

Prevalence and Associations of Preoperative Micronutrient Deficiencies in Bariatric Surgery Candidates with Severe Obesity

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Aim: To determine the prevalence of preoperative micronutrient deficiencies in bariatric surgery candidates with severe obesity and to examine associations with BMI, age, and sex.

Methods: This single-center retrospective observational study included 411 adults (BMI ≥ 35 kg/m²) evaluated for bariatric surgery (2016–2021). Routine chemistry and hematology tests were performed using automated analyzers, hormones and vitamins were measured using automated immunoassays, and trace elements were quantified using validated spectrometric laboratory methods. Deficiency thresholds were based on institutional reference limits and bariatric nutrition guidance.

Results: The most frequent deficiencies were severe vitamin D deficiency (25[OH]D < 10 ng/mL; 42.4%) and selenium deficiency (34.1%). Patients with BMI ≥ 50 kg/m² had higher potassium and PTH levels ($p < 0.05$). With increasing age, sodium, urine calcium, and folate levels increased, whereas albumin decreased ($p < 0.05$). Male patients had higher levels of several micronutrients (including vitamin B12, vitamin D, and zinc) compared with females ($p < 0.05$). Age and sex distributions did not differ significantly across BMI groups.

Conclusion: Preoperative micronutrient deficiencies are common in bariatric surgery candidates, particularly severe vitamin D and selenium deficiency. These findings support guideline-based preoperative screening and targeted correction of deficiencies to optimize perioperative nutritional status.

Keywords: obesity, morbid obesity, micronutrient, mineral, vitamin, deficiency, bariatric surgery

Introduction

Severe obesity is a major public health problem associated with increased cardiometabolic morbidity and reduced life expectancy, and metabolic–bariatric surgery is among the most effective and durable interventions for appropriately selected patients.¹ However, optimal perioperative care is based on the principle that nutritional risk may already be present prior to surgery and should be assessed and managed as part of standard preoperative preparation.^{2,3}

Although the typical perception is that obese and morbidly obese individuals consume excess calories, they may still be deficient in certain vitamins and minerals.^{4,5} Unbalanced eating habits characterized by high-calorie but low-nutrient foods, altered metabolism, and changes in micronutrient utilization may contribute to this condition.^{5,6}

In morbid obesity, micronutrient inadequacy may occur despite excess caloric intake due to poor diet quality and low nutrient density, chronic low-grade inflammation affecting micronutrient metabolism. In particular, the sequestration and volumetric dilution of fat-soluble vitamins such as vitamin D cause changes in distribution and bioavailability.^{4,5} These mechanisms may lead to preoperative deficiencies across multiple vitamins and trace elements even before any bariatric intervention.^{4,6}

Obesity is also linked to immune dysregulation and inflammatory signaling. Vitamin D3 has been discussed in relation to immune responses and autoantibody-associated conditions, supporting the concept that immunometabolic pathways may intersect with micronutrient status in obesity.^{7,8} Importantly, candidates for bariatric surgery frequently

exhibit micronutrient abnormalities preoperatively, and these deficiencies may persist or worsen postoperatively if not identified and corrected through structured nutritional protocols.^{2,3,9}

Despite growing evidence, comprehensive evaluations of a broad micronutrient panel stratified across clinically relevant factors such as BMI and age remain limited in many settings.^{6,9} The present study aimed to determine the prevalence of preoperative micronutrient deficiencies in adults evaluated for bariatric surgery and to examine associations with BMI and age to inform preoperative nutritional assessment priorities.

Materials and Methods

Study Design and Ethical Considerations

This retrospective study was approved by the ethics committee of the University of Health Sciences Derince Education and Research Hospital (Date: 25/03/2021; Number: 2021:59). The requirement for individual patient consent was waived due to the retrospective design. All necessary permissions were obtained from the hospital management to use patient data. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Analyses were planned a priori as stratified comparisons by BMI category, age group, and sex.

Patient Selection

A total of 411 adult patients (≥ 18 years old) with BMI ≥ 35 kg/m², who presented to our clinic requesting bariatric surgery between 01 January 2016–31 December 2021, were retrospectively identified from hospital records. Patients were excluded if they presented with any acute inflammatory condition, had known severe comorbidities such as active malignancy or advanced renal disease, or had missing or incomplete biochemical data.

Data Collection, Data Sources, Access, and Cleaning

Demographic variables including age, gender, height, and weight were obtained from patient records. Height was measured to the nearest 0.1 cm using a standard stadiometer (SECA 220), while weight was measured with patients wearing light clothing and no shoes, using a digital scale with a 300 kg capacity. Body mass index (BMI) was then calculated by dividing weight (in kilograms) by the square of height (in meters).

All variables were obtained from the hospital's electronic medical records by the working team, which had direct access rights under institutional approvals. The data were anonymized prior to analysis. Duplicates and illogical intervals were screened, and unit consistency was cross-checked over the years. Records that failed verification or had missing fields were excluded prior to analysis.

Biochemical Assessments

Venous blood samples were obtained in the morning (09:00–12:00) after an overnight fast. All biochemical analyses were performed in the hospital central laboratory as part of routine clinical care using standardized, quality-controlled, validated automated methods.

Routine Biochemistry and Hematology Assays

Routine chemistry analytes (electrolytes, albumin, calcium, magnesium, phosphorus, iron indices and urinary calcium) were measured using automated spectrophotometric/colorimetric assays, while hemoglobin was measured using an automated hematology analyzer.

Vitamins, Hormones, and Trace Elements

Hormones and vitamins (parathyroid hormone [PTH], thyroid-stimulating hormone, 25-hydroxyvitamin D, vitamin B12, and folate) were measured using automated immunoassays. Trace elements (zinc and selenium) were quantified using the central laboratory's validated spectrometric protocols. Units are reported as recorded in the laboratory information system and are presented in the tables; deficiency thresholds and cutoffs are summarized in [Supplementary Table S1](#).

Group Stratification

The patient cohort was stratified according to BMI, age, and gender to enable a systematic comparison of micronutrient levels across these variables. Specifically, four BMI categories were defined:

Group 1: $<40 \text{ kg/m}^2$, **Group 2:** $40\text{--}44.99 \text{ kg/m}^2$, **Group 3:** $45\text{--}49.99 \text{ kg/m}^2$, **Group 4:** $\geq 50 \text{ kg/m}^2$

Mineral and vitamin levels were compared among these BMI subgroups to capture how varying degrees of obesity might influence nutrient status. In addition, patients were subdivided by age into the following categories:

Group A: <30 years, **Group B:** $30\text{--}39$ years, **Group C:** $40\text{--}49$ years, **Group D:** ≥ 50 years

This age-based grouping was used to explore any potential age-related trends in nutritional parameters. Lastly, data were analyzed separately for female and male patients to examine any sex-specific differences in micronutrient levels.

Statistical Analysis

All data were analyzed using SPSS (IBM SPSS Statistics, version 23, Chicago, IL). Continuous variables are presented as mean $\pm$ standard deviation (SD). Categorical variables are expressed as frequencies (percentage). Comparisons among multiple groups were performed using one-way ANOVA followed by a Tukey post-hoc test. Comparisons between two groups were made with an independent-samples *t*-test for continuous variables or a chi-square (or Fisher's exact) test for categorical variables. Statistical Significance was set at $p < 0.05$. Post-hoc pairwise comparisons following ANOVA were performed using Tukey's HSD test to control for multiple comparisons.

Correlation analysis was performed to evaluate relationships between key micronutrient biomarkers using Spearman's rank correlation coefficient (ρ). Correlation results were summarized visually as a heatmap ([Figure 1](#)). All correlation tests were two-tailed, and statistical significance was set at $p < 0.05$.

Results

Patient Characteristics

A total of 411 patients (344 females [83.7%], 67 males [16.3%]) with a mean age of 39.03 ± 10.6 years were evaluated. There was no statistically significant difference in age or gender distribution among the BMI subgroups ($p > 0.05$). Patient demographics are summarized in [Table 1](#). All deficiency thresholds used for prevalence calculations are summarized in the Methods section and [Supplementary Table S1](#).

Potassium level was significantly higher in patients with BMI $\geq 50 \text{ kg/m}^2$ ($4.62 \pm 0.37 \text{ mEq/L}$) than in lower BMI groups ($p = 0.024$). Similarly, PTH level was significantly higher in the $\geq 50 \text{ kg/m}^2$ group ($104.45 \pm 48.59 \text{ pg/mL}$, $p = 0.010$). No significant differences were observed for other parameters such as calcium, magnesium, ferritin, or vitamin B12 across BMI categories. Detailed comparisons are provided in [Table 2](#).

The prevalence of deficiency levels determined according to the threshold points of the parameters was examined in the four different BMI groups. Accordingly, urinary calcium deficiency was statistically significantly higher in $40\text{--}44.99$ (47.4%) and $45\text{--}49.99$ (31.6%) BMI subgroups. The prevalence of PTH deficiency was significantly higher in $40\text{--}44.99$ (45.0%) and $45\text{--}49.99$ (25.4%) BMI subgroups. There was no significant difference between the groups in terms of the prevalence of deficiency. The prevalences of deficiencies between BMI subgroups are given in [Table 3](#).

Biochemical parameters were further compared between age groups. It was determined that sodium, urinary calcium and folic acid levels of the patients increased significantly as the age increased. Whereas albumin level decreased significantly with increasing age. Comparison of the parameters between age groups is shown in [Table 4](#).

The prevalence of deficiency levels determined according to the threshold points of the parameters was examined in the four different age subgroups. Accordingly, the prevalence of folic acid deficiency was significantly higher in $30\text{--}39$ and $40\text{--}49$ years age groups. The prevalence of potassium deficiency was higher in older age groups. The prevalences of deficiencies between age subgroups are given in [Table 4](#).

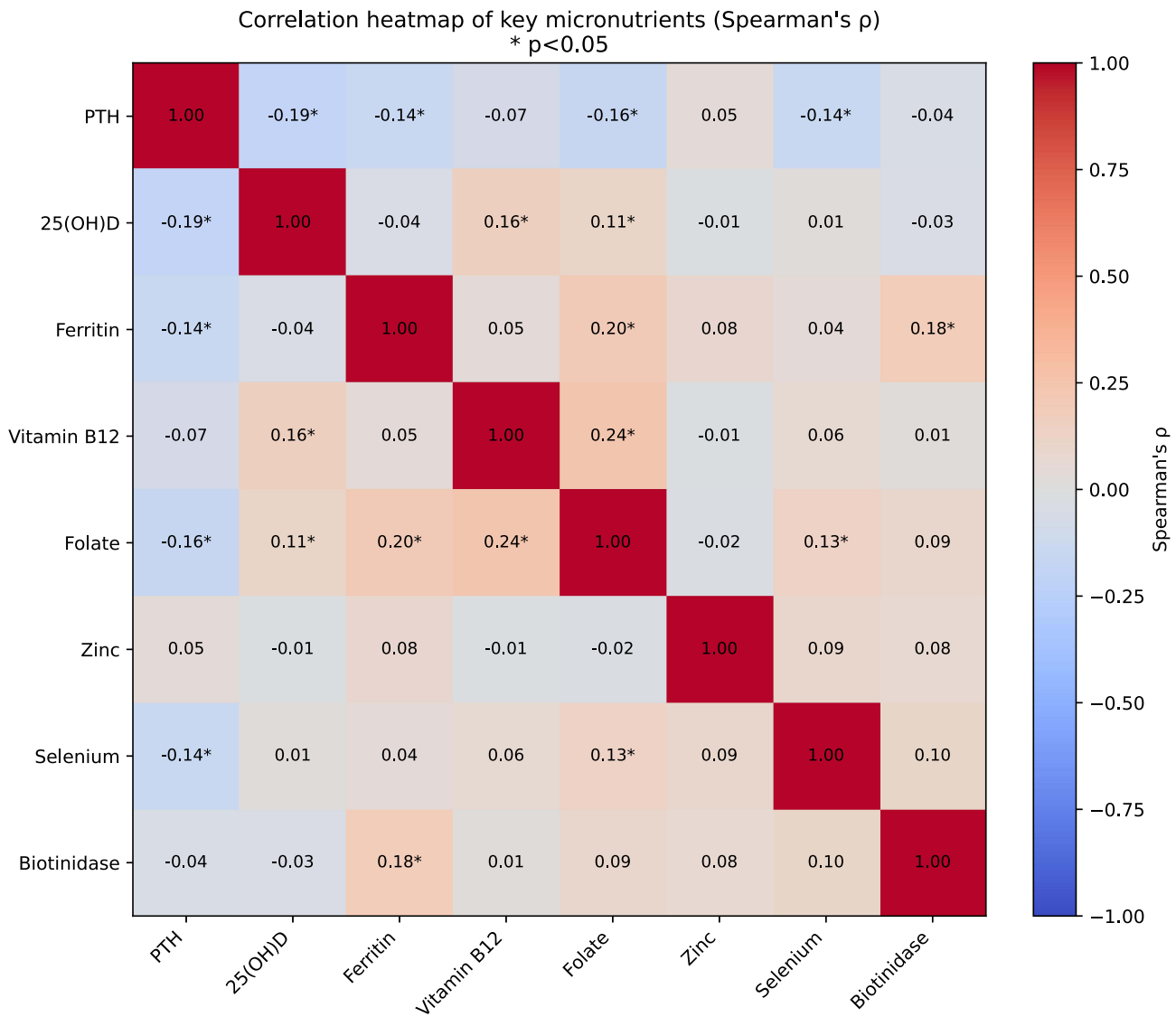


Figure 1 Heatmap of Spearman correlations among key micronutrients (PTH, 25-hydroxyvitamin D, ferritin, vitamin B12, folate, zinc, selenium, and biotinidase).

Male patients had significantly higher hemoglobin, iron, 24-hour urinary calcium, vitamin B12, vitamin D, zinc, and selenium levels (all $p < 0.05$) compared to female patients. Conversely, PTH levels were higher in females ($p = 0.021$) (Table 5).

Table 1 Demographic Features of the Patients

	BMI (kg/m ²)					P
	<40 (n=36)	40–44.99(n=190)	45–49.99 (n=106)	≥50 (n=79)	Total (411)	
Female	29 (80.6)	161 (84.7)	85 (80.2)	69 (87.3)	344 (83.7)	0.545
Male	7 (19.4)	29 (15.3)	21 (19.8)	10 (12.7)		
Age (year)	39.09±10.60	37.56±9.71	40.14±10.27	40.47±11.06	38.91±10.25	0.084
Height (cm)	166.00±8.35	163.40±7.79	164.00±7.97	161.20±8.05	163.30±8.01	0.017
Weight (kg)	104.30±12.81	113.50±12.25	126.80±13.87	143.60±18.33	121.90±18.80	0.001
BMI (kg/m ²)	37.78±2.62	42.42±1.52	47.03±1.37	55.13±4.52	45.64±5.84	0.001

Notes: Cell values indicate Spearman's ρ ; * indicates $p < 0.05$. Data are the mean $\pm$ SD, or count (percentage). P values derive from χ^2 test or ANOVA as appropriate. Demographic characteristics of morbidly obese patients stratified by BMI subgroups. Patient characteristics including age, gender, height, weight, and BMI are presented across four BMI categories: <40, 40–44.99, 45–49.99, and ≥ 50 kg/m². Data are expressed as mean $\pm$ standard deviation or count (percentage). P values are derived from one-way ANOVA or chi-square tests.

Table 2 Comparison of Biochemical Parameters Between BMI Subgroups

	BMI (kg/m ²)					p
	<40	40–44, 99	45–49, 99	≥50	Total	
Hemoglobin, g/dL	13.44±1.21	13.27±2.46	13.27±1.67	13.04±1.41	13.24±2	0.769
Albumin, g/dL	4.32±0.29	4.29±0.24	4.24±0.24	4.22±0.21	4.27±0.24	0.070
Sodium, mEq/L	139.17±2.51	139.14±1.8	139.45±1.89	139.41±1.8	139.27±1.89	0.520
Potassium, mEq/L	^a 4.44±0.41	^a 4.54±0.31	^{ab} 4.50±0.31	^b 4.62±0.37	4.54±0.34	0.024
Chloride, mEq/L	103.86±1.81	103.89±2.38	103.94±2.43	103.46±2.72	103.82±2.42	0.523
Calcium, mg/dl	9.28±0.5	9.31±0.41	9.28±0.41	9.3±0.35	9.3±0.41	0.939
Corrected calcium, mg/dL	9.03±0.44	9.09±0.67	9.03±0.68	9.17±0.53	9.08±0.63	0.485
Magnesium, mg/dL	1.88±0.16	1.93±0.21	1.93±0.22	1.92±0.2	1.92±0.21	0.666
Phosphorus, mg/dL	3.53±1.12	3.33±0.54	3.42±0.55	3.46±0.56	3.4±0.62	0.196
24- Hour urine calcium, mg per 24 h, mg/day	192.86±127.65	161.93±96.61	168.69±118.41	146.97±75.82	163.41±102.02	0.346
Iron, µg/dL	74.47±38.41	64.97±27.58	63.23±26.21	61.59±26.13	64.72±28.18	0.134
Ferritin, ng/mL	44.83±50.15	43.69±50.13	42.34±42.87	36.69±40.75	42.09±46.55	0.704
Vitamin B12, pg/mL	403.61±320.3	358.8±183.9	357.83±213.61	328.3±157.38	356.59±202.73	0.321
Folic acid, ng/mL	8.14±3.49	7.85±3.48	8.17±3.67	8.49±3.66	8.08±3.56	0.594
25-hydroxyvitamin D, ng/mL	15.82±12.17	13.83±9.59	15.02±11.05	15.95±13.37	14.71±11	0.456
Thyroid-stimulating hormone (TSH), micU/mL	3±2.98	4.9±17.94	2.89±2.09	4.48±8.3	4.13±12.77	0.578
Parathormone, pg/mL	^a 77.86±34.58	^{ab} 89.98±38.76	^b 94.07±42.53	^b 104.45±48.59	92.82±41.94	0.010
Zinc, µg/mL	0.89±0.11	0.87±0.11	0.88±0.13	0.91±0.14	0.88±0.12	0.268
Selenium, µg/mL	68.54±13.38	67.80±12.19	66.47±14.22	65.98±14.39	67.22±13.18	0.341

Notes: Bold values indicate statistically significant results. Data are expressed as mean±SD. The p value was obtained from the ANOVA test. Within each row, different superscript letters indicate significant differences ($p < 0.05$) according to the Tukey's test p values subject to finer adjustment. a and ab values indicate the groups with similar statistical significance, while b index show statistical significance compared to the other groups. Comparison of biochemical parameters among BMI subgroups in morbidly obese patients. Serum and urinary micronutrient and hormone levels are compared across four BMI groups. Statistically significant differences are highlighted in bold. Superscript letters denote intergroup significance based on Tukey's post-hoc test ($p < 0.05$).

Abbreviations: SD: standard deviation.

Table 3 Comparison of Deficiency Prevalence in BMI Groups

	BMI					p
	<40	40–44.99	45–49.99	≥50	Total	
Hemoglobin (< 12 g/dL)	4 (4.7%)	39 (45.9%)	27 (31.8%)	15 (17.6%)	85 (21.1%)	0.326
Albumin (<3.5 g/dL)	0 (0%)	1 (100%)	0 (0%)	0 (0%)	1 (0.2%)	0.759
Sodium (<136 mEq/L)	2 (22.2%)	5 (55.6%)	1 (11.1%)	1 (11.1%)	9 (2.2%)	0.371
Potassium (<3.1 mEq/L)	2 (10.5%)	9 (47.4%)	2 (10.5%)	6 (31.6%)	19 (4.7%)	0.334
Chloride (<98 mEq/L)	0 (0%)	6 (42.9%)	4 (28.6%)	4 (28.6%)	14 (3.4%)	0.574
Calcium (<8.2 mg/dl)	1 (50%)	1 (50%)	0 (0%)	0 (0%)	2 (0.5%)	0.188
Corrected calcium (<8.5 mg/dL)	1 (12.5%)	5 (62.5%)	1 (12.5%)	1 (12.5%)	8 (1.9%)	0.718
Magnesium (<1.6 mg/dL)	1 (6.7%)	10 (66.7%)	3 (20%)	1 (6.7%)	15 (3.7%)	0.388
Phosphorus (<2.5 mg/dL)	1 (4.5%)	10 (45.5%)	5 (22.7%)	6 (27.3%)	22 (5.4%)	0.726
Iron <28 µg/dL)	2 (8%)	14 (56%)	6 (24%)	3 (12%)	25 (6.2%)	0.720
Ferritin (<18.5 ng/mL)	3 (8.6%)	17 (48.6%)	9 (25.7%)	6 (17.1%)	35 (8.6%)	0.936
Vitamin B12 (<214 pg/mL)	4 (16.7%)	11 (45.8%)	3 (12.5%)	6 (25%)	24 (5.9%)	0.282
Folic acid (<3.37 ng/mL)	0 (0%)	4 (40%)	4 (40%)	2 (20%)	10 (2.5%)	0.505
25-hydroxyvitamin D (<10 ng/mL)	15 (8.8%)	83 (48.5%)	39 (22.8%)	34 (19.9%)	171 (42.4%)	0.520
Zinc (<0.7 µg/mL)	0 (0%)	7 (63.6%)	1 (9.1%)	3 (27.3%)	11 (2.7%)	0.349
Selenium (<63 µg/mL)	10 (8.3%)	51 (42.5%)	37 (30.8%)	22 (18.3%)	120 (34.1%)	0.257

Notes: Data presented as count (percentages), P value was obtained from chi-square test. Prevalence of micronutrient deficiencies according to BMI subgroups. The proportion of patients with values below institutional or ASMBS reference thresholds is shown for each BMI group. Data are presented as count (percentage). P values are calculated using the chi-square test.

Table 4 Comparison of Deficiency Prevalence in Age Groups

	Age				P
	<30	30–39	40–49	≥50	
Hemoglobin (< 12 g/dL)	17 (20%)	21 (24.7%)	31 (36.5%)	16 (18.8%)	0.715
Albumin (<3.5 g/dL)	0 (0%)	1 (100%)	0 (0%)	0 (0%)	0.458
Sodium (<136 mEq/L)	3 (33.3%)	3 (33.3%)	1 (11.1%)	2 (22.2%)	0.545
Potassium (<3.1 mEq/L)	0 (0%)	2 (10.5%)	7 (36.8%)	10 (52.6%)	0.001
Chloride (<98 mEq/L)	1 (7.1%)	2 (14.3%)	6 (42.9%)	5 (35.7%)	0.126
Calcium (<8.2 mg/dl)	0 (0%)	1 (50%)	1 (50%)	0 (0%)	0.726
Corrected calcium (<8.5 mg/dL)	2 (25%)	2 (25%)	3 (37.5%)	1 (12.5%)	0.975
Magnesium (<1.6 mg/dL)	1 (6.7%)	4 (26.7%)	6 (40%)	4 (26.7%)	0.437
Phosphorus (<2.5 mg/dL)	9 (40.9%)	6 (27.3%)	6 (27.3%)	1 (4.5%)	0.107
Iron <28 µg/dL)	6 (24%)	6 (24%)	11 (44%)	2 (8%)	0.481
Ferritin (<18.5 ng/mL)	6 (17.1%)	6 (17.1%)	17 (48.6%)	6 (17.1%)	0.415
Vitamin B12 (< 214 pg/mL)	5 (20.8%)	6 (25%)	7 (29.2%)	6 (25%)	0.759
Folic acid (<3.37 ng/mL)	2 (20%)	4 (40%)	4 (40%)	0 (0%)	0.010
25-hydroxyvitamin D (<10 ng/mL)	46 (26.9%)	41 (24%)	59 (34.5%)	25 (14.6%)	0.081
Zinc (<0.7 ug/mL)	2 (18.2%)	3 (27.3%)	5 (45.5%)	1 (9.1%)	0.794
Selenium (<63 ug/mL)	25 (20.8%)	33 (27.5%)	41 (34.2%)	21 (17.5%)	0.925

Notes: Data presented as count (percentages), P value was obtained from chi-square test. Bold values indicate statistically significant results. Prevalence of micronutrient deficiencies stratified by age group. Age-based differences in deficiency prevalence for various nutrients are presented. Data are reported as count (percentage). P values are derived from the chi-square test. Significant values are indicated in bold.

Table 5 Comparison of Parameters in Gender Groups

	Female	Male	P
Hemoglobin, g/dL	12.91±1.95	14.95±1.29	0.001
Albumin, g/dL	4.26±0.23	4.31±0.3	0.143
Sodium, mEq/L	139.23±1.81	139.52±2.27	0.242
Potassium, mEq/L	4.53±0.33	4.59±0.35	0.157
Chloride, mEq/L	103.93±2.25	103.24±3.09	0.031
Calcium, mg/dl	9.29±0.4	9.37±0.41	0.110
Corrected calcium, mg/dL	9.07±0.63	9.17±0.59	0.206
Magnesium, mg/dL	1.92±0.2	1.97±0.24	0.055
Phosphorus, mg/dL	3.41±0.63	3.34±0.56	0.412
24-Hour urine calcium, mg per 24 h, mg/dL	154.26±96.18	207.6±117.94	0.001
Iron, µg/dL	60.99±26.29	83.86±29.95	0.001
Ferritin, ng/mL	32±31.54	93.44±70.93	0.001
Vitamin B12, pg/mL	352.61±208.07	376.75±173.18	0.374
Folic acid, ng/mL	7.95±3.52	8.69±3.72	0.120
25-hydroxyvitamin D, ng/mL	14.15±10.24	17.59±14	0.020
Thyroid-stimulating hormone (TSH), micU/mL	3.93±10.31	5.15±21.4	0.477
Parathormone, pg/mL	94.98±42.57	82.03±37.07	0.021
Zinc, ug/mL	0.88±0.12	0.92±0.13	0.006
Selenium, ug/mL	66.46±13.22	70.73±12.53	0.020

Notes: Bold values indicate statistically significant results. Data are the mean ± SD. The p value was obtained from the Student t test. Comparison of biochemical parameters between male and female patients. Sex-specific differences in micronutrient, hormone, and biochemical levels are reported. Data are shown as mean ± standard deviation. Statistically significant p-values (from independent t-tests) are presented in bold.

Table 6 Comparison of Deficiency Prevalence in Gender Groups

	Female	Male	p
Hemoglobin (<12 g/dL)	63 (74.1%)	22 (25.9%)	0.006
Albumin (<3.5 g/dL)	0 (0%)	1 (100%)	0.023
Sodium (<136 mEq/L)	6 (66.7%)	3 (33.3%)	0.166
Potassium (<3.1 mEq/L)	15 (78.9%)	4 (21.1%)	0.577
Chloride (<98 mEq/L)	7 (50%)	8 (55%)	0.001
Calcium (<8.2 mg/dl)	2 (100%)	0 (0%)	0.530
Corrected calcium (<8.5 mg/dL)	7 (87.5%)	1 (12.5%)	0.769
Magnesium (<1.6 mg/dL)	12 (80%)	3 (20%)	0.710
Phosphorus (<2.5 mg/dL)	18 (81.8%)	4 (18.2%)	0.797
Iron (<28 µg/dL)	25 (100%)	0 (0%)	0.023
Ferritin (<18.5 ng/mL)	34 (97.1%)	1 (2.9%)	0.001
Vitamin B12 (< 214 pg/mL)	20 (83.3%)	4 (16.7%)	0.982
Folic acid (<3.37 ng/mL)	9 (90%)	1 (10%)	0.820
25-hydroxyvitamin D (<10 ng/mL)	147 (86%)	24 (14%)	0.141
Zinc (<0.7 µg/mL)	11 (100%)	0 (0%)	0.133
Selenium (<63 µg/mL)	104 (86.7%)	16 (13.3%)	0.129

Notes: Data presented as count (percentages). p values were obtained from the chi-square test. Bold values indicate statistically significant results. Prevalence of micronutrient deficiencies in male versus female patients. Frequencies of deficiencies by sex are summarized. P values are derived from chi-square or Fisher's exact test. Significant differences are highlighted in bold.

The prevalence of albumin and chlorine deficiency was significantly higher in male patients, while the prevalence of Hgb, PTH and ferritin was significantly higher in female patients (Table 6).

Overall, the most prevalent micronutrient deficiencies identified were 25-hydroxyvitamin D (42.4%) and selenium (34.1%). Hemoglobin deficiency, defined as levels below 12 g/dL, was observed in 21.1% of patients and was predominantly noted among female participants. The prevalence rates of other micronutrient deficiencies, including iron, ferritin, and vitamin B12, varied but generally remained below 10%, except for vitamin D and selenium.

Exploratory Correlation Analysis

Spearman correlation heatmap analysis (Figure 1) demonstrated biologically plausible relationships among selected biomarkers. Notably, 25(OH)D was inversely correlated with PTH ($\rho = -0.186$, $p < 0.001$). In addition, vitamin B12 showed a positive correlation with folate ($\rho = 0.237$, $p < 0.001$). These correlations are exploratory and should not be interpreted as causal.

Discussion

Although micronutrient deficiencies are recognized among morbidly obese patients, precise prevalence rates remain unclear due to limited comprehensive research. Increasingly, obesity is recognized as a significant risk factor for multiple micronutrient deficiencies, despite the paradoxical possibility of calorie overconsumption.⁶ However, many of these excessive calories are not from nutritious sources. The surveys conducted in the USA and Canada suggested that many individuals do not meet the recommended levels of micronutrients including minerals and vitamins through diet.^{10,11}

Our findings are broadly consistent with reports showing that vitamin D deficiency or insufficiency is highly prevalent among candidates for bariatric surgery across regions. For example, Berardi et al reported that the great majority of bariatric candidates had deficient or insufficient vitamin D levels preoperatively, and meta-analytic data similarly support a high burden of vitamin D inadequacy in severe obesity. Importantly, our estimate reflects a severe deficiency threshold (25[OH]D <10 ng/mL), and therefore would be expected to be lower than prevalence rates reported using more common cutoffs (eg, <20 ng/mL). In contrast, trace-element deficiencies, particularly selenium, show substantial heterogeneity

across cohorts, with some studies reporting low preoperative selenium deficiency rates, suggesting that geographic dietary patterns, laboratory thresholds, and patient selection may meaningfully influence observed prevalence.^{12–14}

In the present study, preoperative vitamin and mineral deficiencies were evaluated in morbidly obese patients, stratified systematically by BMI and age groups for the first time in the literature. Potassium has been demonstrated to have a protective effect on obesity and adequate intake of vegetables and fruits that are known as the major sources of potassium has been recommended.^{11,15} On the contrary, in our study potassium level was significantly higher in the patients with a BMI value ≥ 50 kg/m². This unexpected finding might reflect differences in dietary patterns, altered renal handling, or selection bias in our patient population, emphasizing the complexity of nutritional metabolism in severely obese individuals.

Although our study did not evaluate postoperative outcomes, preoperative micronutrient status is clinically relevant because bariatric procedures can exacerbate pre-existing deficiencies and may influence perioperative recovery. For example, in Roux-en-Y gastric bypass cohorts, lower preoperative 25-hydroxyvitamin D levels have been associated with higher risks of postoperative hospital-acquired and surgical site infections, suggesting that vitamin D status may represent a potentially modifiable perioperative risk marker.^{15,16} In addition, recent multicenter data indicate that preoperative anemia is independently associated with a substantially higher risk of postoperative anemia and iron deficiency after bariatric surgery, reinforcing the importance of identifying and correcting hematinic deficiencies before surgery.^{16,17} Collectively, these observations support interpreting our findings as a high-prevalence “risk background” in bariatric candidates rather than as direct evidence of postoperative causality.^{2,9}

Current bariatric nutrition guidelines recommend routine preoperative screening and correction of key micronutrient abnormalities, ideally within a multidisciplinary program involving a bariatric dietitian.¹ Guideline-based approaches include targeted repletion of documented deficiencies, followed by reassessment to confirm correction prior to surgery.¹⁷ Beyond micronutrient-specific repletion, structured preoperative nutritional programs have been evaluated for perioperative outcomes.³ Recent systematic synthesis suggests such preoperative dietary interventions may improve operative parameters and postoperative outcomes; importantly, these programs should be implemented with attention to maintaining adequate protein and micronutrient intake.^{18–20} Emerging data suggest that structured preoperative multivitamin supplementation during a short preparation period may reduce the prevalence of key deficiencies, particularly vitamin D, folate and iron, and could be routinely incorporated into standard preoperative protocols.²¹

Several research has highlighted an association between obesity and elevated serum parathyroid hormone (PTH) levels.^{19,22} Tran et al²³ demonstrated that obese individuals exhibited significantly higher serum PTH levels compared to their non-obese counterparts. In that study, serum PTH level was significantly higher in obese patients (150.6 ± 69.9) compared to non-obese patients (135.5 ± 69.2). Consistent with these findings, in our study preoperative PTH level increased as the BMI value increased in morbid obese patients. The highest serum PTH level (104.45 ± 48.59) was obtained in those with a BMI value ≥ 50 kg/m². The elevated PTH observed in obesity could be related to decreased bioavailability of vitamin D, altered calcium metabolism, or increased adiposity-associated inflammatory responses.^{13,24} Recent studies examining the correlations between BMI and immune-inflammatory markers in obese individuals with and without Type 2 diabetes indicate that increased adiposity is associated with increased inflammatory activity and altered immune responses. Although these findings are not specific to bariatric cohorts, they highlight the immunometabolic environment of obesity. This provides an additional context to our findings by suggesting that this environment may interact with endocrine axes such as micronutrient metabolism and the vitamin D-PTH relationship.²⁵ Consistent with this framework, our exploratory correlation heatmap (Figure 1) demonstrated an inverse relationship between 25(OH)D and PTH, supporting biological plausibility of the observed endocrine pattern. Future studies incorporating inflammatory markers alongside micronutrient panels may help clarify whether inflammation modifies the vitamin D–PTH axis and other deficiency patterns in severe obesity.

Several studies have shown an association between urinary calcium excretion and BMI, potentially mediated by hormonal and metabolic factors. In a study by Al-Hayek et al, urinary calcium level was significantly higher in obese patients compared to overweight and non-obese people.²⁶ In another study by Tran et al 24-hour urinary calcium excretion was significantly higher in obese patients compared to normal weight individuals.²³ In our study, 24-hour urinary calcium excretion was found to be statistically significantly higher in male morbidly obese patients. This could

potentially be attributed to hormonal differences, gender-specific dietary patterns, or differential prevalence of vitamin D deficiency, requiring further targeted investigation.²⁷

In our study, vitamin/mineral deficiencies were also investigated by age groups. Our results indicated that sodium, urinary calcium and folic acid levels of the patients increased significantly as the age increased, while albumin level decreased by age. Folic acid level increased with age and folic acid deficiency was more common in the patient group under 50 years of age. The observed age-related increase in folic acid levels, along with changes in sodium and albumin, may reflect physiological alterations in absorption, metabolism, or dietary habits associated with aging. Recent literature supports the necessity of age-tailored nutritional assessments for bariatric surgery candidates.^{14,20}

The association between gender and obesity has been well-established, with females at approximately twice the risk compared to males. In our study, male patients exhibited higher levels of preoperative hemoglobin, iron, urinary calcium, vitamin B12, vitamin D, and zinc compared to females. Gender-based physiological differences, hormonal variations, and distinct nutritional behaviors likely underpin these findings. Nevertheless, these gender-related findings warrant cautious interpretation, as several parameters did not exhibit significant differences across BMI and age subgroups.

Study Limitations

The main limitation of this study is its single-center, retrospective design, which can introduce selection bias and limits causal inference. The cohort represents patients evaluated for bariatric surgery and may not fully reflect the broader population with severe obesity. In this study, several potentially important variables were not consistently available, including detailed comorbidity profiles, medication use, dietary intake, and preoperative supplement use, all of which may influence micronutrient status. Finally, multiple biomarkers were compared across several subgroups; these analyses should be interpreted as exploratory, and some statistically significant findings may reflect chance.

Conclusion

In this cohort of candidates for bariatric surgery with severe obesity, micronutrient deficiencies were prevalent before surgery. Severe vitamin D and selenium deficiencies were the most common abnormalities, and clinically relevant subgroup patterns were observed based on BMI, age, and sex. These findings support the approach of routine, guideline-based preoperative screening and targeted correction of micronutrient deficiencies to rehabilitate preoperative nutritional status and prioritize high-risk patients for closer monitoring. Future prospective multicenter studies should evaluate whether standardized preoperative supplementation protocols lead to improved postoperative outcomes and should include important factors such as comorbidities, medication use, and dietary or supplement intake to clarify causal pathways.

Data Sharing Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Author Contributions

Murat Coskun: Conceptualization; Methodology; Investigation; Data curation; Formal analysis; Writing – original draft; Writing – review & editing; Project administration.

Adem Yuksel: Conceptualization; Methodology; Investigation; Data curation; Formal analysis; Writing – review & editing.

Alp Omer Canturk: Writing – original draft; Writing – review & editing; Validation.

Kerem Karaman: Methodology; Supervision; Validation; Writing – review & editing.

All authors took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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