43% of patients at 1 year contrasts with the report from Hakeam et al. [10] from Saudi Arabia, who reported the development of iron deficiency was insignificant 1 year after sleeve gastrectomy in their Arabic population. However, the study by Hakeam et al. [10] excluded any patient with preoperative anemia, microcytosis, macrocytosis, or iron deficiency. The supplement recommended for patients was an iron-free multivitamin with folate and vitamin B_{12}. Both folate and vitamin B_{12} deficiency occurred during the year of observation, although supplementation with these vitamins was included in the protocol.

Deserving additional comment are the observations relating supplement intake to the nutrient blood levels at our surgical center. No correlation was found. Increases in PTH and low vitamin D levels are consistent findings in the morbidly obese. When supplement usage was evaluated after surgery, normal PTH levels were recorded with and without supplementation of vitamin D and calcium. The same was true for the vitamin D assessments (Table 4). For the 36 patients for whom we have known supplement usage, 33% maintained low vitamin D levels despite supplementation. No problems with magnesium or iron were observed with or without supplementation for ≤5 years. The information on zinc highlights the importance of monitoring this mineral in LSG patients.

From these comments, it is apparent we are just beginning to understand the effects of LSG on nutrient status. What might be inferred from the surgery induced anatomic revision, B_{12} deficiency, is not being observed. Differing individual stores of B_{12}, folate, and iron will affect the observations. The interval since surgery could also be an important variable, allowing for the exhaustion of preoperative stores or the repletion of stores with the use of supplements. Before “evidence-based recommendations” can be established for LSG, additional longer term observations are required, with focused detail on the nutrients provided from food and supplementation.

The data we have reported present an evaluation at 3 points after surgery. It cannot be inferred that the changes reported in weight and nutrient status would follow the same pattern if it had been possible to make consistent longitudinal observations. However, the finding of weight regain between years 3 and 5 reported by Himpens et al. [17], whose patients had an excess weight loss of 72.8% at year 3 and 57.3% at year 6, parallels the observations of our patients. The sample sizes are limited, and because of the variability reported, larger data sets are required if, indeed, these findings can be regarded as contributing to generalized recommendations. It is imperative that patients receive sufficient periodical evaluations to prevent the development of deficiencies. Although nutrient deficiencies were not frequent after LSG, the responses to supplementation have been demonstrated to be highly individualized and require continued follow-up observations.

Conclusions

Patients who were classified as super obese achieved significant weight loss after LSG that was maintained for ≤5 years. Because the BMI was not significantly different for the 3 timed cohorts, it can be inferred that major weight loss occurred during the first year and was maintained. Vitamin D increased from baseline to normalized values that persisted for the 5-year period. In contrast, the PTH values normalized by year 1 but were noted to have increased by year 5, although vitamin D did not change. The hematocrit and hemoglobin levels were low in 25% of the patients at year 5, just as they had been at baseline; however, no iron or vitamin B_{12} deficiency was observed. At year 5, vitamin B_1 deficiency was also observed in 30% of the patients. HbA1c had normalized by year 1 but had returned to preoperative levels by year 5. Compliance with supplement recommendations at the first year was 29% but had increased to 63% by year 5. Such findings emphasize the importance of continual patient education and monitoring to ensure bariatric patients have a healthful intervention that can be maintained.

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Table 1

Baseline demographics, body mass index, and co-morbidities

Variable	Value
Total patients (n)	82
Gender (n)	
Female	55
Male	27
Age (yr)	46.4 ± 13.9
Pre-BMI (kg/m^2)	55.7 ± 13.7
Superobese (BMI >50 kg/m^2) (%)	54/82 (65.9)
Diabetes mellitus (%)	22/81 (27.2)
Dyslipidemia (%)	29/81 (35.8)

BMI = body mass index.

Data presented as mean ± standard deviation or numbers, with percentages in parentheses.

Table 2

Metabolic, mineral, and vitamin laboratory measures

Laboratory tests	Normal range	Baseline (n = 82)	At 1 yr (n = 36)	At 3 yr (n = 27)	At 5 yr (n = 30)
Hematocrit (%)					
Male	38.5–50	41.8 ± 3.6 (27)	42.5 ± 3.8 (12)	44.4 ± 3.0 (7)	39.8 ± 4.1 (6)
Female	35–45	38.3 ± 3.5 (55)	38.3 ± 3.2 (20)	38.0 ± 3.2 (14)	38.4 ± 3.0 (15)
Hemoglobin (g/dL)					
Male	13.2–17.1	14.1 ± 1.3 (27	14.4 ± .8 (12)	14.9 ± 1.0 (7)	13.3 ± 1.7 (6)
Female	11.7–15.5	12.8 ± 1.2 (55)	12.9 ± 1.1 (20)	12.7 ± 1.0 (14)	12.7 ± 1.1 (15)
Ferritin (ng/mL)					
Male	20–380	210.0 ± 122.9 (5)	170.6 ± 135.4 (12)	113.5 ± 106.8 (6)	207.4 ± 168.6 (5)
Female	10–232	41.0 ± 27.9 (7)	158.9 ± 157.0 (20)	135.7 ± 52.5 (12)	107.0 ± 73.0 (13)
Iron (μg/dL)					
Male	45–170	85.6 ± 19.8 (5)	102.4 ± 30.9 (11)	115.8 ± 38.5 (6)	84.3 ± 14.0 (3)
Female	40–160	89.2 ± 63.9 (10)	88.6 ± 28.6 (20)	76.4 ± 39.9 (12)	81.9 ± 37.4 (13)
TIBC (μg/dL)					
Male	250–425	346.8 ± 60.7 (5)	296.5 ± 28.2 (11)	319.2 ± 55.2 (6)	328.7 ± 49.0 (3)
Female	250–450	319.0 ± 63.7 (10)	314.6 ± 67.8 (20)	401.3 ± 83.6 (12)	350.9 ± 68.5 (13)
Total protein (g/dL)	6.2–8.3				
Male		6.9 ± .6 (25)	6.9 ± .6 (12)	7.0 ± .3 (7)	6.7 ± .6 (5)
Female		6.9 ± .6 (47)	6.7 ± .5 (20)	6.2 ± .3 (13)	6.9 ± .4 (13)
Albumin (g/dL)	3.6–5.1				
Male		3.8 ± .3 (24)	4.1 ± .4 (11)	4.2 ± .2 (7)	4.0 ± .4 (4)
Female		3.8 ± .4 (50)	3.9 ± .4 (21)	4.0 ± .3 (13)	4.0 ± .2 (14)
PTH (ng/mL)	10–65				
Male		80.5 ± 60.3 (13)	53.9 ± 40.6 (10)	40.0 ± 20.4 (5)	84.5 ± 41.9 (4)
Female		71.6 ± 40.5 (21)	46.9 ± 32.0 (16)	41.1 ± 12.2 (7)	107.2 ± 83.5 (8)
Calcium (mg/dL)	8.6–10.2				
Male		9.2 ± .5 (27)	9.4 ± .4 (12)	9.5 ± .3 (7)	9.4 ± .3 (5)
Female		9.2 ± .5 (54)	9.4 ± .4 (19)	9.3 ± .3 (11)	9.3 ± .2 (14)
Magnesium (mg/dL)	1.5–2.5				

Laboratory tests	Normal range	Baseline (n = 82)	At 1 yr (n = 36)	At 3 yr (n = 27)	At 5 yr (n = 30)
Male		1.6 ± .1 (26)	1.9 ± .2 (11)	1.9 ± .2 (7)	2.0 ± .3 (3)
Female		1.6 ± .2 (60)	1.9 ± .2 (20)	1.9 ± .2 (11)	2.0 ± .3 (12)
Phosphorus (mg/dL)	2.5–4.5				
Male		3.7 ± .6 (26)	3.6 ± .4 (11)	3.3 ± .5 (6)	3.4 ± .5 (3)
Female		3.4 ± .6 (59)	3.9 ± .5 (20)	3.9 ± .4 (10)	3.7 ± .76 (13)
Zinc (mg/dL)	60–130				
Male		NA	76.3 ± 15.9 (8)	84.2 ± 8.4 (5)	85.3 ± 31.4 (4)
Female		NA	84.7 ± 10.4 (20)	84.2 ± 10.8 (9)	76.0 ± 12.8 (10)
HbA1c (%)	<6.0				
Male		6.1 ± .8 (16)	5.5 ± .2 (9)	5.5 ± .1 (5)	6.1 ± .6 (7)
Female		6.1 ± 1.1 (40)	5.4 ± .6 (13)	5.7 ± .4 (3)	6.0 ± .5 (14)
Vitamin A (mg/dL)	30–80				
Male		NA	48.5 ± 21.1 (9)	60.6 ± 16.7 (6)	53.8 ± 15.7 (4)
Female		NA	52.3 ± 19.1 (15)	62.7 ± 27.4 (10)	59.6 ± 13.6 (10)
Vitamin B_1 (nmol/L)	87–180				
Male		158.8 ± 65.2 (4)	119.7 ± 39.8 (8)	134.2 ± 46.6 (5)	97.0 ± 53.0 (4)
Female		121.0 ± 53 (7)	140.4 ± 40 (13)	138.1 ± 40.5 (8)	124.1 ± 67.2 (9)
Vitamin B_{12} (pg/mL)	200–1100				
Male		NA	473.8 ± 228 (12)	541.3 ± 152.6 (6)	585.0 ± 612.5 (4)
Female		NA	568.1 ± 270.2 (19)	512.2 ± 377.5 (10)	679.8 ± 402.3 (13)
Folate (ng/mL)	>5.4				
Male		NA	13.5 ± 6.9 (12)	19.5 ± 4.3 (6)	15.6 ± 5.8 (4)
Female		NA	16.5 ± 7.3 (19)	15.5 ± 6.4 (10)	16.4 ± 6.7 (12)
Vitamin D (ng/mL)	30–100				
Male		22.2 ± 9.1 (10)	32.2 ± 14.2 (12)	33.6 ± 11.4 (6)	45.5 ± 29.7 (6)
Female		23.5 ± 10.6 (30)	36.5 ± 15.1 (20)	30.6 ± 11.3 (10)	29.8 ± 8.3 (13)

TIBC = total iron binding capacity; PTH = parathyroid hormone; NA = not available; HbA1c = glycated hemoglobin.

Data in parentheses are numbers of patients.

Table 3

Abnormal metabolic, mineral, and vitamin measures

Laboratory tests	Baseline	At 1 yr	At 3 yr	At 5 yr
Hematocrit	18.3% ↓ (15/82)	8.8% ↓ (3/34)	9.1% ↓ (2/22)	25.0% ↓ (5/20)
Hemoglobin	20.7% ↓ (17/82)	8.8% ↓ (3/34)	9.1% ↓ (2/22)	28.6% ↓ (6/21)
Ferritin	.0% (0/12)	8.6% ↓ (3/35)	15.8% ↓ (3/19)	5.6% ↓ (1/18)
Iron	6.6% ↓ (1/15)	3.0% ↓ (1/33)	10.5% ↓ (2/19)	.0% (0/16)
TIBC	6.7% ↑ (1/15)	.0% ↓ (0/33)	10.5% ↑ (2/19)	6.3% ↑ (1/16)
Total protein	9.6% ↓ (7/73)	5.9% ↓ (2/34)	.0% (0/22)	5.6% ↓ (1/18)
Albumin	26.5% ↓ (20/74)	12.9% ↓ (4/32)	5.2% ↓ (2/20)	5.5% ↓ (1/18)
PTH	51.5% ↑ (17/33)	22.2% ↑ (6/27)	7.7% ↑ (1/13)	58.3% ↑ (7/12)
Calcium	9.9% ↓ (8/81)	.0% (0/32)	.0% (0/20)	.0% (0/19)
Magnesium	17.9% ↓ (14/78)	.0% (0/33)	.0% (0/19)	.0% (0/15)
Phosphorus	5.1% ↓ (4/78)	.0% (0/33)	.0% ↑ (0/18)	6.3% ↓ (1/16)
Zinc	NA	10.7% ↓ (3/28)	.0% (0/14)	14.3% ↓ (2/14)
HbA1c	31.4% ↑ (16/51)	.0% ↑ (0/23)	10.5% ↑ (2/19)	47.6% ↑ (10/21)
Vitamin A	NA	7.7% ↓ (2/26)	.0% (0/18)	.0% (0/14)
Vitamin B_1	9.1% ↓ (1/11)	.0% (0/22)	14.3% ↓ (2/14)	30.8% ↓ (4/13)
Vitamin B_{12}	NA	2.9% ↓ (1/35)	.0% (0/19)	.0% (0/17)
Folate	NA	8.8% ↓ (3/34)	5.5% ↓ (1/18)	.0% (0/16)
Vitamin D	75.0% ↓ (27/36)	34.3% ↓ (12/35)	55.6% ↓ (10/18)	42.1% ↓ (8/19)

TIBC = total iron binding capacity; PTH = parathyroid hormone; NA = not available; HbA1c = glycated hemoglobin.

Arrows indicated increases or decreases.

Table 4

Supplement use and nutrient measures

Supplement	Supplement use		*P* value
	Yes	No	
PTH			.74
High	4	9	
Normal	13	19	
Vitamin D			.37
Low	12	4	
Normal	18	2	
Magnesium			NA
Low	0	0	
Normal	26	7	
Iron			NA
Low	0	0	
Normal	8	23	

PTH = parathyroid hormone; NA = not available.

No correlation found between supplement use and nutrient laboratory values.