Published in final edited form as:

Semin Pediatr Surg. 2020 February ; 29(1): 150889. doi:10.1016/j.sempedsurg.2020.150889.

Lifestyle and Pharmacologic Management Before and After Bariatric Surgery

Jaime M. Moore^{1,*}, Matthew A. Haemer¹, Claudia K. Fox²

¹University of Colorado Anschutz Medical Campus, Department of Pediatrics, Section of Nutrition, Aurora, Colorado, 80045

²University of Minnesota Masonic Children's Hospital, University of Minnesota Medical School, Center for Pediatric Obesity Medicine, Department of Pediatrics, Minneapolis, MN 55455

Abstract

As metabolic and bariatric surgery (MBS) increasingly becomes a treatment of choice for adolescents with severe obesity, there is a need to understand how to deliver pre- and postoperative care in ways that maximize long-term safety and efficacy. This article describes major pre- and postoperative goals, lifestyle modification targets, and, when necessary, pharmacologic management strategies for adolescents undergoing MBS. Three categories of evidence were used--studies of pre- and postoperative interventions and factors influencing MBS outcomes in adolescents, studies of pre- and postoperative associations and interventions in adults, and studies of non-surgical weight management applicable to adolescents pursuing MBS. Finally, priority areas for future research within this topic are identified.

Introduction

Metabolic and bariatric surgery (MBS) for the management of severe obesity in adolescents has been steadily increasing.¹ Although there are published consensus statements regarding the indications for MBS in this population,² there is little guidance on the optimal pre- and postoperative care of adolescents undergoing MBS. The purpose of this article is to present the key goals, lifestyle modification targets, and pharmacologic considerations in the pre- and postoperative phases of adolescents undergoing MBS. It is recognized that there are some physiological features of MBS that are common to both adults and adolescents, and therefore some of the adult recommendations for pre- and postoperative management may be extrapolated to adolescents. However, there are other distinct developmental differences which, in turn, dictate the need for adolescent specific recommendations. These differences and gaps in recommendations are highlighted.

*Corresponding Author: jaime.moore@cuanschutz.edu.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Preoperative Period

The goals of the preoperative period include:

1. Determine an individual's candidacy for MBS through a comprehensive, multidisciplinary medical and psychosocial evaluation.²
2. Perform diagnostic testing and interventions in order to minimize intraoperative and postoperative risk.
 - Evaluate and stabilize obesity-related co-morbidities (e.g. hypertension, diabetes); develop a plan for long-acting contraception in females; assess for and treat common micronutrient deficiencies that may exist preoperatively.
3. Provide goal-oriented education and anticipatory guidance on topics including nutrition, eating behaviors, and physical activity.
 - Aims include (re)introduction or refinement of fundamental lifestyle behaviors for healthy weight management in general and a detailed preview/practice of key skills specific to postoperative care.
4. Educate the patient and family on short- and long-term risks and benefits of MBS, including limitations of existing data on MBS in adolescents.
5. Fulfill preoperative requirements of any third-party payer (insurance), which can affect the frequency and duration of preoperative visits.

Weight Trajectory Expectation Preoperatively—There is no universally accepted standard for weight loss in the preoperative period for adults or adolescents. The preponderance of adult data show that while various preoperative lifestyle-based interventions can be effective in achieving weight loss prior to surgery and a modest reduction in hospital length of stay, these interventions have not been clearly associated with greater benefit postoperatively particularly in the domains of weight loss, morbidity, or mortality.^{3,4} In fact, longer presurgical periods caused by weight loss requirements increase dropout.^{5–7} However, the attainment of weight stabilization preoperatively may reflect a degree of patient and family adherence to key lifestyle-based behaviors. This, in turn, may provide the multidisciplinary team with a gauge of families' commitment to the MBS program.

Structure and Frequency of Visits—When considering the structure and frequency of preoperative visits, it is important to consider the objectives of preoperative care. As noted above, one objective is to satisfy the requirements of third party payers which are usually intended for adults and are not always supported by medical evidence.^{7–9} The ASMBS has taken a strong position against insurance-mandated weight loss requirements because they do not improve outcomes.⁸ Insurance programs often apply these adult requirements to adolescent candidates without consideration of their developmental differences.

Acknowledging the influence of third-party payers on current practice, evidence that might guide how adolescents *should* be evaluated and prepared for bariatric surgery

(absent administrative requirements) was examined. Overall, the components of effective preoperative care for adolescents have not been well studied. The 2018 ASMBS Pediatric MBS Guidelines are an excellent summary of recent evidence, though 36% (497/1387) of the papers reviewed included only adults and the guidelines did not focus on nonsurgical weight management approaches.²

The optimal frequency, duration, or content of visits prior to MBS has not been defined in adolescents. Adult studies seem clear that prolonged delay and nutritional counseling that is focused on strict outcomes of weight loss are not beneficial. In adolescence, executive function is not fully developed and family relationships strongly influence success after surgery.¹⁰ Therefore, a focus on building the self-management and relational skills important for healthy development and successful long-term weight management may be more appropriate for adolescents. As noted above, the optimal duration of time for preparation of the adolescent and family has not been defined, and may be individualized. In adults, one retrospective study found that those who were not required by an insurer to prepare for at least 6 months had better weight loss postoperatively than those required to diet for 6 months.⁹ This topic should be studied prospectively in adolescents to empirically determine the optimal timing of preoperative preparation in the younger age group.

There is also a lack of evidence examining surgical outcomes related to *frequency* and *content* of preoperative visits in adolescents. Attendance at preoperative support groups has been associated with better attendance at postoperative clinic visits, and support group attendance has been strongly associated with postoperative weight reduction in adults, so there may be value in establishing peer interactions to reduce loss to follow-up.^{11,12} For non-surgical weight management of children and adolescents, the US Preventive Services Task Force recommends comprehensive, family-centered, intensive behavioral interventions with 26 or more hours of contact, typically delivered in groups over 6–12 months.¹³ These recommendations for intensity of non-operative programs are focused on the optimal contact hours *for the intervention* and not a preparation for the intervention. Without prospective study, it is not possible to directly translate these recommendations to guide preoperative preparation for a surgical intervention. Also, families in many locations do not have access to intensive programs due to limits of insurance coverage and/or distribution of expertise. Moreover, such programs are typically more successful in treating less severe obesity, so participation should be encouraged before a child with obesity reaches a BMI meeting MBS criteria, and participation is *not* a prerequisite for MBS.²

Principles of effective weight management for children and adolescents include multidisciplinary care, family involvement, peer interactions, and frequent contact.¹³ Preoperative interventions that apply these principles could be studied for their effects on surgical outcomes in adolescents. Rather than adhering to an arbitrary timeframe, the duration and frequency of preoperative preparation should be tailored to the needs and abilities of each adolescent and family. The preoperative period should be adequate to complete preoperative medical, psychological, social, and dietary evaluations recommended by ASMBS as well as to assess and build skills for self-management that are judged to be important for success in weight management after surgery. Thus, surgery should be scheduled when the family and multi-disciplinary team reach a consensus decision that an

adolescent and family have the knowledge and skills to proceed safely and effectively with surgery. Preoperative preparation may differ based on baseline health, developmental level, executive capacity, and family relationships.

A recent comprehensive review of preparation for bariatric surgery in adults suggests that current practice meets insurance company requirements but fails to incorporate findings from the broader obesity treatment literature to deliver robust and evidence-based interventions.⁷ Some factors that evidence suggests could be important targets for preoperative intervention are described below.

Nutrition and Eating Behaviors—While bariatric surgery is, on average, the most effective and durable approach to treating severe obesity in adolescents, it is not universally successful. In the Teen Longitudinal Assessment of Bariatric Surgery (Teen-LABS) study, a prospective, observational study of adolescents undergoing MBS across five US sites, 40% of adolescents who underwent Roux-en-Y gastric bypass (RYGB) failed to maintain at least 20% weight reduction at five years after surgery, including 4% who maintained less than 5% loss and 4% who exceeded their baseline weight.¹⁴ The observation that 2 of 5 adolescents did not maintain goal weight reduction highlights a need to investigate adjunctive pre- and postoperative interventions to improve success rates. The association between eating behaviors and surgical outcomes has been examined, with almost all data coming from observational studies of adults. However, many randomized-controlled trials (RCTs) of non-surgical weight loss interventions have identified interventions focused on eating behaviors that may be reasonably hypothesized to improve outcomes for surgical candidates.

Problematic eating behaviors are strongly associated with depression, lower quality of life, and poor weight loss for adults and adolescents undergoing bariatric surgery.^{15–20} Loss of control (LOC) eating, which has been conceptualized to include both grazing (loss of control with repetitive snacking) and binge eating (loss of control with very large portions) is highly prevalent among adolescents (15–28%) and adults (31–61%) seeking bariatric surgery.^{16,19} Within the Teen-LABS cohort, episodic and continuous LOC eating has been studied over time. Continuous LOC eating was most prevalent at baseline, observed in 28%, declined rapidly within the first 6 months postoperatively, and was reported by 13% at 4 years. In some, these symptoms were recurrent while for another portion of participants, LOC eating was a newly reported issue.¹⁶ The 2018 ASMBS pediatric guidelines recommend preoperative assessment for LOC eating and treatment with cognitive behavioral therapy, family-based therapy, executive skill-building, and/or in the case of binge eating disorder, pharmacotherapy,² and the recently published Teen-LABS data adds further support for this recommendation.

One strategy to decrease LOC eating is to practice mindfulness, which requires executive function to engage in nonjudgmental awareness of thoughts, emotions, and sensations. The practice of mindfulness skills is associated with less LOC eating among adults seeking bariatric surgery.²¹ Mindfulness also targets eating in the absence of hunger, including eating past the point of fullness, or eating in response to non-hunger cues, which are associated with poor weight loss after surgery.^{22,23} Studies of brain physiology demonstrate

that objectively measured executive function impacts surgical weight loss. Preoperative functional brain MRI showed that adults who activated cortical areas for self-regulation in response to food stimuli preoperatively lost more weight postoperatively.²⁴ Mindfulness can be trained through low intensity interventions that are highly effective (Cohen's $d > 0.80$) at reducing LOC eating and eating in the absence of hunger, according to a metaanalysis of 12 non-surgical weight management RCTs, a few of which included adolescents.^{25–29} Adding mindfulness training to an already effective adult non-surgical weight management program increased weight loss.²⁶

Factors that support following ASMBS guidelines to intervene on LOC eating preoperatively include: interventions to reduce LOC eating are effective, should be feasible in the preoperative period, and would be less practical to start postoperatively when surveillance opportunities for LOC eating are less frequent. Because LOC eating strongly predicts depression, low quality of life, and poor weight outcomes, a proactive approach seems advisable. Risks of intervening on LOC are minimal compared to the large potential benefits of such intervention.

Preoperative Micronutrient Evaluation—Recommendations for screening for micronutrient deficiencies before MBS in adolescents are extrapolated from adult data, which were recently updated by Parrott et al.³⁰ To improve the application of these recommendations to the adolescent population, it is important to consider the prevalence of micronutrient deficiencies in cohorts of adolescents with severe obesity seeking bariatric surgery. For example, while Parrot et al. and the 2018 ASMBS pediatric guidelines suggest universal preoperative testing of B1, B12, and folate, the reported prevalence of deficiency of these in adolescents with severe obesity is 0–1%, 0–1%, and 0–4%, respectively.^{31,32} Accordingly, it may be prudent to screen all adolescent patients for iron and vitamin D deficiencies, and evaluate other micronutrients only in those with specific risk factors, as illustrated in Table 1.

Physical Activity—The 2018 Physical Activity Guidelines for Americans recommend that adolescents complete at least 60 minutes per day of moderate to vigorous aerobic, muscle- and/or bone-strengthening activities.³³ Weight-related joint pain and other musculoskeletal comorbidities (e.g. slipped capital femoral epiphysis), which significantly impair functional mobility,^{34,35} often make this goal very difficult to achieve for adolescents with severe obesity. In adults, a limited number of RCTs evaluating preoperative exercise interventions have demonstrated associations between greater preoperative physical activity/physical fitness and health-related quality of life,^{36,37} and greater postoperative physical activity and physical fitness up to 1 year.^{38,39} The relationship between preoperative physical activity and postoperative weight loss and body composition in adults is less clear. The effects of preoperative physical activity in adolescents has not been well studied. A single US adolescent bariatric surgery center found that 1) adolescents who report receiving more support from family and friends to exercise also report engaging in more preoperative exercise,⁴⁰ and 2) adolescents who report exercising at least 5 hours per week preoperatively vs. lower amounts have greater weight loss at 6 and 12 months following sleeve gastrectomy (SG).⁴¹

Pharmacotherapy—The use of pharmacotherapy in the preoperative period can be evaluated from two distinct vantage points: the role of potentially obesogenic concomitant medications and the role of anti-obesity pharmacotherapy to enhance presurgical weight loss and co-morbidity improvement. Regarding the former, avoiding the use of medications which may promote weight gain is not unique to the MBS patient but is an important weight management principle for anyone with obesity.⁴² In particular, many of the medications used to treat weight-related co-morbidities have the potential to cause weight gain. Accordingly, when possible, less obesogenic alternatives should be utilized. Although there are no published guidelines that explicitly address this in the pediatric population, it is a logical to extend adult recommendations to children and adolescents. For example, among adults with obesity, it is recommended that angiotensin converting enzyme (ACE) inhibitors or angiotensin receptor blockers (ARBs) should be used for the management of hypertension, instead of beta blockers, and combination oral contraceptives are preferable to injectable progestins.⁴² Furthermore, for adults with type 2 diabetes mellitus (T2DM) and overweight/obesity, it is recommended that weight-losing or weight-neutral medications should be used for first- and second-line treatments for T2DM. Specifically, it is recommended that for adults with obesity and T2DM requiring insulin, metformin or glucagon like peptide-1 agonists, such as liraglutide or exenatide, should be added. While liraglutide was in June of 2019 approved by the FDA for the indication of T2DM in children 10 years of age,⁴³ pediatric T2DM guidelines have not yet been updated to include this treatment strategy.

The role of adjunct anti-obesity pharmacotherapy for presurgical patients has not been studied systematically in adolescents *or* adults. In adolescents, only one medication, orlistat, was FDA-approved for the indication of obesity, though several others have been studied for this indication. These include metformin,⁴⁴ phentermine,⁴⁵ topiramate,⁴⁶ and exenatide.⁴⁷ While expert committee recommendations suggest that use of anti-obesity pharmacotherapy be considered for adolescents with obesity complicated by weight-related co-morbidities or for those with severe obesity, irrespective of co-morbidity status,^{48,49} there is no guidance on the use of anti-obesity pharmacotherapy specifically for those adolescents who are being prepared for surgical therapy. Indeed, as indicated above, the role of presurgical weight loss as a strategy to improve postoperative outcomes is not clear. In exceptional cases, where the adolescent has extremely severe obesity (i.e. BMI > 60 or 70 kg/m²), and preoperative weight loss is strongly desired to decrease perioperative and surgical risks, anti-obesity pharmacotherapy may have a role. Furthermore, there is as of yet no evidence that the use of anti-obesity pharmacotherapy to improve weight-related co-morbidities in the presurgical phase has an effect on peri or postsurgical outcomes. Therefore, the use of obesity pharmacotherapy before surgery in adolescents is individualized, and based on the clinical judgement of the providers on the adolescent bariatric treatment team.

Postoperative Period

The goals of the postoperative period include:

1. Minimize risk of medical and surgical complications in the immediate postoperative period.
2. Provide guidance and oversight during the period of dietary advancement.

3. Perform targeted surveillance and treatment of micronutrient deficiencies.
4. Provide an individualized physical activity plan that can enhance weight loss, promote weight loss maintenance, and/or help to treat weight regain.
5. Systematically identify decreased weight loss velocity, plateau, or regain, assess for underlying etiologies (e.g. anatomic concerns, reversion to unhealthy eating behaviors), and intervene using lifestyle intensification, adjunct pharmacotherapy, and/or revisional surgery as indicated.
6. Communicate and identify areas of collaboration with the primary care physician.
 - These may include shared efforts to reduce attrition for bariatric surgery follow-up care, to improve adherence to lifelong lifestyle recommendations, and to transition the patient to an adult weight management medical home.

Structure/Frequency of Visits: For adolescents, the optimal frequency of visits and the provider type involved in the visits after MBS to ensure long-term success is unknown. Clinical practice guidelines for adults who undergo SG or RYGB, recommend postoperative visits at 1-month, 3–6 months, and then every 12 months to monitor weight change, co-morbidity status, adherence to dietary and physical activity recommendations, and to screen for nutrient deficiencies.⁵⁰ Because adolescence is a time of rapid physiological, psychological, and social change, more frequent postoperative visits may be indicated in this population.

Dietary Advancement—In the immediate postoperative period, initiation of a sugar-free clear liquid diet as soon as possible as part of an enhanced recovery after surgery (ERAS) protocol is considered a best practice for adults,⁵¹ and has been adopted by some adolescent MBS centers. In adolescents, the first 30 days after surgery represent a higher risk period for readmissions secondary to abdominal pain, nausea, and dehydration.⁵² Structured phone calls to review pain, nausea and ability to meet hydration, protein, and micronutrient goals may facilitate early interventions, but has not been specifically studied in adolescents. Postoperatively, there is not any one prescribed set of dietary stages that define standard of care.^{53,54} Consequently, there is variation in the limited published literature regarding the recommended number and duration of postoperative diet stages, caloric goals, and specific breakdown of macronutrients.⁵⁵ In adults, greater caloric restriction at 6 months postoperatively has been associated with significantly greater weight loss up to 10 years after surgery, but the ideal macronutrient composition of the postoperative meal plan to maximize weight loss or achieve weight loss maintenance has not been determined.^{56,57} Unifying features across protocols, regardless of surgical procedure, include gradual advancement in texture/complexity, slowly increasing portion sizes, delayed introduction of carbohydrates, small/frequent meals and snacks, and prioritization of protein intake with the goal of preserving lean body mass.^{58,59} A sample postoperative diet stage progression is shown in Table 2.

Anticipatory education about the postoperative nutrition plan is typically provided by a registered dietitian early and with repetition in the preoperative period and includes: a review of the diet stages, skill-building including weighing, measuring and self-monitoring, and selection of high protein very low carbohydrate products and vitamins/minerals that will be needed after surgery. Grocery lists and sample menus/schedules for each stage are practical aids to provide to families.

Micronutrient supplementation—The lifelong need for micronutrient supplementation after MBS is necessitated by decreased oral intake (both volume and variety) and anatomic changes that alter bioabsorption and utilization of vitamins and minerals. Current adolescent recommendations following RYGB and SG have largely been extrapolated from adult data,³⁰ though important differences exist during this dynamic period of growth and development and warrant further study. Large, prospective trials of adolescents 3–12 years after surgery demonstrate very high rates of iron deficiency with and without anemia in both sexes that progress over time, as well as vitamin D and B12 deficiencies.^{31,60,61} RYGB, compared to SG, poses a higher risk for fat malabsorption and related fat-soluble vitamin (ADEK) deficiencies. Recommended preventive postoperative supplementation includes vitamin B1 for 6 months (with the highest risk of deficiency in the first few weeks after surgery, especially in the setting of poor intake and vomiting), and daily lifelong intake of vitamin B12, multivitamin with iron, calcium, and vitamin D. Higher *treatment* doses of specific micronutrients are required if deficiencies develop. Table 1 summarizes suggested screening and preventive supplementation of key micronutrients. Adolescents' known poor adherence to oral micronutrient supplementation (27% at 6 months postoperatively in one of the only studies that has objectively measured this behavior), underscores the need for regular screening, and development of novel routes/schedules of administration.⁶²

Physical Activity—After MBS, adolescents in the Teen-LABS study demonstrated improvements in resting heart rate, heart rate response to exercise, and a reduction in walking-associated musculoskeletal pain, beginning at 6 months postoperatively, which was maintained up to 2 years.⁶³ Participants in the Adolescent Morbid Obesity Surgery (AMOS) study, a national prospective study of adolescents undergoing RYGB in Sweden, showed improvements in walking distance and maximal oxygen consumption through 2 years after surgery.⁶⁴ Overall, these changes indicate improved physical functional capacity and represent an important opportunity to advance physical activity goals postoperatively. Adolescents, like adults, experience significant losses in both fat and fat free mass during the first postoperative year, which appear to stabilize thereafter.⁶⁴ Physical activities that include resistance training can preserve or increase fat free mass,⁶⁵ which is the primary determinant of resting energy expenditure,⁶⁶ and may be a critical factor in maintaining weight loss. However, no exercise intervention studies in the postbariatric setting in adolescents were found, so this hypothesis still needs to be tested. In adults, objective measures of physical activity (e.g. accelerometers/other physiologic sensors), demonstrate that postbariatric physical activity and sedentary behaviors improve very modestly if at all and differ dramatically from self-report.⁶⁷ For adults engaged in postoperative physical activity interventions, a 2018 meta-analysis of eight RCTs⁶⁸ found improved physical function and a modest weight loss benefit (mean difference –1.94kg) for those assigned

to any exercise intervention compared to controls. Furthermore, the combination of aerobic and resistance exercise compared to either alone was associated with greater weight loss. Regarding cardiometabolic benefits in adults, there is also evidence for a dose-dependent effect of postoperative exercise on insulin sensitivity, and a minimum exercise duration threshold (4–5 hours per week) to achieve greater weight loss, lower fat mass, improved maximal oxygen consumption, and greater skeletal muscle mitochondrial capacity.⁶⁹

Treating Weight Regain:

The causes of weight regain after MBS in adolescents have not been examined extensively. One study of 50 adolescents who underwent bariatric surgery assessed predictors of weight regain at eight years after surgery. This study found no significant difference in weight-related behaviors (i.e. sitting more than 3 hours per day) or eating behaviors (i.e. eating 60 grams protein per day or limiting volume of food to 1.5 cups per meal) between those who maintained weight loss and those who regained weight. Only quality of life was different – being lower in those who regained weight.⁷⁰ In addition to being a small study, it is not clear if improving quality of life will reduce postoperative weight regain. Another study, this one examining the Teen-LABS cohort, identified that LOC eating at 1, 2, and 3 years postoperatively was associated with lower percent BMI change from baseline at the next consecutive postoperative visit.¹⁶

For adults, it has been fairly well established that postsurgical weight regain is multifactorial and may include both anatomic/surgical factors (for example pouch/sleeve/stoma dilation) and patient-related factors (such as dietary non-compliance, mental illness, and metabolic disorders). There are no guidelines for adolescents regarding the evaluation for inadequate initial weight loss or weight regain after surgical treatment, nor evidence based recommendations for subsequent revisional surgery. A comprehensive assessment of lifestyle behaviors and family functioning may provide insight into contributors to the weight regain. For example, a review of the patient's diet may reveal food intolerances which may lead to maladaptive eating behaviors, such as avoiding protein rich foods. Review of eating behaviors may uncover a return to food cravings, strong hunger, binge eating, grazing, or emotional eating. Once identified, the appropriate interventions can then be implemented. This may include re-engaging more frequently with a bariatric dietitian and/or psychologist, returning to self-monitoring and stimulus control, or cognitive behavioral therapy.⁷¹ The type and timing of physical activity to prevent or treat weight regain after bariatric surgery has not been well established in any age. Existing adult data in the broader obesity literature, not specific to bariatric surgery, suggest that weight loss maintenance likely requires more exercise than what is recommended to lose weight (150 minutes/week) and may approach >250minutes/week.⁷² Obesity pharmacotherapy may additionally have a role in treating weight regain, however, again, only a handful of small retrospective studies have been reported on the topic and none in the pediatric population. The largest study included a sample of 319 adults whose data were pooled from two institutions.⁷³ The most frequently prescribed medications used to treat postsurgical weight regain were topiramate, phentermine, metformin, bupropion, and zonisamide. Importantly, evidence suggests that starting obesity pharmacotherapy at the time that the patient reaches weight loss plateau instead of waiting until weight regain may provide the best overall

weight outcomes. Currently, a double-blind placebo controlled study of liraglutide for weight regain 18 months after RYGB is underway [NCT03048578],⁷⁴ but does not include adolescents.

Conclusion

While there is clear evidence supporting the safety and efficacy of MBS in adolescents with severe obesity, many questions remain as to how the medical management of these adolescents in the pre- and postoperative periods can best enhance and sustain the beneficial effects of MBS. Future areas of research should take into account the physical, cognitive, and social maturation that defines adolescence, which may reveal important differences in their care before and after MBS compared to adults. Suggested priority areas for future study are presented in Table 3

References

1. Kyler KE, Bettenhausen JL, Hall M, Fraser JD, Sweeney B. Trends in Volume and Utilization Outcomes in Adolescent Metabolic and Bariatric Surgery at Children's Hospitals. *J Adolesc Health*. 2019;65(3):331–336. [PubMed: 31196785]
2. Pratt JSA, Browne A, Browne NT, et al. ASMBS pediatric metabolic and bariatric surgery guidelines, 2018. *Surg Obes Relat Dis*. 2018;14(7):882–901. [PubMed: 30077361]
3. Roman M, Monaghan A, Serraino GF, et al. Meta-analysis of the influence of lifestyle changes for preoperative weight loss on surgical outcomes. *Br J Surg*. 2019;106(3):181–189. [PubMed: 30328098]
4. Ochner CN, Dambkowski CL, Yeomans BL, Teixeira J, Xavier Pi-Sunyer F. Pre-bariatric surgery weight loss requirements and the effect of preoperative weight loss on postoperative outcome. *Int J Obes (Lond)*. 2012;36(11):1380–1387. [PubMed: 22508337]
5. Kalarchian MA, Marcus MD, Courcoulas AP, Cheng Y, Levine MD. Preoperative lifestyle intervention in bariatric surgery: a randomized clinical trial. *Surgery for obesity and related diseases : official journal of the American Society for Bariatric Surgery*. 2016;12(1):180–187. [PubMed: 26410538]
6. Love KM, Mehaffey JH, Safavian D, et al. Bariatric surgery insurance requirements independently predict surgery dropout. *Surgery for obesity and related diseases : official journal of the American Society for Bariatric Surgery*. 2017;13(5):871–876. [PubMed: 28233687]
7. Tewksbury C, Williams NN, Dumon KR, Sarwer DB. Preoperative Medical Weight Management in Bariatric Surgery: a Review and Reconsideration. *Obes Surg*. 2017;27(1):208–214. [PubMed: 27761723]
8. Kim JJ, Rogers AM, Ballem N, Schirmer B. ASMBS updated position statement on insurance mandated preoperative weight loss requirements. *Surgery for obesity and related diseases : official journal of the American Society for Bariatric Surgery*. 2016;12(5):955–959. [PubMed: 27523728]
9. Keith CJ Jr., Goss LE, Blackledge CD, Stahl RD, Grams J. Insurance-mandated preoperative diet and outcomes after bariatric surgery. *Surgery for obesity and related diseases : official journal of the American Society for Bariatric Surgery*. 2018;14(5):631–636. [PubMed: 29454535]
10. Zeller MH, Hunsaker S, Mikhail C, et al. Family factors that characterize adolescents with severe obesity and their role in weight loss surgery outcomes. *Obesity (Silver Spring)*. 2016;24(12):2562–2569. [PubMed: 27753228]
11. Sawhney P, Modi AC, Jenkins TM, et al. Predictors and outcomes of adolescent bariatric support group attendance. *Surgery for obesity and related diseases : official journal of the American Society for Bariatric Surgery*. 2013;9(5):773–779. [PubMed: 23810608]
12. Robinson AH, Adler S, Stevens HB, Darcy AM, Morton JM, Safer DL. What variables are associated with successful weight loss outcomes for bariatric surgery after 1 year? *Surgery for*

obesity and related diseases : official journal of the American Society for Bariatric Surgery. 2014;10(4):697–704. [PubMed: 24913590]

13. Grossman DC, Bibbins-Domingo K, Curry SJ, et al. Screening for Obesity in Children and Adolescents: US Preventive Services Task Force Recommendation Statement. *Jama*. 2017;317(23):2417–2426. [PubMed: 28632874]
14. Inge TH, Courcoulas AP, Jenkins TM, et al. Five-Year Outcomes of Gastric Bypass in Adolescents as Compared with Adults. *N Engl J Med*. 2019;380(22):2136–2145. [PubMed: 31116917]
15. Utzinger LM, Govey MA, Zeller M, et al. Loss of control eating and eating disorders in adolescents before bariatric surgery. *Int J Eat Disord*. 2016;49(10):947–952. [PubMed: 27196378]
16. Goldschmidt AB, Khoury J, Jenkins TM, et al. Adolescent Loss-of-Control Eating and Weight Loss Maintenance After Bariatric Surgery. *Pediatrics*. 2018;141(1).
17. Smith KE, Orcutt M, Steffen KJ, et al. Loss of Control Eating and Binge Eating in the 7 Years Following Bariatric Surgery. *Obes Surg*. 2019;29(6):1773–1780. [PubMed: 30820886]
18. Kalarchian MA, King WC, Devlin MJ, et al. Psychiatric Disorders and Weight Change in a Prospective Study of Bariatric Surgery Patients: A 3-Year Follow-Up. *Psychosomatic medicine*. 2016;78(3):373–381. [PubMed: 26569540]
19. White MA, Kalarchian MA, Masheb RM, Marcus MD, Grilo CM. Loss of control over eating predicts outcomes in bariatric surgery patients: a prospective, 24-month follow-up study. *The Journal of clinical psychiatry*. 2010;71(2):175–184. [PubMed: 19852902]
20. Sysko R, Devlin MJ, Hildebrandt TB, Brewer SK, Zitsman JL, Walsh BT. Psychological outcomes and predictors of initial weight loss outcomes among severely obese adolescents receiving laparoscopic adjustable gastric banding. *The Journal of clinical psychiatry*. 2012;73(10):1351–1357. [PubMed: 23140654]
21. Levin ME, Dalrymple K, Himes S, Zimmerman M. Which facets of mindfulness are related to problematic eating among patients seeking bariatric surgery? *Eat Behav*. 2014;15(2):298–305. [PubMed: 24854822]
22. Mitchell JE, Christian NJ, Flum DR, et al. Postoperative Behavioral Variables and Weight Change 3 Years After Bariatric Surgery. *JAMA surgery*. 2016;151(8):752–757. [PubMed: 27096225]
23. Courcoulas AP, Christian NJ, O'Rourke RW, et al. Preoperative factors and 3-year weight change in the Longitudinal Assessment of Bariatric Surgery (LABS) consortium. *Surgery for obesity and related diseases : official journal of the American Society for Bariatric Surgery*. 2015;11(5):1109–1118. [PubMed: 25824474]
24. Ness A, Bruce J, Bruce J, et al. Pre-surgical cortical activation to food pictures is associated with weight loss following bariatric surgery. *Surgery for obesity and related diseases : official journal of the American Society for Bariatric Surgery*. 2014;10(6):1188–1195. [PubMed: 25443066]
25. Ruffault A, Czernichow S, Hagger MS, et al. The effects of mindfulness training on weight-loss and health-related behaviours in adults with overweight and obesity: A systematic review and meta-analysis. *Obesity research & clinical practice*. 2017;11(5 Suppl 1):90–111. [PubMed: 27658995]
26. Spadaro KC, Davis KK, Sereika SM, Gibbs BB, Jakicic JM, Cohen SM. Effect of mindfulness meditation on short-term weight loss and eating behaviors in overweight and obese adults: A randomized controlled trial. *Journal of complementary & integrative medicine*. 2017;15(2).
27. Hendrickson KL, Rasmussen EB. Mindful eating reduces impulsive food choice in adolescents and adults. *Health Psychol*. 2017;36(3):226–235. [PubMed: 27808529]
28. Dalen J, Brody JL, Staples JK, Sedillo D. A Conceptual Framework for the Expansion of Behavioral Interventions for Youth Obesity: A Family-Based Mindful Eating Approach. *Child Obes*. 2015;11(5):577–584. [PubMed: 26325143]
29. Dunn C, Haubenreiser M, Johnson M, et al. Mindfulness Approaches and Weight Loss, Weight Maintenance, and Weight Regain. *Current obesity reports*. 2018;7(1):37–49. [PubMed: 29446036]
30. Parrott J, Frank L, Rabena R, Craggs-Dino L, Isom KA, Greiman L. American Society for Metabolic and Bariatric Surgery Integrated Health Nutritional Guidelines for the Surgical Weight Loss Patient 2016 Update: Micronutrients. *Surg Obes Relat Dis*. 2017;13(5):727–741. [PubMed: 28392254]

31. Henfridsson P, Laurenius A, Wallengren O, et al. Micronutrient intake and biochemistry in adolescents adherent or nonadherent to supplements 5 years after Roux-en-Y gastric bypass surgery. *Surg Obes Relat Dis*. 2019.
32. Inge TH, Courcoulas AP, Jenkins TM, et al. Weight Loss and Health Status 3 Years after Bariatric Surgery in Adolescents. *N Engl J Med*. 2016;374(2):113–123. [PubMed: 26544725]
33. Piercy KL, Troiano RP, Ballard RM, et al. The Physical Activity Guidelines for Americans. *JAMA*. 2018;320(19):2020–2028. [PubMed: 30418471]
34. Bout-Tabaku S, Michalsky MP, Jenkins TM, et al. Musculoskeletal Pain, Self-reported Physical Function, and Quality of Life in the Teen-Longitudinal Assessment of Bariatric Surgery (Teen-LABS) Cohort. *JAMA Pediatr*. 2015;169(6):552–559. [PubMed: 25915190]
35. Perry DC, Metcalfe D, Lane S, Turner S. Childhood Obesity and Slipped Capital Femoral Epiphysis. *Pediatrics*. 2018;142(5).
36. Bond DS, Thomas JG, King WC, et al. Exercise improves quality of life in bariatric surgery candidates: results from the Bari-Active trial. *Obesity (Silver Spring)*. 2015;23(3):536–542. [PubMed: 25611582]
37. Baillot A, Mampuya WM, Dionne IJ, Comeau E, Meziat-Burdin A, Langlois MF. Impacts of Supervised Exercise Training in Addition to Interdisciplinary Lifestyle Management in Subjects Awaiting Bariatric Surgery: a Randomized Controlled Study. *Obes Surg*. 2016;26(11):2602–2610. [PubMed: 27038045]
38. Baillot A, Vallee CA, Mampuya WM, et al. Effects of a Pre-surgery Supervised Exercise Training 1 Year After Bariatric Surgery: a Randomized Controlled Study. *Obes Surg*. 2018;28(4):955–962. [PubMed: 28963710]
39. Bond DS, Thomas JG, Vithiananthan S, et al. Intervention-related increases in preoperative physical activity are maintained 6-months after Bariatric surgery: results from the bari-active trial. *Int J Obes (Lond)*. 2017;41(3):467–470. [PubMed: 28025574]
40. Mackey ER, Olson A, Merwin S, Wang J, Nadler EP. Perceived Social Support for Exercise and Weight Loss in Adolescents Undergoing Sleeve Gastrectomy. *Obes Surg*. 2018;28(2):421–426. [PubMed: 28770423]
41. Mackey ER, Jacobs M, Nadler EP. Preoperative exercise as a predictor of weight loss in adolescents and young adults following sleeve gastrectomy: a cohort study. *Surg Obes Relat Dis*. 2019;15(7):1051–1057. [PubMed: 31130404]
42. Apovian CM, Aronne LJ, Bessesen DH, et al. Pharmacological management of obesity: an endocrine Society clinical practice guideline. *J Clin Endocrinol Metab*. 2015;100(2):342–362. [PubMed: 25590212]
43. Tamborlane WV, Barrientos-Perez M, Fainberg U, et al. Liraglutide in Children and Adolescents with Type 2 Diabetes. *N Engl J Med*. 2019;381(7):637–646. [PubMed: 31034184]
44. McDonagh MS, Selph S, Ozpinar A, Foley C. Systematic review of the benefits and risks of metformin in treating obesity in children aged 18 years and younger. *JAMA pediatrics*. 2014;168(2):178–184. [PubMed: 24343296]
45. Ryder JR, Kaizer A, Rudser KD, Gross A, Kelly AS, Fox CK. Effect of phentermine on weight reduction in a pediatric weight management clinic. *Int J Obes (Lond)*. 2017;41(1):90–93. [PubMed: 27773937]
46. Fox CK, Kaizer AM, Rudser KD, et al. Meal replacements followed by topiramate for the treatment of adolescent severe obesity: A pilot randomized controlled trial. *Obesity (Silver Spring)*. 2016;24(12):2553–2561. [PubMed: 27807925]
47. Kelly AS, Rudser KD, Nathan BM, et al. The effect of glucagon-like peptide-1 receptor agonist therapy on body mass index in adolescents with severe obesity: a randomized, placebo-controlled, clinical trial. *JAMA Pediatr*. 2013;167(4):355–360. [PubMed: 23380890]
48. Barlow SE, Expert C. Expert committee recommendations regarding the prevention, assessment, and treatment of child and adolescent overweight and obesity: summary report. *Pediatrics*. 2007;120 Suppl 4:S164–192. [PubMed: 18055651]
49. Srivastava G, Fox CK, Kelly AS, et al. Clinical Considerations Regarding the Use of Obesity Pharmacotherapy in Adolescents with Obesity. *Obesity (Silver Spring)*. 2019;27(2):190–204. [PubMed: 30677262]

50. Mechanick JI, Youdim A, Jones DB, et al. Clinical practice guidelines for the perioperative nutritional, metabolic, and nonsurgical support of the bariatric surgery patient—2013 update: cosponsored by American Association of Clinical Endocrinologists, The Obesity Society, and American Society for Metabolic & Bariatric Surgery. *Obesity (Silver Spring)*. 2013;21 Suppl 1:S1–27. [PubMed: 23529939]
51. Malczak P, Pisarska M, Piotr M, Wysocki M, Budzynski A, Pedziwiatr M. Enhanced Recovery after Bariatric Surgery: Systematic Review and Meta-Analysis. *Obes Surg*. 2017;27(1):226–235. [PubMed: 27817086]
52. Inge TH, Zeller MH, Jenkins TM, et al. Perioperative outcomes of adolescents undergoing bariatric surgery: the Teen-Longitudinal Assessment of Bariatric Surgery (Teen-LABS) study. *JAMA Pediatr*. 2014;168(1):47–53. [PubMed: 24189578]
53. Aills L, Blankenship J, Buffington C, Furtado M, Parrott J. ASMBS Allied Health Nutritional Guidelines for the Surgical Weight Loss Patient. *Surg Obes Relat Dis*. 2008;4(5 Suppl):S73–108. [PubMed: 18490202]
54. Heber D, Greenway FL, Kaplan LM, Livingston E, Salvador J, Still C. Endocrine and nutritional management of the post-bariatric surgery patient: an Endocrine Society Clinical Practice Guideline. *J Clin Endocrinol Metab*. 2010;95(11):4823–4843. [PubMed: 21051578]
55. Fullmer MA, Abrams SH, Hrovat K, et al. Nutritional strategy for adolescents undergoing bariatric surgery: report of a working group of the Nutrition Committee of NASPGHAN/NACHRI. *J Pediatr Gastroenterol Nutr*. 2012;54(1):125–135. [PubMed: 21857247]
56. <Kanerva et al. - 2017 - Changes in total energy intake and macronutrient c.pdf>.
57. Swenson BR, Saalwachter Schulman A, Edwards MJ, et al. The effect of a low-carbohydrate, high-protein diet on post laparoscopic gastric bypass weight loss: a prospective randomized trial. *J Surg Res*. 2007;142(2):308–313. [PubMed: 17631904]
58. Schollenberger AE, Karschin J, Meile T, Kuper MA, Konigsrainer A, Bischoff SC. Impact of protein supplementation after bariatric surgery: A randomized controlled double-blind pilot study. *Nutrition*. 2016;32(2):186–192. [PubMed: 26691769]
59. Henfridsson P, Laurenius A, Wallengren O, et al. Five-year changes in dietary intake and body composition in adolescents with severe obesity undergoing laparoscopic Roux-en-Y gastric bypass surgery. *Surg Obes Relat Dis*. 2019;15(1):51–58. [PubMed: 30497848]
60. Inge TH, Courcoulas AP, Jenkins TM, et al. Weight Loss and Health Status 3 Years after Bariatric Surgery in Adolescents. *N Engl J Med*. 2016;374(2):113–123. [PubMed: 26544725]
61. Inge TH, Jenkins TM, Xanthakos SA, et al. Long-term outcomes of bariatric surgery in adolescents with severe obesity (FABS-5+): a prospective follow-up analysis. *The lancet Diabetes & endocrinology*. 2017;5(3):165–173. [PubMed: 28065736]
62. Modi AC, Zeller MH, Xanthakos SA, Jenkins TM, Inge TH. Adherence to vitamin supplementation following adolescent bariatric surgery. *Obesity (Silver Spring)*. 2013;21(3):E190–195. [PubMed: 23404956]
63. Ryder JR, Edwards NM, Gupta R, et al. Changes in Functional Mobility and Musculoskeletal Pain After Bariatric Surgery in Teens With Severe Obesity: Teen-Longitudinal Assessment of Bariatric Surgery (LABS) Study. *JAMA Pediatr*. 2016;170(9):871–877. [PubMed: 27429076]
64. Brissman M, Ekblom K, Hagman E, et al. Physical Fitness and Body Composition Two Years after Roux-En-Y Gastric Bypass in Adolescents. *Obes Surg*. 2017;27(2):330–337. [PubMed: 27379769]
65. Hassannejad A, Khalaj A, Mansournia MA, Rajabian Tabesh M, Alizadeh Z. The Effect of Aerobic or Aerobic-Strength Exercise on Body Composition and Functional Capacity in Patients with BMI ≥ 35 after Bariatric Surgery: a Randomized Control Trial. *Obes Surg*. 2017;27(11):2792–2801. [PubMed: 28527156]
66. Nelson KM, Weinsier RL, Long CL, Schutz Y. Prediction of resting energy expenditure from fat-free mass and fat mass. *Am J Clin Nutr*. 1992;56(5):848–856. [PubMed: 1415003]
67. Bond DS, Thomas JG. Measurement and Intervention on Physical Activity and Sedentary Behaviours in Bariatric Surgery Patients: Emphasis on Mobile Technology. *Eur Eat Disord Rev*. 2015;23(6):470–478. [PubMed: 26331982]

68. Ren ZQ, Lu GD, Zhang TZ, Xu Q. Effect of physical exercise on weight loss and physical function following bariatric surgery: a meta-analysis of randomised controlled trials. *BMJ open*. 2018;8(10):e023208.
69. Woodlief TL, Carnero EA, Standley RA, et al. Dose response of exercise training following roux-en-Y gastric bypass surgery: A randomized trial. *Obesity (Silver Spring)*. 2015;23(12):2454–2461. [PubMed: 26537198]
70. Ryder JR, Gross AC, Fox CK, et al. Factors associated with long-term weight-loss maintenance following bariatric surgery in adolescents with severe obesity. *Int J Obes (Lond)*. 2018;42(1):102–107. [PubMed: 28894289]
71. Paul L, van der Heiden C, Hoek HW. Cognitive behavioral therapy and predictors of weight loss in bariatric surgery patients. *Curr Opin Psychiatry*. 2017;30(6):474–479. [PubMed: 28795980]
72. Chin SH, Kahathuduwa CN, Binks M. Physical activity and obesity: what we know and what we need to know. *Obes Rev*. 2016;17(12):1226–1244. [PubMed: 27743411]
73. Stanford FC, Alfaris N, Gomez G, et al. The utility of weight loss medications after bariatric surgery for weight regain or inadequate weight loss: A multi-center study. *Surg Obes Relat Dis*. 2017;13(3):491–500. [PubMed: 27986587]
74. Clinical Efficacy and Safety of Using 3.0mg Liraglutide to Treat Weight Regain After Roux-en-Y Gastric Bypass Surgery. National Library of Medicine (US). <https://clinicaltrials.gov/ct2/show/NCT03048578?term=liraglutide&cond=weight+regain&rank=1>. Accessed Oct 8, 2019.
75. Duggan C, Watkins JB, Koletzko B, & Walker WA. *Nutrition in Pediatrics*. Shelton, CT: Peoples Medical Publishing House-USA; 2016.
76. Butler CC, Vidal-Alaball J, Cannings-John R, et al. Oral vitamin B12 versus intramuscular vitamin B12 for vitamin B12 deficiency: a systematic review of randomized controlled trials. *Fam Pract*. 2006;23(3):279–285. [PubMed: 16585128]

Table 1.

Suggested pre/postoperative screening & preventive supplementation for select micronutrients after bariatric surgery^{30,75}

	B1	Iron	Vit D	B12⁷⁶	Folate	Vit A	Trace Minerals (Zinc, Copper)
Preop Screening	High Risk only	All	All	High Risk only	No	High Risk only	No
Postop Screening	All (6mo, 1y, annually)	All (3,6,9 mo, 1y, annually)	All (3mo, 6mo, 1y, annually)	All (6mo, 1y, annually)	All (6mo, 1y, annually)	High Risk only	High Risk only
Lab Test	Whole blood thiamin	Ferritin + ESR + Iron Panel	25-OH Vit D	B12 level (screen) or Methylmalonic acid	RBC or Serum Folate	Retinol Level + Retinol Binding Protein	Zinc Level; Serum Copper + Ceruloplasmin
Risk Factors for Deficiency	Diuretics; acid blockers; vomiting; poor oral intake; poor vitamin intake; alcohol abuse	Menstruation; low intake of animal protein; preop iron deficiency; intraoperative bleeding; poor vitamin adherence; acid blockers	<i>S/p gastric bypass</i> ; low dietary intake; poor vitamin adherence; antiepileptics, systemic glucocorticoids, acid blockers; preop Vit D deficiency	Vegan/strict vegetarian diet; acid blockers; poor vitamin adherence	Low dietary intake; poor vitamin adherence; phenytoin, methotrexate, sulfasalazine, trimethoprim; oral contraceptives; alcohol abuse	<i>S/p gastric bypass</i> ; any condition/medication associated with fat malabsorption	<i>S/p gastric bypass</i> ; poor vitamin adherence; high zinc to copper supplement ratio (> 15mg zinc: 1mgCu)
Standard Postop Preventive Supplementation (dose and duration)	50–100 mg/d <i>x 6mo</i>	45–60mg elemental iron/d titrated to normal range ferritin <i>Indefinite</i>	3,000 IU D3/d titrated to a 25(OH) level >30ng/mL <i>Indefinite</i>	Sublingual 1,000ug/d OR 3,000ug IM injection q6 months <i>Indefinite</i>	Female (child bearing potential): 800–1,000ug/d Male: 400–800ug/d <i>Indefinite</i>	5,000–10,000 IU/d <i>Indefinite</i>	Zinc: SG: 8–11mg/d RYGB: 8–22mg/d Copper: SG: 1mg/d RYGB: 2mg/d <i>Indefinite</i>

ESR = erythrocyte sedimentation rate | SG = sleeve gastrectomy | RYGB = Roux-en-Y Gastric Bypass

Table 2.

Sample Postoperative Diet Stages

Diet Stage	Time After Surgery	Calorie Limit	Protein Goal	Meal Volume	Fluid Goal
#1: Sugar-Free Clear Liquids	Days 1 and 2	Less than 300	N/A	1 oz every 15 min	64 – 80 ounces daily
#2: Full High Protein Liquids	Day 3 – 14	300 – 500	60 – 90 grams	2 oz every 15 minutes	
#3: Soft Protein Foods	Weeks 2 and 3	About 500	60 – 90 grams	¼ to ½ cup per meal	
#4: High Protein Foods, Vegetables & Fruits	Weeks 4 – 12	500 – 750	60 – 90 grams	½ to 1 cup per meal	
#5: High Protein Foods, Vegetables, Fruits & Whole Grains	Lifelong after week 12	About 1000	60 – 90 grams or more	About 1 cup per meal	

Table 3.**Priority Topics for Future Research Before and After Adolescent Bariatric Surgery**

1) Develop evidence-based, opposed to insurance-driven, standards that define a successful preoperative period (patient/family factors, duration, frequency, content)
2) Establish adolescent-specific micronutrient guidelines. (Requires studies that a) evaluate absorption, regulation, and utilization to determine needs after MBS in this population and b) test innovative routes/schedules to deliver micronutrients given known poor adherence to daily oral pill regimens)
3) Assess optimal content and timing of interventions to prevent and treat postoperative LOC eating, taking into account adolescents' maturing executive function
4) Design postoperative physical activity interventions and study their association with postsurgical outcomes, including weight loss maintenance
5) Identify predictors and timing of suboptimal weight loss and weight regain, and define the ideal timing and type of intervention(s) to address these
6) Evaluate the safety and efficacy of anti-obesity pharmacotherapy in adolescents in the postoperative setting to augment weight loss and/or prevent or treat weight regain
7) Develop and test interventions that aim to decrease attrition after MBS, including clinical care models that strengthen collaborations with primary care physicians and that effectively transition adolescents to an adult weight management medical home