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Review article

American Society for Metabolic and Bariatric Surgery Integrated Health Nutritional Guidelines for the Surgical Weight Loss Patient 2016 Update: Micronutrients

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Abstract

Background: Optimizing postoperative patient outcomes and nutritional status begins preoperatively. Patients should be educated before and after weight loss surgery (WLS) on the expected nutrient deficiencies associated with alterations in physiology. Although surgery can exacerbate preexisting nutrient deficiencies, preoperative screening for vitamin deficiencies has not been the norm in the majority of WLS practices. Screening is important because it is common for patients who present for WLS to have at least 1 vitamin or mineral deficiency preoperatively.

Objectives: The focus of this paper is to update the 2008 American Society for Metabolic and Bariatric Surgery Nutrition in Bariatric Surgery Guidelines with key micronutrient research in laparoscopic adjustable gastric banding, Roux-en-Y gastric bypass, laparoscopic sleeve gastrectomy, biliopancreatic diversion, and biliopancreatic diversion/duodenal switch.

Methods: Four questions regarding recommendations for preoperative and postoperative screening of nutrient deficiencies, preventative supplementation, and repletion of nutrient deficiencies in pre-WLS patients have been applied to specific micronutrients (vitamins B1 and B12; folate; iron; vitamins A, E, and K; calcium; vitamin D; copper; and zinc).

Results: Out of the 554 articles identified as meeting preliminary search criteria, 402 were reviewed in detail. There are 92 recommendations in this update, 79 new recommendations and an additional 13 that have not changed since 2008. Each recommendation has a corresponding graded level of evidence, from grade A through D.

Conclusions: Data continue to suggest that the prevalence of micronutrient deficiencies is increasing, while monitoring of patients at follow-up is decreasing. This document should be viewed as a guideline for a reasonable approach to patient nutritional care based on the most recent research, scientific evidence, resources, and information available. It is the responsibility of the registered dietitian nutritionist and WLS program to determine individual variations as they relate to patient nutritional care. (Surg Obes Relat Dis 2017;13:727–741.)

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The role of the registered dietitian nutritionist (RDN) continues to be a vital component of the weight loss surgery (WLS) process. Recent guidelines recommend that all

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Table 1
Pre-WLS Nutrient Screening Recommendations

Micronutrient	Pre-WLS Nutrient Screening Recommendation	Rationale	Other Considerations
Thiamin	• Routine pre-WLS screening* is recommended for all patients. (Grade C, BEL 3)* ☑	• Prevalence of thiamin deficiency pre-WLS is reported to be as high as 29%.	• Thiamin diphosphate, the biologically active form of thiamin, is not found in measurable concentrations in plasma, and is best determined in whole blood specimens. Plasma thiamin concentration reflects recent intake rather than body stores. Thiamin carried by albumin will be decreased with concomitant hypoalbuminemia.
Vitamin B12 (cobalamin)	• Routine pre-WLS screening of B12 is recommended for all patients. (Grade B, BEL 2) ☑ • Serum MMA is the recommended assay for B12 evaluation for symptomatic or asymptomatic patients and in those with history of B12 deficiency or preexisting neuropathy. (Grade B, BEL 2) ☑	• Prevalence of B12 deficiency is reported to be 2–18% in patients with obesity and 6–30% in patients taking proton pump inhibitors.	• Serum B12 levels alone may not be adequate to identify B12 deficiency. • Elevated MMA levels (values >0.4 μmol/L) may be a more reliable indicator of B12 status because it indicates a metabolic change that is highly specific to B12 deficiency.
Folate (Folic Acid)	• Routine pre-WLS screening is recommended for all patients. (Grade B, BEL 2) ☑	• Prevalence of folate deficiency is reported to be as high as 54% in patients with obesity.	• ↓RBC folate and ↑serum homocysteine and normal MMA levels indicate folate deficiency.
Iron	• Routine pre-WLS screening is recommended for all patients. (Grade B, BEL 2) ☑ • Screening patients for iron status, but not for the purpose of diagnosing iron deficiency, may include the use of ferritin levels. (Grade B, BEL 2) ☑ • A combination of tests (serum iron with serum transferrin saturation and total iron-binding capacity) is recommended for diagnosing iron deficiency. (Grade B, BEL 2) • Screening for iron deficiency should include assessment of clinical signs and symptoms common to this condition (e.g., feeling tired and weak, decreased work performance, decreased immune function, and glossitis). (Grade B, BEL 2)	• Prevalence of iron deficiency is reported to be as high as 45% in patients with obesity.	• Ferritin levels should not be used to diagnose deficiency because iron is an acute-phase reactant and may fluctuate with age, inflammation, and infection. • Lab tests indicate iron deficiency if iron <50 μg/dL, ferritin <20 μg/dL, TIBC >450 μg/dL.
Vitamin D and Calcium	• Routine pre-WLS screening is recommended for all patients. (Grade A, BEL 1) ☑ • Routine pre-WLS screening of calcium status, vitamin D deficiency and insufficiency is particularly important for pre- and postmenopausal women. (Grade D, BEL 4) ☑	• Prevalence of vitamin D deficiency is reported to be as high as 90% in patients with obesity. • Elevated values of carboxy-terminal telopeptide have been reported in 66.7% of patients under 50 years of age.	• Use a combination of laboratory tests: vitamin D, 25-OH, serum alkaline phosphatase, PTH, and 24-hr urinary calcium in relationship to dietary intake. • Peri- and postmenopausal women may be screened for increased bone resorption by using urinary and/or serum type I collagen N-telopeptide levels, which are higher in patients with decreasing estrogen production.

Fat-soluble vitamins (A, E, K)	• Routine pre-WLS screening is recommended for all patients. (Grade C, BEL 3) ☑	• Prevalence of deficiencies pre-WLS is reported to be vitamin A 14%, vitamin E 2.2%. • There are no data on vitamin K deficiencies in pre-WLS patients.	• Use physical signs and symptoms and labs (Table 5) for: o *Vit A deficiency*: ↓Retinol binding protein and ↓plasma retinol o *Vit E deficiency*: ↓plasma α-tocopherol o *Vit K deficiency*: ↑DCP
Zinc	• Routine pre-WLS screening of zinc status is recommended for patients before RYGB or BPD/DS. (Grade D, BEL 3) ☑ • Zinc assays in pre-WLS patients should be interpreted in light of the fact that patients with obesity have lower serum zinc levels and lower concentrations of zinc in plasma and erythrocytes than leaner patients. Thus, repletion of zinc is indicated when signs and symptoms are evident and zinc assays are severely low. (Grade C, BEL 3) ☑	• Prevalence of zinc deficiency is reported to be 24–28% in WLS samples overall, • and 74% of patients seeking BPD/DS.	• Use physical signs and symptoms and labs (Table 5): o ↓ serum or urinary zinc or RBC zinc
Copper	• Routine pre-WLS screening of copper using serum copper and ceruloplasmin is recommended for patients before RYGB or BPD/DS, but results must be interpreted with caution. (Grade D, BEL 4) ☑ • Erythrocyte superoxide dismutase is the preferred assay for determining copper status in patients who have undergone WLS. It is a more precise biomarker for screening of copper deficiency when it is available and affordable. (Grade D, BEL 4) ☑	• Prevalence of copper deficiency is reported to be as high as 70% in pre-BPD women.	• Serum copper and ceruloplasmin are recommended for screening indices, but are acute-phase reactants and thus affected by inflammation, age, anemia, and medications.

WLS = weight loss surgery; BEL = best evidence level; MMA = methyl malonic acid; RBC = red blood cell; TIBC = total iron-binding capacity; PTH = parathyroid hormone; DCP = des-gamma-carboxy prothrombin; RYGB = Roux-en-Y gastric bypass; BPD/DS = biliopancreatic diversion/duodenal switch.

Recommendations were formulated for each question within each micronutrient with reference to the previous guidelines. Once this was completed, grades A through D (strongest to weakest) were assigned to the recommendations by following the AACE protocol (see Appendices B–E).

*"Routine pre-WLS screening" refers to acquiring a nutrient baseline before WLS. ☑New recommendation since 2008 [1] is noted by ☑, otherwise there is no change in the current recommendation.

Table 2
Post-WLS Nutrient Screening Recommendations

Micronutrient	Post-WLS Nutrient Screening Recommendation	Rationale	Other Considerations
Thiamin	• Routine post-WLS screening* is recommended for high-risk WLS groups (Grade B, BEL 2) ☑: o Patients with risk factors for TD (Grade B, BEL 2) ☑ o Females (Grade B, BEL 2) ☑ o Blacks (Grade B, BEL 2) ☑ o Patients not attending a nutritional clinic after surgery (Grade B, BEL 2) ☑ o Patients with GI symptoms (intractable nausea and vomiting, jejunal dilation, mega-colon, or constipation) (Grade B, BEL 2)☑ o Patients with concomitant medical conditions such as cardiac failure (especially those receiving furosemide) o Patients with SBBO (Grade C, BEL 3) ☑ • If signs and symptoms or risk factors are present in post-WLS patients, thiamin status should be assessed at least during the first 6 mo, then every 3–6 mo until symptoms resolve. (Grade B, BEL 2) ☑	• Prevalence of TD post-WLS ranges from <1% to 49% and varies by type of WLS and post-WLS time frame.	• Risk of TD in WLS patients increases with other risk factors: o malnutrition, excessive and/or rapid weight loss, and excessive alcohol use.
Vitamin B12	• Routine post-WLS screening of vitamin B12 status is recommended for patients who have undergone RYGB, SG, or BPD/DS. (Grade B, BEL 2) ☑ • More frequent screening (e.g., every 3 mo) is recommended in the first post-WLS year, and then at least annually or as clinically indicated for patients who chronically use medications that exacerbate risk of B12 deficiency: nitrous oxide, neomycin, metformin, colchicine, proton pump inhibitors, and seizure medications. (Grade B, BEL 2) ☑ • Serum B12 may not be adequate to identify B12 deficiency. It is recommended to include serum MMA with or without homocysteine to identify metabolic deficiency of B12 in symptomatic and asymptomatic patients and in patients with history of B12 deficiency or preexisting neuropathy. (Grade B, BEL 2) ☑	• Prevalence of B12 deficiency post-WLS at 2–5 yr is <20% in RYGB and 4–20% in SG.	• Vitamin B12 deficiency can occur due to food intolerances or restricted intake of protein and vitamin B12–containing foods.
Folate	• Routine post-WLS screening of folate status is recommended for all patients. (Grade B, BEL 2) ☑ • Particular attention should be given to female patients of childbearing age. (Grade B, BEL 2) ☑	• Prevalence of folate deficiency is reported in up to 65% patients post-WLS.	• Poor dietary intake of folate-rich foods and suspected nonadherence with multivitamin may contribute to folate deficiency.
Iron	• Routine post-WLS screening of iron status is recommended within 3 mo after surgery, then every 3–6 mo until 12 mo, and annually for all patients. (Grade B, BEL 2) ☑ • Iron status in post-WLS patients should be monitored at regular intervals using an iron panel, complete blood count, total iron-binding capacity, ferritin, and soluble transferrin receptor (if available), along with clinical signs and symptoms. (Grade C, BEL 3) ☑	• Prevalence of iron deficiency is reported to occur in post-WLS patients from 3 mo to 10 yr: AGB 14%, SG <18%, RYGB 20–55% BPD 13–62% DS 8–50%	• Post-WLS iron deficiency can occur after any WLS procedure, despite routine supplementation.

	• Additional iron screening in post-WLS patients should be conducted as warranted by clinical signs or symptoms and/or laboratory findings, or in other instances in which a deficiency is suspected. (Grade B, BEL 2) ☑		
Vitamin D and Calcium	• Routine post-WLS screening of vitamin D status is recommended for all patients. (Grade B, BEL 2) ☑ • More research is needed to establish a recommendation regarding the use of vitamin D binding protein assays as an additional tool for determining vitamin D status in post-WLS patients. (Grade C, BEL 3) ☑	• Prevalence of vitamin D deficiency is reported to occur in up to 100% of post-WLS patients.	• 25(OH)D is the preferred biochemical assay of vitamin D • Elevated PTH levels • Increased bone formation/resorption markers
Vitamins A, E, K	• Post-WLS patients should be screened for vitamin A deficiency within the first postoperative year, particularly those who have undergone BPD/DS, regardless of symptoms. (Grade B, BEL 2) ☑ • Vitamin A should be measured in patients who have undergone RYGB and BPD/DS, particularly in those with evidence of protein-calorie malnutrition. (Grade B, BEL 2) • While vitamin E and K deficiencies are uncommon after WLS, patients who are symptomatic should be screened. (Grade B, BEL 2) ☑	• Prevalence of vitamin A deficiency is reported to occur in up to 70% of patients with RYGB and BPD/DS within 4 years post-WLS. Deficiencies of vitamins E and K are uncommon after WLS.	
Zinc	• Post-RYGB and post-BPD/DS patients should be screened at least annually for zinc deficiency. (Grade C, BEL 3) ☑ • Serum and plasma zinc are the most appropriate biomarkers for zinc screening of post-WLS patients. (Grade C, BEL 3) ☑ • Zinc should be evaluated in all post-WLS patients when the patient is symptomatic for iron deficiency anemia but screening results for iron deficiency anemia is negative. (Grade C, BEL 3) ☑ • Post-WLS patients who have chronic diarrhea should be evaluated for zinc deficiency. (Grade D, BEL 4) ☑	• Prevalence of zinc deficiency occurs in: up to 70% post-BPD/DS; 40% post-RYGB; 19% post-SG; 34% post-AGB	• Deficiency of zinc is possible, even if taking zinc supplements and especially if primary sites of absorption (duodenum and proximal jejunum) are bypassed.
Copper	• Routine post-WLS screening of copper status is recommended at least annually after BPD/DS and RYGB, even in the absence of clinical signs or symptoms of deficiency. (Grade C, BEL 4) ☑ • In post-WLS patients, serum copper and ceruloplasmin are the recommended biomarkers for determining copper status because they are closely correlated with physical symptoms of copper deficiency. (Grade C, BEL 4) ☑	• Prevalence of copper deficiency is reported to be as high as 90% of patients post-BPD/DS and 10–20% post-RYGB. • Only 1 case report noted for post-SG copper deficiency; no data reported for post-AGB patients.	

WLS = weight loss surgery; BEL = best evidence level; GI = gastrointestinal; SBBO = small bowel bacterial overgrowth; TD = thiamin deficiency; RYGB = Roux-en-Y gastric bypass; SG = sleeve gastrectomy; BPS/DS = biliopancreatic diversion/duodenal switch; MMA = methyl malonic acid; PTH = parathyroid hormone; AGB = adjustable gastric band.

☑ New recommendation since 2008 [1] is noted by ☑, otherwise there is no change in the current recommendation

*"Routine post-WLS screening" refers to performing a nutrient assessment every 3–6 months in the first year and annually thereafter, unless otherwise specified.

Table 3
Supplement Recommendations to Prevent Post-WLS Micronutrient Deficiency

Vitamin B1 (Thiamin)

Thiamin supplementation above the RDA is suggested to prevent thiamin deficiency.

All post-WLS patients should take at *least* 12 mg thiamin daily (Grade C, BEL 3) and preferably a 50 mg dose of thiamin from a B-complex supplement or multivitamin once or twice daily (Grade D, BEL 4) to maintain blood levels of thiamin and prevent TD. ☑

Vitamin B12 (Cobalamin)

All post-WLS patients should take vitamin B12 supplementation. (Grade B, BEL 2) ☑

Supplement dose for vitamin B12 in post-WLS patients varies based on route of administration (Grade B, BEL 2): ☑

Orally by disintegrating tablet, sublingual, or liquid: 350–500 μg daily

Nasal spray as directed by manufacturer

Parenteral (IM or SQ): 1000 μg monthly

Folate (Folic Acid)

Post-WLS patients should take 400–800 μg oral folate daily from their multivitamin. (Grade B, BEL 2) ☑

Women of childbearing age should take 800–1000 μg oral folate daily. (Grade B, BEL 2) ☑

Iron

Post-WLS patients at low risk (males and patients without history of anemia) for post-WLS iron deficiency should receive at least 18 mg of iron from their multivitamin. (Grade C, BEL 3) ☑

Menstruating females and patients who have undergone RYGB, SG, or BPD/DS should take at least 45–60 mg of elemental iron daily (cumulatively, including iron from all vitamin and mineral supplements). (Grade C, BEL 3) ☑

Oral supplementation should be taken in divided doses separately from calcium supplements, acid-reducing medications, and foods high in phytates or polyphenols. (Grade D, BEL 3) ☑ Recommendation is downgraded to D, since majority of evidence is from non-WLS patients.

Vitamin D and Calcium

All post-WLS patients should take calcium supplementation. (Grade C, BEL 3) ☑

The appropriate dose of daily calcium from all sources varies by surgical procedure:

BPD/DS: 1800–2400 mg/d

LAGB, SG, RYGB: 1200–1500 mg/d

The recommended preventative dose of vitamin D in post-WLS patients should be based on serum vitamin D levels: Recommended vitamin D3 dose is 3000 IU daily, until blood levels of 25(OH)D are greater than sufficient (30 ng/mL) (Grade D, BEL 4) ☑

A 70–90% lower vitamin D3 bolus dose is needed (compared to vitamin D2) to achieve the same effects as those produced in healthy non-bariatric surgical patients. (Grade A, BEL 1) ☑

To enhance calcium absorption in post-WLS patients (Grade C, BEL 3): ☑

Calcium should be given in divided doses.

Calcium carbonate should be taken with meals.

Calcium citrate may be taken with or without meals.

Vitamins A, E, and K

Post-WLS patients should take vitamins A, E, and K, with dosage based on type of procedure:

LAGB: Vitamin A 5000 IU/d and vitamin K 90–120 ug/d (Grade C, BEL 3) ☑

RYGB and SG: Vitamin A 5000–10,000 IU/d and vitamin K 90–120 ug/d (Grade D, BEL 4) ☑

LAGB, SG, RYGB, BPD/DS: Vitamin E 15 mg/d (Grade D, BEL 4) ☑

DS: Vitamin A (10,000 IU/d) and vitamin K (300 μg/d) (Grade B, BEL 2) ☑

Higher maintenance doses of fat-soluble vitamins may be required for post-WLS patients with a previous history of deficiency in vitamin A, E, or K. (Grade D, BEL 4)

Water-miscible forms of fat soluble vitamins are also available to improve absorption (Grade D, BEL 4)

Special attention should be paid to post-WLS supplementation of vitamin A and K in pregnant women. (Grade D, BEL 3) ☑

Zinc

All post-WLS patients should take > RDA zinc, with dosage based on type of procedure (Grade C, BEL 3): ☑

BPD/DS: Multivitamin with minerals containing 200% of the RDA (16–22 mg/d)

RYGB: Multivitamin with minerals containing 100–200% of the RDA (8–22 mg/d)

SG/LAGB: Multivitamin with minerals containing 100% of the RDA (8–11 mg/d)

To minimize the risk of copper deficiency in post-WLS patients, it is recommended that the supplementation protocol contain a ratio of 8–15 mg of supplemental zinc per 1 mg of copper. (Grade C, BEL 3) ☑

Formulation and composition of zinc supplements should be considered in post-WLS patients to calculate accurate levels of elemental zinc provided by the supplement. (Grade D, BEL 4) ☑

Table 3
Continued.

Copper
All post-WLS patients should take > RDA copper as part of routine multivitamin and mineral supplementation, with dosage based on type of procedure (Grade C, BEL 3): ☑
BPD/DS or RYGB: 200% of the RDA (2 mg/d)
SG or LAGB: 100% of the RDA (1 mg/d)
In post-WLS patients, supplementation with 1 mg copper is recommended for every 8–15 mg of elemental zinc to prevent copper deficiency. (Grade C, BEL 3) ☑
In post-WLS patients, copper gluconate or sulfate is the recommended source of copper for supplementation. (Grade C, BEL 3) ☑

WLS = weight loss surgery; RDA = recommended dietary allowance; BEL = best evidence level; TD = thiamin deficiency; IM = intramuscular; SQ = subcutaneous; RYGB = Roux-en Y gastric bypass; SG = sleeve gastrectomy; BPD/DS = biliopancreatic diversion/duodenal switch; LAGB = laparoscopic adjust gastric band.

☑ New recommendation since 2008 [1] is noted by ☑, otherwise there is no change in the current recommendation.

patients pursuing WLS undergo a preoperative clinical nutrition evaluation by an RD [1]. This evaluation is necessary to identify preoperative nutritional deficiencies, as well as to evaluate a patient's ability to incorporate nutritional changes before and after WLS [2]. These guidelines also recommend including medical nutrition therapy for all bariatric patients as an essential component of comprehensive healthcare. Medical nutrition therapy provided by RDs incorporates a systematic 4-step nutrition care process. This process is dynamic and ongoing and consists of (1) nutrition assessment, (2) nutrition diagnosis, (3) nutrition intervention, and (4) monitoring and evaluation [3,4]. This paper is intended to facilitate all 4 steps of this process by focusing on the pre- and post-WLS assessment, supplementation, and repletion of micronutrient deficiencies.

In 2008, the American Society for Metabolic and Bariatric Surgery (ASMBS) Nutrition Committee published the Allied Health Nutritional Guidelines for the Surgical Weight Loss Patient [2]. Before the publication of these guidelines, no uniform nutritional guidelines were available for WLS patients. The 2008 guidelines provided some standardization across surgical practices, but considerable variation remains. Although much of the content of this document remains relevant, clinical and empirical knowledge of the nutritional care of patients pursuing WLS is ever increasing. What follows is an update based on current literature review.

The term "WLS," as is it used in this clinical practice guideline, is meant to encompass the metabolic and physiologic changes of bariatric surgery. Various bariatric and metabolic procedures are performed in patients in need of weight loss and metabolic control. Laparoscopic procedures are preferred because of their lower rates of morbidity and mortality. Laparoscopic adjustable gastric banding, Roux-en-Y gastric bypass (RYGB), laparoscopic sleeve gastrectomy (SG), biliopancreatic diversion (BPD), and BPD/duodenal switch (BPD/DS) are the primary procedures performed. These procedures have traditionally been classified as restrictive, malabsorptive, or combination procedures, based on their mechanisms for weight loss and metabolic control [5]. However, the early, weight-independent effects of RYGB, BPD/DS, and SG on glucose control for patients with prediabetes or type 2 diabetes is a strong indicator supporting the metabolic nature of these surgeries. Because the mechanisms of bariatric surgery continue to be elucidated, we will use WLS to encompass "bariatric and metabolic surgery" [6,7].

Optimizing postoperative patient outcomes and nutritional status begins preoperatively [1–3,8]. Patients should be educated before and after WLS on the expected nutrient deficiencies associated with alterations in physiology, especially those involving nutrient digestion, absorption, metabolism, and excretion [9]. Even though surgery can exacerbate preexisting nutrient deficiencies, preoperative screening for vitamin deficiencies has not been the norm for the majority of WLS practices [10]. Screening is important because it is common for patients presenting for WLS to have at least 1 vitamin or mineral deficiency preoperatively [11]. Data continue to suggest that the prevalence of micronutrient deficiencies is increasing, while monitoring of patients in follow-up is decreasing [10–13].

Organization of the guidelines

The following guideline narrative is organized into sections by micronutrient, with subsections corresponding to 4 domains: preoperative screening, postoperative screening, supplementation, and repletion for deficiencies. Evidence for recommendations is presented in each of these sections. The content covered within each section differs somewhat due to the nature of the developing research and the extent of available data regarding each micronutrient. The evidence discussed for each micronutrient is, therefore, not completely standardized, but follows the emphases and new developments within each of the fields of research. Summaries of all recommendations are graded by level of supporting evidence and are available in Tables 1 to 4.

Further details and resources for application (assessment and treatment options) are provided in Tables 5 and 6.

Table 4
Repletion Recommendations for Post-WLS Micronutrient Deficiency

Thiamin

- Practitioners should treat post-WLS patients with suspected thiamin deficiency before or in the absence of laboratory confirmation of deficiency AND monitor and evaluate resolution of signs and symptoms. (Grade C, BEL 3) ☑
- Repletion dose for TD varies based on route of administration and severity of symptoms:
  - *Oral therapy:* 100 mg 2–3 times daily until symptoms resolve (Grade D, BEL 4) ☑
  - *IV therapy:* 200 mg 3 times daily to 500 mg once or twice daily for 3–5 d, followed by 250 mg/d for 3–5 d or until symptoms resolve, then consider treatment with 100 mg/d orally, usually indefinitely or until risk factors have been resolved (Grade D, BEL 4) ☑
  - *IM therapy:* 250 mg once daily for 3–5 d or 100–250 mg monthly (Grade C, BEL 3) ☑
- Simultaneous administration of magnesium, potassium, and phosphorus should be given to patients at risk for refeeding syndrome. (Grade C, BEL 3) ☑

Vitamin B12 (Cobalamin)

- Post-WLS patients with B12 deficiency should take 1000 μg/d to achieve normal levels and then resume dosages recommended to maintain normal levels. (Grade B, BEL 2) ☑

Folate (Folic Acid)

- All post-WLS patients with folate deficiency should take an oral dose of 1000 μg of folate daily to achieve normal levels and then resume recommended dosage to maintain normal levels. (Grade B, BEL 2) ☑
- Folate supplementation above 1 mg/d is not recommended in post-WLS patients because of the potential masking of vitamin B12 deficiency. (Grade B, BEL 2)

Iron

- In post-WLS patients with post-WLS iron deficiency, oral supplementation should be increased to provide 150–200 mg of elemental iron daily to amounts as high as 300 mg 2–3 times daily. (Grade C, BEL 3)
- Oral supplementation should be taken in divided doses separately from calcium supplements, acid-reducing medications, and foods high in phytates or polyphenols. (Grade D, BEL 3) Recommendation is downgraded to D, since majority of evidence is from non-WLS patients.
- If iron deficiency does not respond to oral therapy, intravenous iron infusion should be administered. (Grade C, BEL 3)

Vitamin D and Calcium

- Vitamin D levels must be repleted if deficient or insufficient to normalize calcium. (Grade C, BEL 3) ☑
- All post-WLS patients with vitamin D deficiency or insufficiency should be repleted with the following doses:
  - Vitamin D3 at least 3000 IU/d and as high as 6000 IU/d, or 50,000 IU vitamin D2 1–3 times weekly (Grade A, BEL 1) ☑
  - Vitamin D3 is recommended as a more potent treatment than vitamin D2 when comparing frequency and amount needed for repletion. However, both forms can be efficacious, depending on the dosing regimen (Grade A, BEL 1) ☑
- The recommendations for repletion of calcium deficiency varies by surgical procedure (Grade C, BEL 3):
  - *BPD/DS:* 1800–2400 mg/d calcium
  - *LAGB, SG, RYGB:* 1200–1500 mg/d calcium ☑

Vitamin A

- In post-WLS patients with vitamin A deficiency without corneal changes: a dose of vitamin A 10,000–25,000 IU/d should be administered orally until clinical improvement is evident (1–2 wk). (Grade D, BEL 4)
- In post-WLS patients with vitamin A deficiency with corneal changes: a dose of vitamin A 50,000–100,000 IU should be administered IM for 3 d, followed by 50,000 IU/d IM for 2 wk. (Grade D, BEL 4)
- Post-WLS patients with vitamin A deficiency should also be evaluated for concurrent iron and/or copper deficiencies because these can impair resolution of vitamin A deficiency. (Grade D, BEL 4)

Vitamin E

- The optimal therapeutic dose of vitamin E in post-WLS patients has not been clearly defined. There is potential for antioxidant benefits of vitamin E to be achieved with supplements of 100–400 IU/d. This is higher than the amount typically found in a multivitamin, thus additional vitamin E supplementation may be required for repletion. (Grade D BEL 4)

Vitamin K

- For post-WLS patients with acute malabsorption, a parenteral dose of 10 mg vitamin K is recommended. (Grade D, BEL 4)
- For post-WLS patients with chronic malabsorption, the recommended dosage of vitamin K is either 1–2 mg/d orally or 1–2 mg/wk parenterally. (Grade D, BEL 4)

Zinc

- There is insufficient evidence to make a dose-related recommendation for repletion. The previous recommendation of 60 mg elemental zinc orally twice a day needs to be reevaluated in light of emerging research that this dose may be inappropriate.
- Repletion doses of zinc in post-WLS patients should be chosen carefully to avoid inducing a copper deficiency. (Grade D, BEL 3) ☑
- Zinc status should be routinely monitored using consistent parameters throughout the course of treatment. (Grade C, BEL 3) ☑

Table 4
Continued.

Copper
● In post-WLS patients with copper deficiency, the recommended regimen for repletion of copper will vary with the severity of the deficiency (Grade C, BEL 3): ☑
o *Mild to moderate deficiency* (including low hematologic indices): Treat with 3–8 mg/d oral copper gluconate or sulfate until indices return to normal
o *Severe deficiency*: 2–4 mg/d intravenous copper can be initiated for 6 d or until serum levels return to normal and neurologic symptoms resolve
● Once copper levels are normal: monitor copper levels every 3 mo (Grade C, BEL 3) ☑

WLS = weight loss surgery; BEL = best evidence level; TD = thiamin deficiency; IV = intravenous; IM = intramuscular; BPD/DS = biliopancreatic diversion/duodenal switch; LAGB = laparoscopic adjustable gastric band; SG = sleeve gastrectomy; RYGB = Roux-en-Y gastric bypass.
☑New recommendation since Aills et al. 2008 is noted by ☑, otherwise there is no change in the current recommendation.

Detailed supporting evidence and rationale for all micronutrient recommendations are provided in the Supplementary Materials.

Methods

Clinical guidelines work group and question identification

The literature reviews involved in preparing this document followed standards set out in the American Association of Clinical Endocrinologists (AACE)/Obesity Society/ASMBS Protocol for Standardized Production of Clinical Practice Guidelines [14] and by the Institute of Medicine [15]. Selection of the chair, primary writers, and reviewers as well as the process for creating these evidence-based clinical practice guidelines was conducted in accordance with the ASMBS Process for Developing Clinical Practice Guidelines and using the 4-step grading approach outlined in the AACE Protocol for Standardized Production of Clinical Practice Guidelines 2010 update [14].

After questions were developed for the update, a systematic review of the literature was conducted. Four questions that were applied to each of the micronutrients discussed (vitamins B1 and B12; folate; iron; vitamins A, D, E, and K; calcium; copper; and zinc) guided the literature search in updating the 2008 ASMBS nutrition guidelines:

Q1: What is the recommendation for preoperative screening of nutrient deficiencies in patients who plan to have WLS? (Table 1)
Q2: What is the recommendation for postoperative screening of nutrient deficiencies in patients who have had WLS? (Table 2)
Q3: What are the supplement recommendations to help prevent nutrient deficiencies in patients who have had WLS? (Table 3)
Q4: What are the repletion recommendations to treat nutrient deficiencies in patients who have had WLS? (Table 4)

The 2008 Nutrition Guidelines included several topics that are still valid and did not require updating: (1) preoperative nutrition assessment, (2) preoperative nutrition education, and (3) diet and texture progression. Topics outside the scope of this current update include restriction versus malabsorption and an update for protein and other macronutrients. Recent publications have addressed some nutrition-related aspects of macronutrients [16,17]. Vitamin B6, selenium, and magnesium, briefly mentioned in 2008 as "other micronutrients," were not updated, whereas copper has been added because of its intertwined relationship with zinc and potential impact on WLS patients.

Search methods

Electronic database searches. The Integrated Health Clinical Issues and Guidelines Nutrition Subcommittee conducted a literature search for articles related to WLS and specific nutrients. The specific search terms included "bariatric" or "weight loss" and "surgery" as well as all of the most commonly performed bariatric procedures, including laparoscopic adjustable gastric banding, RYGB, SG, and BPD/DS. These were combined with each of the nutrients of interest (e.g., calcium).

The search was limited to relevant literature focusing on adults aged 18 years or older, published in English between January 1, 2007, and April 1, 2016, with a sample size >10 patients, except for pertinent case studies. Earlier literature was included on an ad hoc basis, determined by relevance.

Other evidence sources. This review also incorporates existing sets of published guidelines relevant to the nutritional care of the WLS patient, including the combined AACE, Obesity Society, and ASMBS sponsored guidelines. [2]

Search results

In total, 554 articles were initially identified, of which 471 were found to be relevant and were screened. Of these articles, 402 were reviewed in detail (Appendix A). Search results identified meta-analyses of randomized and nonrandomized controlled trials, randomized controlled trials, meta-analyses of nonrandomized prospective or case-controlled trials, prospective and retrospective cohort studies, cross-sectional studies,

Table 5
Signs and Symptoms of Micronutrient Deficiencies

Normal Lab Ranges	Additional Laboratory Indices	Critical Range	Signs and Symptoms of Deficiency, Including Nutrition-Focused Physical Assessment (NFPA)
B1 (Thiamin)			
• Plasma thiamin by HPLC: 4–15 nmol/L* • Whole blood or erythrocyte (RBC) thiamin via HPLC: 2.5–7.5 μg/dL or 74–222 nmol/L† • TDP: 70–180 nmol/L • Transketolase: >150 nmol/L • Erythrocyte transketolase activity (ETKA)/ activity coefficients <1.15 (0–15%) *Low sensitivity and specificity †Erythrocytes contain 80–90% of total thiamin in the form of TDP.	• ETKA/activity coefficient: 1.16 and 1.20 (16–20%) moderate deficiency • Transketolase: 120–150 nmol/L = marginal thiamin status • ↑ pyruvate or ↓ lactate (lactic acidosis) • ↓Urinary thiamin	• TDP < 70 nmol/L • Transketolase concentration: <120 nmol/L = deficiency • ETKA/activity coefficient: >1.20 (>20%) = deficiency • ETKA >1.25 (25%) = very deficient • Urinary thiamin <40 μg or <27 μg/g creatinine	**Early signs/symptoms:** • *Dry beriberi (without edema):* brisk tendon reflexes, peripheral neuropathy and/or polyneuritis (with or without paresthesias), muscle weakness and/or pain of upper and lower extremities, gait ataxia, convulsions • *Wet beriberi:* heart failure with high cardiac output, edema in the lower extremities, tachycardia or bradycardia, lactic acidosis, dyspnea, heart hypertrophy and dilation (particularly of the right ventricle), respiratory distress, systemic venous hypertension, bounding arterial pulsations • *Other/gastroenterologic:* slow gastric emptying, nausea, vomiting, jejunal dilation or megacolon, constipation **Advanced signs/symptoms:** • *Wernicke's encephalopathy:* polyneuropathy and ataxia, ocular changes (ophthalmoplegia and nystagmus), confabulation, short-term memory loss • If psychosis and/or hallucinations are present, also known as *Korsakoff psychosis* and/or *Wernicke-Korsakoff syndrome* **NFPA:** numbness, tingling in extremities could denote neuropathy, gait ataxia, convulsions, edema, vomiting, ophthalmoplegia, nystagmus, confusion, confabulation, hallucinations, psychosis
B12 (Cobalamin)			
• Serum B12 (cobalamin) 200–1000 pg/mL	• ↑Serum MMA • ↑Serum tHcy	• Serum B12: <200 pg/mL deficiency <400 pg/mL suboptimal sMMA >0.376 umol/Lt Hcy >13.2 umol/L	**Early signs/symptoms:** • Pernicious anemia (due to absence of intrinsic factor)/megaloblastic anemia, pale with slightly icteric skin and eyes, glossitis (magenta or "beefy red" tongue), fatigue, anorexia, diarrhea • Numbness and paresthesia (tingling or prickly feeling) in extremities, ataxia (poor muscle coordination), changes in reflexes, demyelination and axonal degeneration, especially of peripheral nerves, spinal cord, and cerebrum • Light-headedness or vertigo, shortness of breath • Tinnitus (ringing in ears) • Palpitations, rapid pulse **Advanced signs/symptoms:** • Angina or symptoms of congestive failure • Altered mental status, ranging from mild irritability and forgetfulness to severe dementia or frank psychosis **NFPA:** sore tongue, smooth and "beefy red" tongue (magenta tongue), pale skin, slightly icteric skin and eyes, fatigue, numbness and tingling in extremities could denote neuropathy, gait ataxia, dementia, psychosis
Folate			
• RBC • Folate 340–1020 ng/mL age ≥18 yr	• Urinary formiminoglutamic acid • Normal serum and MMA • ↑Serum tHcy	• RBC folate <305 nmol/L deficiency • <227 nmol/L anemia	**NFPA:** changes in pigmentation or ulceration of skin, nails, or oral mucosa

Iron

- Iron panel, ferritin, CBC, transferrin, transferrin saturation
- Serum iron: 60–170 ug/dL
- Transferrin 200–360 ug/dL
- Transferrin saturation: 20–50%
- Ferritin: 12–300 ng/mL (male)
- Ferritin: 12–150 ng/mL (female)
- **NOTE**: Ferritin fluctuates with inflammation, age, and infection

- ↑TIBC
- UIBC
- sTfR
- Stage 1: Serum ferritin ↓ 20 ng/mL
- Stage 2: Serum iron ↓50 g/dL; transferrin saturation <16%
- Stage 3: Anemia with normal-appearing RBCs and indexes
- Stage 4: Microcytosis, then hypochromia
- Stage 5: Fe deficiency affects tissues, resulting in signs and symptoms

- Iron <50 ug/dL
- Ferritin <20 ug/dL
- TIBC >450 ug/dL

- Fatigue, decreased work performance, impaired learning ability
- Microcytic anemia
- Decreased immune function, enteropathy
- Glossitis, dysphagia
- Spoon-shaped nails (koilonychias), vertical ridges on nails
- Rapid heart rate/palpitations

NFPA: glossitis, spoon-shaped nails, vertical ridges

Calcium

- Serum PTH
- 25(OH)D

- iPTH >65 pg/mL indicates ↓calcium
- Serum calcium (poor indicator of bone stores)
- Ionized calcium corrects for low albumin
- ↑Urinary N- and C- telopeptide
- ↑Urinary cross-links type 1 collagen telopeptides (indicator of bone resorption)
- DXA scan findings baseline in pre-post menopause
- DXA every 2 yrs

- Serum calcium should be WNL (9–10.5 mg/dL) in patients without renal disease

- Leg cramping, tetany
- Hypocalcemia
- Neuromuscular hyperexcitability
- Muscle weakness
- Osteoporosis

NFPA: present in toddlers as rickets
Present in adults as osteomalacia, may have bone pain and muscle weakness

Vitamin D

- -↓25(OH)D >30 ng/mL (>75nmol/L) sufficiency
- May see ↑serum PTH (PTH adult < 65pg/mL WNL)

- ↓Serum phosphorus
- ↑Alkaline phosphatase
- ↓Urinary calcium
- ↓Serum estradiol post-RNY with
- ↓Intestinal calcium absorption and ↑N-telopeptide (marker of bone resorption)
- ↑Osteocalcin (marker for bone formation)

- Insufficiency: 20–30 ng/mL (50–75 nmol/L)
- Deficiency: <20 ng/mL (<50 nmol/L)

- Hypocalcemia, tetany, tingling, cramping
- Metabolic bone disease, rachitic tetany

NFPA: present in toddlers as rickets
Present in adults as osteomalacia, may have bone pain and muscle weakness

Vitamin A

- Plasma retinol 20–80 ug/dL

- Retinol binding protein

- Plasma retinol <10 μg/dL

Early signs/symptoms:

- Nyctalopia (night blindness or difficulty seeing in dim light), Bitot's spots (foamy white spots on sclera of eye), endophthalmitis, poor wound healing
- Hyperkeratinization of the skin, loss of taste (vitamin A and zinc metabolism interrelated)
- **Advanced signs/symptoms:**
- Corneal damage, xerosis, keratomalacia, perforation
- Blindness, xerosis

NFPA: Bitot's spots, poor wound healing, hyperkeratosis, xerosis

Table 5
Continued.

Normal Lab Ranges	Additional Laboratory Indices	Critical Range	Signs and Symptoms of Deficiency, Including Nutrition-Focused Physical Assessment (NFPA)
Vitamin E			
• Plasma alpha tocopherol	• Plasma lipids	• <5 μg/mL	• Hyporeflexia, gait disturbances, neurologic damage, muscle weakness, decreased proprioception, and vibration • Ophthalmoplegia, nystagmus, nyctalopia • RBC hemolysis (hemolytic anemia) **NFPA:** gait ataxia, hyporeflexia/weakness, nystagmus, ophthalmoplegia, ceroid deposition in muscle
Vitamin K			
• PT 10–13 sec • PT is not a sensitive measure of vitamin K status 1 nmol/L	• ↑DCP ↓plasma phylloquinone	• Variable	**Early signs/symptoms:** o Hemorrhage due to deficiency of prothrombin and other factors o Easy bruising, bleeding gums, delayed blood clotting, heavy menstrual or nose bleeding **Advanced symptoms:** o Osteoporosis (due to interrelationship between vitamin K and bone metabolism) **NFPA:** skin hemorrhages (petechia, purpura, ecchymosis [bruising])
Zinc			
• Plasma zinc 60–130 ug/dL	• Decreased serum zinc • Decreased erythrocyte zinc (RBC zinc) • Decreased urinary zinc • Physical signs and symptoms	<70 ug/dL for women <74 ug/dL for men	**Early (mild to moderate) symptoms:** • Rash, acne • Hypogeusia or ageusia (change in or absence of taste) • Immune deficiency, increased infections • Infertility • Growth retardation, delayed sexual maturation **Advanced (severe) symptoms:** • Hypogonadism • Alopecia (hair loss) • Skin lesions/rashes (bullous pustular dermatitis, acrodermatitis enteropathica) • Diarrhea • Impaired appetite/anorexia • Night blindness • Recurrent infections. delayed wound healing **NFPA:** alopecia, skin lesions, delayed wound healing
Copper			
• Serum or plasma copper –11.8 to 22.8 mmol/L • Ceruloplasmin 75-145 ug/dL	• Decreased erythrocyte superoxide dismutase activity • 24-hour urine copper	<10 ìmol/L <75 ug/dL	**Early signs/symptoms:** • Hypochromic anemia, neutropenia, pancytopenia • Hypopigmentation of hair, skin, nails • Hypercholesterolemia • Impaired biomarkers of bone metabolism **Advanced signs/symptoms:** • Gait abnormalities **NFPA:** Hypopigmentation of skin, hair, or nails, peripheral neuropathy myelopathy

HPLC = high-performance liquid chromatography; RBC = red blood cell; TDP = thiamin, whole blood; ETKA = erythrocyte transketolase activity; NFPA = nutrition-focused physical assessment; MMA = methyl malonic acid; tHcy = homocysteine; CBC = complete blood count; TIBC = total iron-binding capacity; UIBC = unsaturated iron binding capacity; sTfR = soluble transferrin receptor; PTH = parathyroid hormone; DXA = dual-energy x-ray absorptiometry; WNL = within normal limits; RNY = Roux-en Y gastric bypass; PT = prothrombin time.

Table 6
Nutrient Supplementation for Patients with WLS and Without WLS.

Nutrients	Non-WLS		WLS Preventative Supplements			
	Dietary Reference Intake (DRI)	**Tolerable Upper Intake Level (UL) Daily Value (DV)**	**AGB**	**LSG**	**RYGB**	**BPD/DS**
Vit B 1	1.2 mg/d 14 yrs+ M 1.1 mg/d 19 yrs+ F	**UL:** none set; no reports of adverse effects from >50 mg B1/d from food or supplements **DV: 1.5 mg**	At least 12 mg/d At risk patients: at least 50 -100mg/d			
Vit B 12	2.4 ug/d 14 yrs+ M,F	**UL:** none set; due to its low potential for toxicity **DV: 6 ug**	350–500 ug/d oral, disintegrating tablet, SL or liquid or nasal – as directed or 1000 mcg/mo IM			
Folate	400 ug/d 19 yrs+ M,F	**UL:** 1000 mcg all ages & pregnancy **DV: 400 ug**	400–800 mcg oral 800–1000 mcg F childbearing ages			
Calcium	1000 mg/d 19–70 yrs M, 19–50 yrs F 1200 mg 51–70 + yrs F	**UL:** 2000–3000 mg /d **DV:** 1000 mg	1200–1500 mg/d			1800–2400 mg/d
Vit A	900 ug/d 14 yrs+ M; 700 ug/d 14 yrs+ F	**UL:** 10,000 IU/d (3000 mcg RAE/d)* retinol **DV:** 5000 IU	5000 IU/d		5000–10,000 IU/d	10,000 IU/d
Vit E	15 mg/d 14 yrs+ M,F	**UL:** 1000 mg/d (1500 IU/d) **DV:** 30 mg	15 mg/d			
Vit K	120 ug/d 19 yrs+ M 90 ug/d 19 yrs+ F	**UL:** none set; due to its low potential for toxicity **DV:** 80 ug	90–120 ug/d			300 ug/d
Vit D	600 IU/d (15 ug/d) 14 yrs+ M,F	**UL:** 4000 IU/d (100 ug/d) **DV:** 400 IU	At least 3000 IU/d to maintain D,25(OH) levels > 30 ng/mL			
Iron	8 mg/d 19 yrs+ M 8 mg/d 51 yrs+ F 18 mg/d 19–50 yrs F	**UL:** 45 mg/d **DV**: 18 mg	At least 18 mg/d from multivitamin	At least 45–60 mg/d in F with menses and/ patients with history of anemia		
Zinc	11 mg/d 19 yrs+ M 8 mg/d 19 yrs+ F	**UL:** 40 mg/d **DV:** 15mg	8–11 mg/d		8–11 mg/d to 16–22 mg/d	16–22 mg/d
Copper	900 ug/d 19 yrs+ M,F	**UL:** 10,000 mcg/d **DV**: 2 mg	1 mg/d		1–2 mg/d	2 mg/d

WLS =weight loss surgery; UL = upper intake level; DV = daily value; AGB = adjustable gastric band; LSG = laparoscopic sleeve gastrectomy; RYGB = Roux-en-Y gastric bypass; BPD/DS = biliopancreatic diversion/duodenal switch; SL = sublingual; IM = intramuscular; RAE = retinol activity equivalents; SQ = subcutaneous

Supplementation for non-WLS patients: Dietary Reference Intake (DRI), Daily Value (DV), Tolerable Upper Intake Level (UL) Supplementation for WLS patients: Actual dose for nutrients by type of WLS.

https://www.nal.usda.gov/sites/default/files/fnic_uploads//RDA_AI_vitamins_elements.pdf accessed 02/27/2017;
https://www.nal.usda.gov/sites/default/files/fnic_uploads//DRI_Elements.pdf accessed 02/27/2017

systematic reviews, clinical practice guidelines, epidemiologic/survey studies, consecutive case series, and single case reports.

Hierarchy of evidence

Risk of bias and level of confidence were evaluated using the AACE Protocol for Standardized Production of Clinical Practice Guidelines hierarchy of evidence framework [14]. Each article was assigned an evidence level (see Appendices B–E). This hierarchy does not include all possible types of study design. Studies reviewed that did not fall under the AACE hierarchy were integrated into our own hierarchy, guided by the Oxford Centre for Evidence-Based Medicine's levels of evidence framework [18].

Recommendation formulation and grading

Recommendations were formulated for each domain within each micronutrient category, with reference to the previous guidelines. Once this was completed, the grading strategy published by AACE was followed to provide consistent and systematic grades, with strongest to weakest levels noted as A through D and best evidence level from strongest to weakest noted as 1–4 for each recommendation [14]. There are 92 recommendations in this update: 79 new recommendations (noted by ☑ in Tables 1–4) and an additional 13 that have not changed since 2008 [1]. Each recommendation has a corresponding graded level of evidence:

- Grade A = Strong (4 ☑; 0 not changed)
- Grade B = Intermediate (29 ☑; 3 not changed)
- Grade C = Weak (33 ☑; 2 not changed)
- Grade D = No evidence (13 ☑; 8 not changed)

For recommendation Tables 1–6, please see the text. For Micronutrients: Evidence and Recommendations, please see Supplementary Materials.

Summary

This paper is an update of the ASMBS Nutrition Committee's Allied Health Nutritional Guidelines for the Surgical Weight Loss Patient (2008) [2] and serves as an educational tool not only for dietitians but also for other providers working with pre-WLS patients. The focus of this paper is to update the guidelines with findings from the current literature regarding key micronutrient deficiencies and WLS. As evidence-based guidelines continue to be updated and recommendations become more established in the daily practice of perioperative nutrition care, it will be important to investigate differences in responses to treatment and new potential mechanisms explaining changes in nutrient status. Additionally, controlling for confounding factors in nutrient-related studies (such as dietary intake of nutrients from both food and supplements; food-medication interactions; food-nutrient interactions; and whether, how, and by whom nutrition assessment and counseling is conducted) will increase the rigor of data collection and the consistency and quality of research reported.

The Nutrition Committee of the ASMBS Integrated Health Clinical Issues and Guidelines Committee sincerely hopes that this document will serve to enhance the general nutrition knowledge necessary for the care of pre- and postoperative patients, with consideration for the individual patient's unique medical needs, as well as the variable protocols established among surgical centers and individual practices.

Disclaimer

The American Society for Metabolic and Bariatric Surgery (ASMBS) is established as an educational professional medical society. This document is intended to update the 2008 ASMBS Allied Health Nutritional Guidelines for the Surgical Weight Loss Patient [2]. These guidelines are based on expert opinion as well as a literature review of empirical and clinical data and are not intended to serve as training, standard of care, or scientific consensus.

Disclosure

The authors have no commercial associations that might be a conflict of interest in relation to this article.

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Appendix

Supplementary Materials

Detailed supporting evidence and rationale for all micronutrient recommendations are provided in the Supplementary Materials associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.soard.2016.12.018.

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