

# UPDATE ON MICRONUTRIENTS IN BARIATRIC SURGERY: A COMPREHENSIVE SYSTEMATIC REVIEW

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## ABSTRACT

**Background:** Obesity is a major problem in the world and bariatric surgery is an effective solution for weight loss and resolving related health issues. There are three different types of bariatric surgeries. However, nutritional imbalances are a common issue after these procedures. Therefore, individuals who opt for bariatric surgery require continuous monitoring of their micronutrient levels and ongoing supplementation. This study aims to serve as a comprehensive systematic review of updates on micronutrients in bariatric surgery in the literature of the last 10 years.

**Methods:** This review adhered to the PRISMA 2020 guidelines and analyzed English literature published between 2014 and 2024, inclusive of full-text articles. Articles such as editorials, review papers from the same journal, and those without a DOI were not included in the review. The literature was obtained from various online platforms, including PubMed, SagePub, and Science Direct.

**Result:** Our team of researchers initially collected 3165 articles from credible sources that included PubMed, SagePub, and Science Direct. Following a rigorous three-level screening process, only six articles were found to be directly relevant to our ongoing systematic review and were then selected for further analysis through thorough full-text reading.

**Conclusion:** Bariatric surgery, especially RYGB, can cause micronutrient deficiencies. Vitamin deficiencies (A, D) are common and iron deficiency anemia is prevalent. Zinc, copper, and selenium deficiencies can also occur. Regular supplement intake is crucial to maintain optimal micronutrient levels.

**Keyword:** Obesity, bariatric surgery, micronutrient

## INTRODUCTION

Obesity, a chronic disease characterized by a body mass index (BMI) of 30 kg/m<sup>2</sup> or higher, is becoming more prevalent in the United States. Recent data from the Centers for Disease Control and Prevention indicates that 42.4% of adults aged 18 and over were classified as obese between 2017 and 2018.<sup>1</sup> While there are many approaches to managing weight loss in patients with obesity, such as lifestyle and behavioral changes and medications, bariatric surgery has the highest success rate for weight loss and resolution of associated comorbidities.<sup>2</sup> Over recent decades, the incidence of BS has increased globally, with an estimated 468,609 surgeries performed in 2013.<sup>3</sup> It's estimated that the number of bariatric surgeries performed annually is on the rise.<sup>2</sup>

Bariatric surgeries fall into three categories: restrictive, malabsorptive, or a combination of the two. The surgical procedures of laparoscopic adjustable gastric banding (LAGB) and laparoscopic sleeve gastrectomy (LSG) are undoubtedly restrictive. However, the Roux-en-Y gastric bypass (RYGB) not only restricts the intake of food but also has significant malabsorptive effects. Biliopancreatic diversion (BPD) and duodenal switch (DS) are the primary malabsorptive procedures.<sup>4</sup> Although bariatric surgery has been shown to effectively promote weight loss and decrease the occurrence of associated comorbidities, it can also lead to various complications. Nutritional imbalances are a frequent and persistent issue following bariatric procedures, stemming from malnourishment related to obesity, failure to adhere to recommended postoperative supplements, and the inherent malabsorption associated with such procedures.<sup>5</sup> Conventional multivitamin supplements are frequently insufficient in preventing nutritional deficiencies following procedures such as the RYGB.<sup>6</sup>

As a result, individuals who have undergone bariatric surgery require ongoing preventative supplementation and careful monitoring of their micronutrient levels.<sup>4</sup> Despite these efforts, deficiencies in micronutrients remain a common complication, with particular prevalence varying based on the type of surgery and any post-surgical complications that may arise.<sup>7</sup> The deficiencies most commonly reported after bariatric surgery include vitamins A and D, as well as calcium, while deficiencies in iron, zinc, and copper are more commonly observed in individuals who have undergone BPD as opposed to RYGB and SG.<sup>4</sup> This study aims to serve a comprehensive systematic review on update of micronutrients in bariatric surgery in literatures of the last 10 years.

## METHODS

### Protocol

The study's author meticulously adhered to the guidelines outlined in the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020. The purpose of doing so was to ensure that the study met all of its requirements. The selection of this methodology was specifically intended to guarantee the accuracy and dependability of the conclusions drawn from the investigation.

### Criteria for Eligibility

This review systematically examines the management of micronutrients in patients who have undergone bariatric surgery in the literature from the past decade. Through meticulous analysis of data, this study aims to provide insights and enhance patient treatment strategies. The primary objective of this paper is to emphasize the collective significance of key points identified in the literature.

To ensure the quality of the included literature, this study has strict inclusion and exclusion criteria. Inclusion criteria require that papers must be in English and published between 2014 and 2024. Exclusion criteria include editorials, submissions without a DOI, previously published review articles, and duplicate entries in journals.

### Search Strategy

The keywords used for this research are "micronutrients", "therapy", and "bariatric surgery". The Boolean MeSH keywords inputted on databases for this research are: *"micronutrients"[All Fields] AND ("therapeutics"[MeSH Terms] OR "therapeutics"[All Fields] OR "treatments"[All Fields] OR "therapy"[MeSH Subheading] OR "therapy"[All Fields] OR "treatment"[All Fields] OR "treatment s"[All Fields]) AND ("bariatric surgery"[MeSH Terms] OR ("bariatric"[All Fields] AND "surgery"[All Fields]) OR "bariatric surgery"[All Fields])*

### Data retrieval

In conducting this systematic review, the authors carefully evaluated each study by analyzing their abstracts and titles to determine their relevance. Only those studies that adhered to the inclusion criteria, which were aligned with the article's objectives, were selected for further consideration. A consistent trend observed across multiple studies ultimately led to a conclusive result. The chosen submissions needed to meet the eligibility criteria of being in English and full-text. The review was conducted with the utmost rigor, incorporating only literature that met all predefined inclusion criteria and directly pertained to the investigated topic. Studies that failed to meet these criteria were systematically excluded, and

their findings were not taken into consideration. A comprehensive analysis was carried out, examining various details uncovered during the research process, including titles, authors, publication dates, locations, study methodologies, and parameters.

### Quality Assessment and Data Synthesis

The research presented in the title and abstract of each publication was evaluated independently by the authors to identify the ones that warranted further exploration. The next step involved scrutinizing all the articles that met the pre-established criteria for inclusion in the review. The decision to include an article in the review was based on the findings that emerged during this evaluation process. This criterion served the purpose of simplifying the paper selection process for further assessment, enabling a comprehensive discussion of past investigations and the factors that rendered them appropriate for inclusion in the review.

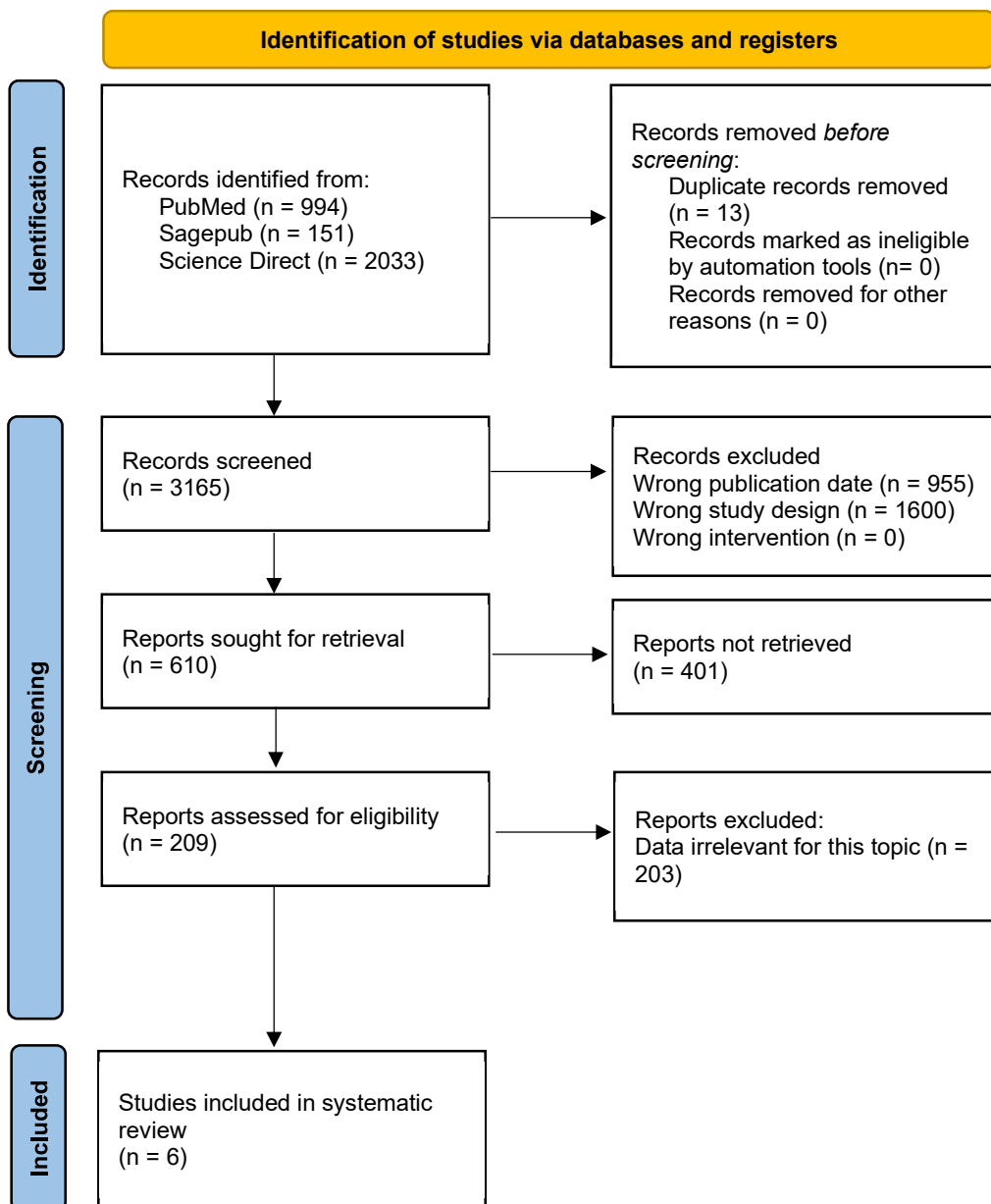


Figure 1. Article search flowchart

### RESULT

In the initial stages, our research team retrieved a total of 3165 articles from reputable sources such as PubMed, SagePub, and Science Direct. After a meticulous three-level screening process, only six articles were deemed directly relevant to

our ongoing systematic review and were selected for further analysis through thorough full-text reading. For ease of presentation, we have compiled the literature that has been included in this analysis into Table 1.

**Table 1. The literature included in this study**

Author	Origin	Method	Sample	Result
<b>Gao et al. 2023<sup>8</sup></b>	China	Meta Analysis	7688 patients	A summary prevalence of 42% (95% CI: 36–48%, 7688 individuals) was reported from a meta-analysis of 72 studies on Vitamin D Deficiency (VDD) after RYGB, with significant heterogeneity (I <sup>2</sup> =98.1%). The optimal daily dose of Vit D supplement for preventing VDD after RYGB is currently unknown. The 2019 revised clinical practice guidelines in the US recommend a routine daily dose of 3,000 IU. Carlin et al. have suggested that a weekly dose of 50,000 IU was more effective than a daily dose of 800 IU in reducing the rate of VDD one year after RYGB. According to the recommendations, the daily VitD supplementation should vary from 3000 IU to 6000 IU and should be increased to 50,000 IU once or thrice a week in cases with VDD.
<b>Stocker et al. 2022<sup>9</sup></b>	Switzerland	Systematic Review	5,645 patients	For vitamin A, 5000-10,000 U/d suppl. p.o. (BPD-DS: 10 000 IU/d). Vitamin B1, ≥12 mg/d suppl. p.o. (preferably 50-100 mg/d). Vitamin B12, 350-1000 µg/d suppl. p.o.(1000 µg/mo parenteral). Vitamin D, 3000 IU/d vit. D3-suppl. p.o. until blood level of 25(OH)D is >30 ng/mL. Daily calcium from all sources: 1200-1500 mg/d (BPD DS:1800-2400 mg/d). Vitamin E, 15 mg/d suppl. p.o. Vitamin K 90-120 mg/day suppl. p.o. (BPD-DS: 300 mg/day p.o.). Folic acid, 400-800 µg/d suppl. p.o. (800-1000 µg/d in women of child- bearing age). Iron, 40-60 mg/d elemental iron p.o. Zinc, 8-22 mg/d from multimineral preparation. Copper, 1-2 mg/d ffrom multimineral preparation.
<b>Mozaffar &amp; Idris, 2022<sup>10</sup></b>	Saudi Arabia	Literature Review	3,264 patients	Twelve studies have investigated zinc status following BS. A randomized controlled trial of zinc absorption and zinc status after RYGB found that zinc absorption decreased significantly, from 23.3 to 13.6%, during the first 6 months after surgery. Patients' zinc levels thus diminished, despite zinc supplementation at 15 mg/day. In Papamargaritis's study, the author

				found that zinc deficiency doubled from 7 to 15%—before and after surgery, respectively. The percentage of zinc deficiency peaked at 6 months after surgery (n = 24; 13.8%). Ruz, Carrasco and Papamargaritis found in cohort studies of zinc deficiency after SG, RYGB, and duodenal switch (DS) that zinc deficiency was common in 42.5% of patients, out of a sample of 324 patients at 12 months after surgery.
<b>Dagan et al. 2017<sup>11</sup></b>	Israel	Narrative review		It is recommended to take two adult multivitamin-mineral supplements per day, which contain iron, folic acid, zinc, copper, selenium, and thiamin at 200% of the recommended daily allowance. In addition, a daily calcium supplement of 600mg and 3000 IU of either ergocalciferol (vitamin D2) or cholecalciferol (vitamin D3) should be taken, with titration to achieve normal concentrations of 30 ng/mL. Multivitamins and supplements should provide 45-60 mg elemental iron daily, while vitamin B-12 supplements of 250-350 µg per day or 1000 µg per week sublingual, 1000 µg per month i.m., or 3000 µg per 6 months i.m. may be necessary to maintain B-12 concentrations. Thiamin at 400 µg per day should be included in the routine multivitamin supplement, and pregnant women or those planning to conceive should take 800-1000 µg of folic acid daily. A routine multivitamin containing 6000 IU of vitamin A is also recommended, with pregnant women or those planning to conceive preferring the β carotene form of vitamin A over retinol. To prevent copper deficiency, a daily multivitamin containing 15 mg/d and at least 1 mg Cu per 8-15 mg Zn is recommended.
<b>Ciobarca et al. 2020<sup>12</sup></b>	Romania	Narrative Review		Dietary sources and postoperative recommended supplementation of micronutrients in order to prevent deficiencies after Bariatric Surgery (BS). Vitamin B12, 350–500 mcg daily (sublingual/liquid) or 1000 mcg monthly (parenteral). Vitamin B1, 12 mg daily/50 mg dose from B complex supplement/multivitamin twice daily. Folic acid, 400–800 mcg daily. Vitamin D, 3000 IU daily until plasma concentration exceeds 30 ng/mol. Calcium, 1200–1500

				mg/day. Iron supplementation, 18 mg daily (multivitamin). Vitamin A, 5000–10,000 IU/day. Vitamin E, 15 mg/day. Vitamin K, 90–120 ug/day. Zinc, 8–11 mg/day. Copper, 1 mg/day.
<b>Chamberlain et al. 2020<sup>6</sup></b>	USA	Narrative Review		Recommendations for management of postoperative micronutrient deficiencies as discussed in this review are summarized below. For iron supplementation, patient given Ferrous sulfate 300mg 2-3 times/day taken with vitamin C. Vitamin B12 should be given 250-300 µg/day PO. Folic acid given at least 400 µg/day. Vitamin A, if symptoms present, 5000 IU/day after LAGB; up to 10,000 IU/day after RYGB, LSG, BPD. Vitamin E, 100-400 U/day. Vitamin D, 400-800 U/day of D2, titrated to maintain a 25(OH)D level of >30 ng/mL. Calcium citrate dose of 1200-1500 mg/day after LAGB and LSG. For vitamin B1, 100mg/d of thiamine for 7-14 days with IV solution, followed by at least 10 mg/d PO thiamine (50-100 mg/d preferred) until symptoms resolve. 300 mg Magnesium citrate daily, and 1 mg of copper for each 15 mg zinc. Oral zinc will be provided 8-15 mg elemental zinc (up to 200% RDA).

In a study by Gao et al. the prevalence and influencing factors of vitamin D deficiency (VDD) following Roux-en-Y gastric bypass (RYGB) were examined. After screening 1119 studies, 72 studies with a total of 7688 individuals were included in the final analysis. The study found that VDD prevalence after RYGB was estimated to be 42%. Further analysis showed that VDD prevalence was positively associated with follow-up time. Additionally, studies with inadequate vitamin D supplementation and those conducted in Asia had a higher prevalence of VDD compared to those in South America, Europe, and North America. It is worth noting that there were variations in the recommended vitamin D supplementation across the studies reviewed.<sup>8</sup>

Stocker et al. provided guidance on micronutrient intake for individuals who have undergone bariatric surgery. Their recommendations include supplementing with 5000-10,000 IU of vitamin A daily (10,000 IU for those who have undergone BPD-DS), at least 12 mg of vitamin B1 daily (preferably 50-100 mg), 350-1000 µg of vitamin B12 daily (or 1000 µg monthly via injection), and 3000 IU of vitamin D3 daily until blood levels of 25(OH)D reach above 30 ng/mL. Daily calcium intake should be between 1200-1500 mg from all sources (or 1800-2400 mg for those who have undergone BPD-DS), 15 mg of vitamin E daily, 90-120 mg of vitamin K daily (or 300 mg daily for those who have undergone BPD-DS), 400-800 µg of folic acid daily (800-1000 µg for women of childbearing age), 40-60 mg of elemental iron daily, 8-22 mg of zinc daily from a multimineral preparation, and 1-2 mg of copper daily from a multimineral preparation.<sup>9</sup>

In regards to bariatric surgery (BS), Mozaffar and Idris conducted research on the correlation between taste alteration and zinc deficiency. Their study analyzed the effects of zinc replacement on taste perception and speculated on the potential influence of zinc deficiency in initiating taste change following BS. Although their analysis did not substantiate a direct causal relationship, the similar timing of occurrences suggests an indirect link. The study found that supplementing with 45-50 mg of zinc sulfate, a higher dosage than the current recommendation, was successful in enhancing taste.<sup>10</sup>

According to Dagan et al.'s research, experts recommend specific nutritional care during the perioperative and long-term postoperative periods. This includes taking two doses of multivitamin-mineral supplements containing iron, folic acid, zinc, copper, selenium, and thiamin (equivalent to 200% of the recommended daily allowance), a 600-mg calcium supplement daily, and 3000 IU of vitamin D per day (either ergocalciferol or cholecalciferol). Titration should be done to



ensure normal vitamin D concentrations of 30 ng/mL. Additionally, multivitamins and supplements should provide 45-60 mg of elemental iron per day, and vitamin B-12 supplements (at a dose of 250-350 µg per day, 1000 µg per week sublingual, 1000 µg per month i.m., or 3000 µg every 6 months i.m.) should be considered as needed to maintain vitamin B-12 concentrations. A routine multivitamin supplement should also include the recommended daily intake of thiamin (400 µg/d), and pregnant women or those planning to conceive should take 800-1000 µg of folic acid daily. Furthermore, a routine multivitamin should contain 6000 IU of vitamin A, with pregnant women or those planning to conceive preferring the beta-carotene form of vitamin A over retinol. Finally, it's recommended that the routine daily multivitamin contain at least 15 mg/d of copper per 8-15 mg of zinc to prevent copper deficiency.<sup>11</sup>

Ciobarca et al. recommend dietary sources and postoperative supplementation of micronutrients to prevent deficiencies following Bariatric Surgery (BS). They suggest a daily intake of 350-500 mcg of Vitamin B12 (sublingual/liquid) or a monthly injection of 1000 mcg (parenteral). For Vitamin B1, they recommend a daily dose of 12 mg or a 50 mg dose from a B complex supplement/multivitamin taken twice a day. Folic acid intake should be 400-800 mcg daily, while Vitamin D should be taken in a daily dose of 3000 IU until the plasma concentration exceeds 30 ng/mol. Calcium intake should be 1200-1500 mg/day, and iron supplementation should be 18 mg daily (multivitamin). Vitamin A should be taken in a daily dose of 5000-10,000 IU, while Vitamin E should be taken in a daily dose of 15 mg. Vitamin K intake should be 90-120 µg/day, and Zinc intake should be 8-11 mg/day, with a daily intake of 1 mg of copper.<sup>12</sup>

Chamberlain et al. presented the following recommendations for managing postoperative micronutrient deficiencies. To supplement iron, patients were given Ferrous sulfate 300mg two to three times daily, along with vitamin C. Vitamin B12 should be taken orally at a dose of 250-300 µg/day. Folic acid should be taken at a minimum of 400 µg/day. For vitamin A, a dose of 5000 IU/day is recommended if symptoms are present after LAGB, while up to 10,000 IU/day is suggested after RYGB, LSG, and BPD. For vitamin E, a daily dose of 100-400 U is recommended. Vitamin D should be taken at a dose of 400-800 U/day of D2, adjusted to maintain a 25(OH)D level of >30 ng/mL. Calcium citrate should be taken at a dose of 1200-1500 mg/day after LAGB and LSG. To supplement vitamin B1, patients were given 100 mg/d of thiamine for 7-14 days via IV solution, followed by at least 10 mg/d of PO thiamine (50-100 mg/d preferred) until symptoms resolved. Patients should also take 300 mg of magnesium citrate daily, and 1 mg of copper for each 15 mg of zinc. Oral zinc supplements should be provided at 8-15 mg of elemental zinc (up to 200% RDA).<sup>6</sup>

## DISCUSSION

Obesity is a well-known risk factor for micronutrient deficiencies, despite the presence of excess calorie reserves.<sup>13</sup> Bariatric surgery is usually performed using one of three techniques: sleeve gastrectomy (SG), Roux-en-Y gastric bypass (RYGB), and laparoscopic adjustable gastric banding (LAGB). Current data suggest that RYGB is more likely to cause micronutrient deficiencies than SG and LAGB.<sup>14</sup> Malabsorptive procedures can cause deficiencies in fat-soluble vitamins due to postoperative steatorrhea and reduced surface area for absorption. In this context, routine screening for fat-soluble vitamin deficiencies is recommended after malabsorptive procedures, with a focus on vitamin A deficiency.<sup>4</sup> Vitamin A deficiency can lead to poor wound healing, skin changes (xerosis and acne), brittle hair, and eventually blindness (xerophthalmia).<sup>15</sup> Vitamin D deficiency is also common in patients with obesity before surgery and is often detected postoperatively.<sup>16</sup> After malabsorptive procedures such as RYGB, between 17% and 52% of patients develop a vitamin D deficiency within two years, and 50-63% develop a deficiency within four years.<sup>17</sup> To prevent vitamin D deficiency in postoperative bariatric surgery patients, supplementation of 400-800 U/day of vitamin D2 (ergocalciferol) or D3 (cholecalciferol) is recommended.<sup>6</sup> Screening for vitamin E deficiencies is not recommended for asymptomatic patients, and multivitamin supplementation is usually sufficient.<sup>17</sup> However, vitamin E supplementation of 100 to 400 U/day is recommended when patients are symptomatic.<sup>6</sup> Although rare, vitamin K deficiencies can occur postoperatively and lead to coagulopathies, easy bruising, or increased bleeding. A research study revealed that vitamin K levels were low in 50% to 60% of patients following the BPD procedure, but no clinical signs of deficiency were observed.<sup>17</sup> Oral calcium citrate supplementation is essential to prevent hypocalcemia. Calcium carbonate supplements should be taken with meals to enhance their absorption.<sup>6</sup>

Iron deficiency anemia is a prevalent issue among those who have undergone malabsorptive procedures, with up to 47% of patients experiencing it. It can even be present before bariatric surgery in up to 44% of adults. Our meta-analysis revealed a nearly twofold increase in anemia occurrence at 12 months after RYGB surgery, with a decline in hemoglobin/hematocrit over time. To address iron deficiency anemia, it is crucial to intervene early with ferritin profiling and increased supplementation of vitamin B12, which may occur later, from 12 months post-operation.<sup>13</sup> To maximize iron absorption, patients should take iron and calcium at least 2 hours apart, as up to 50% to 60% of iron absorption is inhibited when consumed with calcium or dairy products.<sup>18</sup> Treatment regimens include oral ferrous sulfate, fumarate, or gluconate, along with multivitamin supplementation. Vitamin C can also be beneficial in increasing iron absorption.<sup>6</sup> To prevent B12 deficiencies, oral supplementation with crystalline vitamin B12 1000 µg/day is indicated within 6 months of surgery.<sup>4</sup> Folate deficiencies are less common due to folic acid-fortified foods and vitamin supplementation, but nutritional supplementation of at least 400 µg/day should still be considered.<sup>2,12</sup>

Wernicke encephalopathy is a severe complication of bariatric surgery that results from a deficiency in vitamin B1 (thiamine). A study of 84 procedures, 95% of which were gastric bypass or restrictive surgeries, found that 94% of patients were admitted to the hospital for Wernicke encephalopathy. Mild thiamine deficiencies can be treated with 100 mg/d of thiamine for 7 to 14 days with an IV solution not containing glucose, followed by at least 10 mg/day of oral thiamine until symptoms resolve.<sup>6</sup> Severe thiamine deficiency requires 500 mg/d of thiamine IV for 3 to 5 days, followed by 250 mg/d for another 3 to 5 days or until symptom resolution.<sup>4</sup> Micronutrient deficiencies after bariatric surgery can include zinc, copper, and selenium. Zinc deficiency is prevalent in obese patients before and after surgery, with rates ranging from 12% to 91% depending on the type of procedure. Zinc supplementation can impair the absorption of copper, so it's recommended to supplement 1 mg of copper for every 8 to 15 mg of zinc. Copper plays an essential role in iron absorption and red blood cell formation and can be an underlying cause of persistent anemia.<sup>4,19</sup> Magnesium deficiency is also common in preoperative patients with obesity, and deficiencies can lead to osteoporosis in postoperative patients. Prevention of hypomagnesemia can include supplementation with 300 mg of magnesium citrate daily.<sup>19</sup> Adherence to supplement regimens is crucial to achieving optimal micronutrient concentrations and hemoglobin levels after surgery. Proper adherence has been shown to result in higher micronutrient concentrations, even in pregnant women who have undergone bariatric surgery.<sup>20</sup> Overall, the recommendations for micronutrient supplementation based on recent data are quite reliable.

## CONCLUSION

Bariatric surgery can cause micronutrient deficiencies, particularly malabsorptive procedures such as RYGB. Fat-soluble vitamin deficiencies, especially vitamins A and D, are common after RYGB, and vitamin supplementation is recommended. Iron deficiency anemia is prevalent, and early intervention with ferritin profiling and increased vitamin B12 supplementation is essential. Wernicke encephalopathy is a severe complication resulting from a deficiency in vitamin B1, and zinc, copper, and selenium deficiencies can also occur. Adherence to supplement regimens is crucial to achieving optimal micronutrient concentrations.

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