



Nutrition, Physical Activity, and Prescription of Supplements in Pre- and Post-bariatric Surgery Patients: a Practical Guideline

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Abstract

According to ASMBS, the rate of bariatric surgery increased from 158,000 in 2011 to 196,000 in 2015. Nevertheless, this growth in invasive techniques does not eliminate unhealthy habits, so lifestyle modification such as healthy nutrition and correct physical activity programs may improve surgical results. The objective of the present narrative review was to categorize the guidelines related to nutrition, physical activity, and supplement prescription before and after bariatric surgery. The main key words including nutrition, diet, physical activity, exercise, supplements, macronutrients, micronutrients, weight reduction, bariatric surgery, Roux-en-Y gastric bypass, sleeve gastrectomy, laparoscopic adjustable gastric banding, and biliopancreatic diversion with duodenal switch were searched in databases including PubMed/Medline, Cochrane, and some other sources such as Google scholar. The recommendations are classified based on the type of surgery. The indications for surgery and the type of bariatric surgery are not included in this review. This review helps medical teams, including bariatric surgeons, nutritionists, and sports medicine specialists, with proper management before and after bariatric surgery.

Keywords Nutrition · Physical activity · Supplements · Bariatric surgery

Nutritional Strategies Before Bariatric Surgery

In order to optimize the outcomes of bariatric surgery, adhering to calorie-restricted diets is usually recommended. It is estimated that preoperative weight loss may decrease the risk of bariatric surgery complications in 10% of the patients [1] and improves weight management after the surgery [2]. It has

been reported that only 10% reduction of the initial weight decreases comorbidities significantly [3].

A larger BMI or waist circumference, thicker abdominal wall or intra-abdominal fat, and higher liver volume are the most common factors for complicated and time-consuming surgery that increases the possibility of surgical conversion from laparoscopic to open surgery as well as the average length of hospitalization [4–8].

The critical outcomes of prebariatric weight loss are summarized in Table 1.

However, there are some conflicting data about the effect of presurgical weight loss on clinical outcomes. Some studies found no significant positive effects on surgical or post-operative outcomes [2, 24–26]. Some other studies reported increased treatment costs and even morbidity rates [2, 9, 27]. It seems that preoperative weight loss could positively affect the overall surgical outcomes. There is no proper guideline about the most effective and useful preoperative dietary program to improve surgical outcomes. Thus, it seems that determining an appropriate dietary prescription is useful for bariatric multidisciplinary teams to achieve the best clinical results.

Common concerns related to presurgical weight loss and diet planning will be discussed in the following. Then, typical diets will be evaluated according to their effects on weight loss and improvement of surgical outcomes.

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Table 1 The benefits of prebariatric weight loss

Effect	Outcomes
Increase	Preoperative excess weight loss [9] Post-operative weight loss [10]
Decrease	Preoperative BMI [11, 12] Liver size or volume [12–17] Intrahepatic fat content [14, 15, 17] Visceral adipose tissue (VAT) mass [18] Abdominal wall depth [18] Technical challenges of surgery and conversion rate of operation [15, 18] Operative time [9, 10, 19] Perioperative blood loss [20] Post-operative complication rates [1, 18] Post-operative hospitalization after lap-GBP [21] Anastomotic ulcers in patients treated by LCD, 1 month after lap-GBP [22]
Improvement	Body composition [11] Medical comorbidities <ul style="list-style-type: none"> • Obesity-related co-morbidities [14] • Systolic and diastolic blood pressure [16] • Metabolic profile (fasting glucose, fasting insulin, LDL, and TAG) [16] Access to the gastro-esophageal junction and upper stomach and retraction of the left lobe of the liver without damage to it [12, 15, 17] <ul style="list-style-type: none"> • Facilitation of lap-GBP [23] or LRYGBP [16]

Who Should Lose Weight Preoperatively?

Preoperative weight loss could be advised to all patients with bariatric surgery due to its benefits, especially in patients with a higher risk of operation (Table 1). It seems that patients whose BMI is above 50 kg/m² have excessively large livers, who are considered as technically difficult cases, and those who suffer from comorbidities may benefit more [28].

In obese patients with BMI above 35–40 kg/m², the liver may have additional stores of glycogen, water, and fatty deposits. Therefore, technical difficulties in liver retraction are expected during the operation in these patients. By following calorie-restricted diets before surgery, the amount of glycogen, water, and fatty deposits will reduce, allowing the surgeon to safely retract the liver and expose the stomach and intestines [11].

However, some patients may gain weight or may be unable to achieve desirable levels of weight loss despite dietary calorie restriction; however, they should not be deprived of surgery that is the most effective method to achieve healthy weight in severe obesity [28].

What Amount of Preoperative Weight Loss Is Needed?

Previous studies showed that a 10% or more significant reduction of weight, 3 kg of fat, or 5% of excess body weight might be associated with a reduction in the liver size and the additional benefit of a shorter operative time [23, 28].

What Is the Appropriate Time to Start a Preoperative Weight Loss Diet?

In studies evaluating the preoperative weight loss process, regardless of the diet type, the time of the beginning of calorie restriction to achieve the goals varies from 2 to 12 weeks. A shorter duration of the diet is reported to be associated with a lower reduction in the BMI and liver size [13], although the highest reduction in the liver volume occurs in the first 2 weeks of the program [14]. Accordingly, the starting time and duration of the program should be determined individually based on the existing conditions (such as BMI, comorbidities, and response to diet) [18].

In conclusion, the minimum time required for obtaining the benefits of liver volume reduction or weight loss is 2 weeks with a mean duration of 4 weeks.

The Most Common Nutritional Strategies for Prebariatric Weight Loss

It seems that dietary methods, which contribute to the reduction of weight, liver volume, or fat content, are acceptable to be used preoperatively. However, the highlighted points that help physicians make the best decision include clinical judgments, patient characteristics (e.g., BMI, comorbidities, and compliance) and waiting time for surgery. The most common nutritional strategies for prebariatric weight loss are summarized in Table 2.

Based on previous studies and clinical practices, low calorie diet (LCD) and very low calorie diet (VLCD) can be considered as the most appropriate, endurable, and applicable diets for preoperative weight loss. VLCD is more utilized for rapid preoperative weight loss, especially where there is little time. Despite achieving more significant short-term weight loss with VLCD, it does not induce a greater weight reduction in comparison to LCD in the long term. Thereby, liquid low-energy meals can be used as part of LCD to make it more effective as with an equivalent calorie intake [31].

Some other dietary plans are available. For example, low carbohydrate diet has beneficial effects on reducing the liver fat content and liver size in morbidly obese patients [15]. Another example is the Mediterranean diet that has a positive effect on weight, liver size, visceral fat, and fat mass without any significant reduction of fat free mass [32]. However, the effect of these types of diets has no evidence in prebariatric patients.

Regardless of the selected dietary method before surgery, one of the crucial issues about preoperative dietary plans is the amount of macronutrient intake and portion size, which play a significant role in the efficacy of the program [13]. Recently,

Table 2 The most common nutritional strategies for prebariatric weight loss

Type of diet	Description
Low-calorie diet (LCD)	Recommended daily calorie intake: 800–1200 kcal/day. Portion control, along with some “regular” food or high-protein supplements. Beneficial dietary plan for diabetic patients [29].
Very low-calorie diet (VLCD)	Recommended daily calorie intake: 500–800 kcal. In order to prevent lean mass loss, the daily amount of protein intake should be carefully adjusted. Careful medical supervision is needed to early diagnosis and management of some probable and usually mild side effects including gallstones, cold intolerance, hair loss, headache, fatigue, dizziness, volume depletion (with electrolyte abnormalities), muscle cramps, and constipation and to prevent unusual serious complications [29].
Liquid low-energy formula diet	A low-calorie or very low-calorie diet which contained powder-based meals. Example: Cambridge Weight Plan that has four powder-based meals, 1 l skimmed milk, 295 g vegetables and 100 g low-fat yogurt per day, with the provision of 1000 kcal/day [30]

Albanese et al. explored the differences between preoperative very low-calorie ketogenic diet (VLCKD) and VLCD in prebariatric patients. However, they reported no significant difference in weight loss before surgery but concluded that VLCKD patients obtained better results of those variables, which are highly linked to surgical outcomes such as the mean procedure time, post-operative hemoglobin level, and duration of hospital stay [33].

Furthermore, patients should be advised to consume adequate amounts of water (≥ 1.5 – 2 l) or calorie-free beverages and increase their daily fiber intake by using more vegetables (especially lower calorie types) along with recommended daily intake of essential vitamins, minerals, and trace elements [14, 15, 34, 35].

In summary, according to the existing evidence, the most effective dietary plans in prebariatric patients are LCD (800–1200 kcal/day, carbohydrates ≥ 100 g, protein 1 g/kg, and fat $\leq 30\%$) and VLCD (500–800 kcal/day, carbohydrates ≥ 50 g/day, protein 1.5 g/kg or ≥ 65 – 70 g/day, and Fat $\leq 30\%$) [36]. However, there are some controversies in total prescribed calorie and macronutrient distribution in LCD and VLCD.

Prebariatric Supplementation with Omega-3 Polyunsaturated Fatty Acids

Convincing evidence supports the effect of omega-3 (n-3) polyunsaturated fatty acids (PUFAs) on reducing the liver fat content or other markers of non-alcoholic fatty liver disease (NAFLD) [37]. Kunesova et al. found that supplementation with n-3 PUFA added to a very low-calorie diet compared to VLCD alone led to a more significant reduction in weight,

BMI, and hip circumference as well as lesser lipogenesis [38]. Recently, Iannelli et al. investigated the effect of oral n-3 PUFAs as part of a preoperative dietary plan to evaluate its influence on reducing the liver volume and bariatric surgery facilitation. The results showed a 20% decrease in the mean volume of the left hepatic lobe. Moreover, simple access to the gastro-esophageal junction was reported by the operating surgeon in all cases [16].

NAFLD is a common condition in morbidly obese patients that is associated with hepatomegaly and may lead to some technical challenges in liver retraction and adequate access to the gastro-esophageal junction in laparoscopic bariatric surgery. Therefore, supplementation with omega-3 polyunsaturated fatty acids may be appropriate in these cases [15].

Nutrition After Bariatric Surgery

Nutritional management plays a vital role in patients undergoing bariatric surgery. It has been proven that nutritional care not only prevents malnutrition and gastro-intestinal complications but also decreases the risk of weight regain in morbidly obese patients.

The objective of short-term post-operative diets is to meet the nutritional needs of the patients based on their tolerance to food texture. Primary diets are divided into three general categories: clear liquid diets, full liquid diets, and soft diets [30].

The exact calorie intake for better weight loss after bariatric surgery is not known yet and should be defined based on age, sex, and daily activity level [39, 40]. However, a negative energy balance is vital [41, 42].

Table 3 Diet stages RYGB, SG, LAGB, and BPD/DS

Diet stages after RYGB/SG BPD/DS	Time to begin	Food	Guidelines
1	Immediately after surgery	Gastric bypass clear liquids	<ul style="list-style-type: none"> • Patients should have encouraged to begin fluid intake after swallow test for a leak. If there is no problem, sipping water is allowed. • For the first 2 h after surgery, 15 ml liquid should be eaten every 30 min for the first 2 h, and increase to 15 ml every 15 min for the rest of the day. • Liquids with no calorie are allowed, for example, water and light tea. Carbonated liquids or those with caffeine and sugar should not be used. • Using straw should be limited. • At days 2–3, patients should consume 30 ml of no carbonated and no sugar liquids every 15 min. • Caffeine should be restricted. • Patients should have encouraged to sip their liquids slowly. • 0.5 cup fruit juice should be diluted with 0.5 cup water. • Using straw should be limited. • Recommended total fluid intake is 1500–1800 ml per day. • Patients should be encouraged to consume 120–170 ml of liquids every hour. • Daily intake of protein supplement should be limited to 25–30 g per serving (100–200 cal; < 10 g sugar; < 15 g carbohydrates) • Consumption of plain yogurt, with more than 25 g added sugar, should be limited. • Patients should be encouraged to consume salty liquids in moderation. • Carbonated liquids or those with caffeine and sugar should not be used. • Using straw should be limited. • Recommended total fluid intake is 1500–1800 ml per day. • At least 4 cups of water should be included. • Soft, pureed food should be started. • Patients should have encouraged to consume 3–5 small meal. • Protein-rich foods should be included. • Patients should have encouraged not to drink water with or immediately after meal (no problem to drink 15 min before or 30 min after meal). • As soon as patients can tolerate a 0.5 cup of food at one sitting, daily intake should be limited to 3 small meals and 2 snacks. • Since some patients cannot provide their daily nutritional needs for protein through food at this stage, the use of protein powders should be continued. • Patients should be encouraged to stay well hydrated (at least 1500–1800 ml of liquids per day). • New foods should be reintroduced separately to determine which foods are intolerable. • Patients should have encouraged not to drink water with or immediately after meal (no problem to drink 15 min before or 30 min after meal). • Raw fruits and vegetables should be included slowly due to some problem in tolerating their skin or texture. • Intake of rice, bread, and pasta should be limited until patients can tolerate protein-rich food comfortably. • Patients should be informed that as their sense of a hunger increase in following weeks, food intake should increase gradually (considering recommended daily calorie intake).
2	Day 2	Water; crystal light; natural diluted fruit juice without sugar; diluted Gatorade; sugar-free jelly and broth.	
	Day 4	Low or no fat milk; soy milk; almond milk; plain or Greek yogurt; whey; isolated whey or soy protein powder; protein shakes; crystal light; broth; diluted natural fruit or vegetable juice; sugar-free jelly; smooth vegetable soup with no chunks, mixed with 1% or skim milk or water; sugar-free ice pops.	
3	Days 14–10 (depending on patient tolerance)	Ground or pureed low-fat meat, poultry and fish; eggs, egg whites or egg substitute; low-fat cheese, cottage cheese; soft tofu; strained soups; well-cooked vegetables; unsweetened applesauce; homemade compote without sugar; canned fruit in water; pureed and soft banana and non-fibrous, pureed of other fruits.	
4	Week 4 post-op and beyond	An advance diet based on the patient's tolerance	

Table 3 (continued)

Diet stages after RYGB/SG BPD/DS	Time to begin	Food	Guidelines
Diet stages after LAGB	Time to begin	Food	<ul style="list-style-type: none"> • Patients should get at least 20 min for every meal and chew every food slowly and adequately in order to prevent blockage.
1	Immediately after surgery	LAGB clear liquids; ice chips	<p>Guidelines</p> <ul style="list-style-type: none"> • Patients should be encouraged to begin fluid intake immediately after surgery. • Carbonated liquids or those with caffeine and sugar should not be used. • Patients should be encouraged to begin the intake of high protein liquids. • Recommended total fluid intake is 1500–1800 ml per day. • 700–900 ml of fluid intake should be assigned to clear liquids, and full liquids could provide the rest. • Liquids with more than 25 g sugar per servings and/or 2 g fat, should be limited. • Daily intake of protein supplement should be limited to 25–30 g per serving (100–200 cal; < 10 g sugar; < 15 g carbohydrates) • Consumption of plain yogurt with more than 25 g added sugar, should be limited. • Patients should be encouraged to consume salty liquids in moderation. • Carbonated liquids or those with caffeine and sugar should not be used. • Using straw should be limited.
2	Day 2	LAGB clear liquids plus LAGB full liquids; low fat or skim milk; protein shakes; whey; whey isolate or soy protein powder; soy or almond milk, plain or Greek yogurt; crystal light; broth; diluted natural fruit or vegetable juice; sugar-free jelly; smooth vegetable soup with no chunks, mixed with 1% or skim milk or water; sugar-free ice pops.	<ul style="list-style-type: none"> • Patients should be informed that the sense of hunger is normal at this stage. • Having 3–5 small protein-rich meal increase satiety and prevent high-calorie intake. • Patients should get at least 20 min for every meal and chew every food well. • Patients should be encouraged to stay well hydrated (at least 1500–1800 ml of liquids per day). • Patients should be encouraged not to drink water with or immediately after meal (no problem to drink 15 min before or 30 min after meal).
3	Days 10–14 (depending on patient tolerance)	LAGB clear liquids plus soft, pureed foods.	<ul style="list-style-type: none"> • Carbonated liquids or those with caffeine and sugar should not be used. • Patients should be encouraged to stay well hydrated (at least 1500–1800 ml of liquids per day). • New foods should be reintroduced separately to determine which foods are intolerable.
4	4 weeks post op and beyond	An advance diet based on the patient's tolerance	<ul style="list-style-type: none"> • Patients should be encouraged not to drink water with or immediately after meal (no problem to drink 15 min before or 30 min after meal). • Raw fruits and vegetables should be included slowly due to some problem in tolerating their skin or texture. • Intake of rice, bread, and pasta should be limited until patients can tolerate protein-rich food comfortably. • Patients should be informed that as their sense of hunger increase in following weeks, food intake should increase gradually (considering recommended daily calorie intake). • Patients should get at least 20 min for every meal and chew every food well. • Patients should be encouraged to include protein in every meal and shakes.

-There are several types of post-surgical dietary plans that vary in terms of authorized and unauthorized food and the duration of each stage. Patient's food tolerance should be considered at the beginning of each stage

-Patients should be aware of symptoms of dehydration such as dark-colored urine, nausea, fatigue, hypotension by standing, dizziness, and confusion
 RYGB Roux-en-Y gastric bypass, SG sleeve gastrectomy, LAGB laparoscopic adjustable gastric banding, BPD/DS biliopancreatic diversion with duodenal switch

Daily calorie intake is estimated from 400 to 500 kcal on the first day post-surgery to 1000 at the end of the first year [43–45].

There is no important difference between post Roux-en-Y gastric bypass (RYGB) and sleeve gastrectomy (SG) diet during the first weeks although meal planning for patients who undergone laparoscopic adjustable gastric banding (LAGB) is somehow different. Progression of post-bariatric diets is outlined in Table 3 [42, 43].

Macronutrients

Protein

Post-bariatric (SG and RYGB) metabolic alteration and weight loss are highly associated with anatomical changes in the digestive system which affected food intake and the process of digestion and absorption of macro- and micronutrients especially the essential amino acids [46]. Bariatric surgery leads to a significant reduction in the gastric capacity and secretion of hydrochloric acid and digestive enzymes. In addition, changes in the sense of taste and smell may increase the risk of some nutrient deficiencies [47–50].

Previous studies showed that protein intake after bariatric surgery could not only enhance satiety but also alter long-term surgical outcomes in terms of weight and fat loss. Furthermore, post-surgery high protein diets play an important role in preserving the fat-free mass [46, 51, 52]. Kanerva et al. suggested that individuals who consumed more dietary protein and less fat lost more weight during 10 years after bariatric surgery [51]. Dagan et al. reported more loss of fat-free mass among those who consumed less than daily recommended protein intake after surgery [53]. Despite the effect of protein intake on body composition and its positive effects on blood glucose and triglyceride levels after surgery, it seems that bariatric patients face some problems in providing their daily protein needs. Previous studies found a low protein intake, especially among women and those who underwent restrictive bariatric surgery [54]. Nutritional guidelines recommend a protein intake of 60–160 g/day after RYGB and 60–80 g or 1.1 g/kg of

ideal weight (i.e., BMI = 25) after SG [55, 56]. In some cases, daily consumption could increase to 2.1 g/kg/day ideal body weight [28]. Therefore, the minimum amount of daily intake should not be less than 60 g [46, 57] and 90 g/day for biliopancreatic diversion (BPD) to prevent protein-energy malnutrition [58, 59].

Based on renal function, restriction of daily protein intake may be considered in patients with chronic kidney disease or diabetic kidney disease [60]. Furthermore, too much protein intake could affect daily consumption of other macronutrients and in long-term risk of bone and calcium homeostasis, liver function disorders, or certain kind of cancers increase [61].

Since some bariatric patients are exposed to protein deficiency and complications [62], they are often advised to use protein supplements to achieve daily intake goals [30, 62, 63]. Additionally, daily protein supplement intake enhances body composition in bariatric patients [62]. Today, a different type of protein supplements is available with the source of egg white, whey, casein, milk, and soy. All of the essential amino acids are found in these supplements [64]; however, in most cases, whey protein is recommended due to the high amounts of branched chain amino acids that are needed in the rapid weight loss stage [30]. For those who experience lactose intolerance after surgery, especially RYGB patients, lactose-free supplements are prescribed.

Carbohydrates

There is no definite recommendation for carbohydrates after bariatric surgery [52]. Previous studies found that 35–48% of post-surgery energy needs comes from carbohydrates [59, 65–67]. However, for maintaining an optimal brain function, daily intake of carbohydrates should not be less than 50 g [68]. Moizé et al. and Mechanick et al. suggested that after bariatric surgery, the calorie intake of carbohydrate should be limited to 45% of the total calorie intake [28, 39]. According to Kanerva et al., limiting carbohydrate and fat intake and prioritizing the use of protein lead to a greater weight loss [51].

Patients should be educated to decrease the intake of high-glycemic carbohydrates to prevent nausea [51]. Eliminating refined sugars and processed carbohydrates and

Table 4 Physical activity importance in patients undergoing bariatric surgery

Physical activity importance before surgery	Physical activity importance after surgery
1. Lose more weight	1. Increase weight loss
2. Better surgery results	2. Prevention of weight regain
3. Lose weight from fat storage and preserve LBM	3. Keep ideal body weight and increase LBM at long term
4. Improve cardiometabolic risk factors	4. Improve cardiometabolic risk factors
5. Decrease the side effects of chronic disease	5. Increase the quality of life

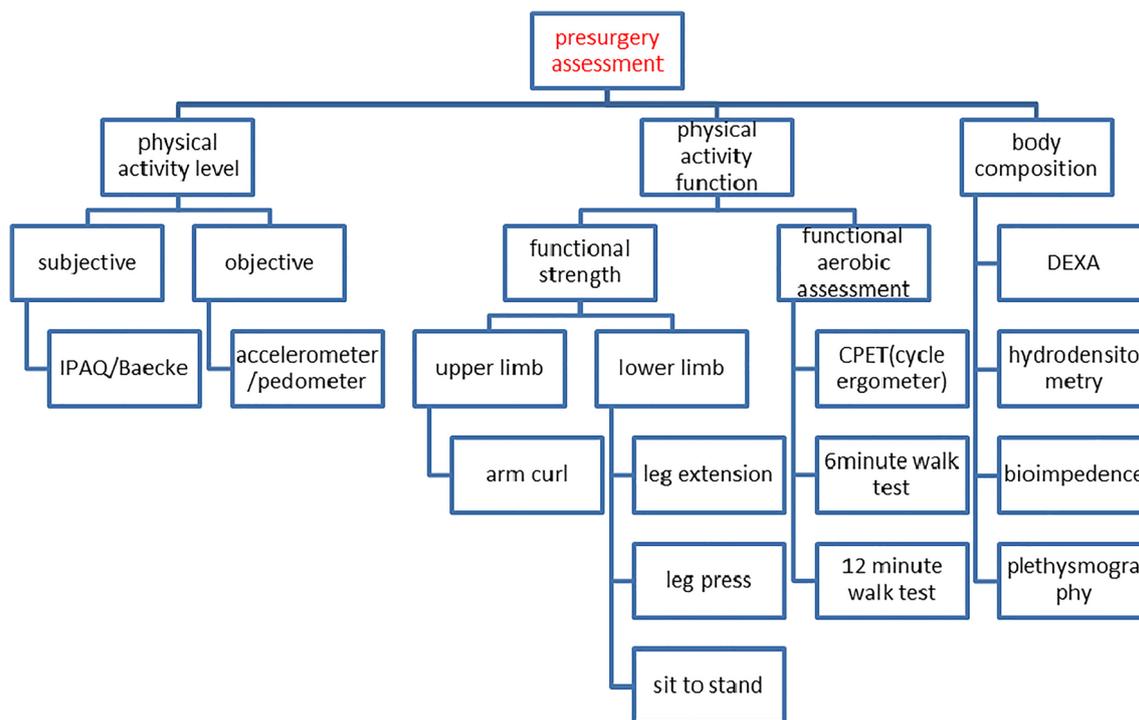


Fig. 1 Recommended assessments before exercise prescription

increasing the use of whole, fiber-rich carbohydrates is recommended. In addition, patients should be encouraged to use five servings of fruits and vegetables per day [30, 57].

Calorie Goals

One of the main concerns of patients undergoing bariatric surgery is weight regain. Therefore, their tendency to keep the daily calorie intake at a minimum level is understandable. In the first weeks, calorie intake is usually equal to 500–800 kcal/day, which is gradually increased to 800–1000 kcal/day during 3–12 months [54, 69, 70]. Regular nutritional follow-ups help patients to develop healthy eating habits and to meet their nutritional needs instead of focusing on the calorie intake.

Physical Activity Before and After Bariatric Surgery

Importance of Physical Activity Before and After Surgery

Physical activity not only has a vital role in preventing chronic diseases such as cardiovascular disease, diabetes mellitus, and obesity but also reduces the risk of death associated with chronic diseases and other health problems [71]. Physical activity is vital part of weight management programs for enhancing weight loss, keeping ideal body weight, and preventing weight regain [72].

Most patients undergoing bariatric surgery may suffer from some musculoskeletal problems and chronic diseases, which might affect their exercise tolerance and

Table 5 Classification of exercises according to intensity

	METs*	Borg	Examples
Low-intensity physical activity	< 3	9–11	Walking slowly, simple daily living activity such as using a computer at a desk, using light hand tools, washing dishes, ironing, and preparing food
Moderate intensity physical activity	3–6	12–13	Walking at brisk space, cleaning the house, washing car, vacuuming, sports training
High-intensity physical activity	> 6	14–17	Walking very brisk, jogging, running, bicycling, swimming, competitive sports

*Metabolic equivalents (METs): MET is an index of EE; the ratio of the rate of energy expended during an activity to the rate of energy expended at rest. By convention, 1 MET (rate of EE while sitting at rest) is equal to an oxygen uptake of 3.5 ml/kg/min

Table 6 Step-by-step physical activity prescription

Type of exercise	Start before surgery	Start after surgery	Progress	Goal	Examples
Aerobic	150–250 min/week moderate intensity	Day 1–week 4: walking around, slowly increase speed, time and intensity	Week 5–12: 150–200 min/week, 3–5 days/week, moderate intensity, Borg scale 12–14*	300 min/week, 5–6 days/week 60%–80% max HR**	- Walking and running (outdoor or on the treadmill) - Cycling - Dancing - Swimming
Resistive	2–3 sets 8–12 Repetition (48 h rest for large muscle groups)	Week 6, starting without weight such as active range of motion hip and shoulder against gravity and then adding devices such as weight or elastic band with caution	Gradually Increase of sets/reps/intensity	60–80% 1RM, 2–3 set, 10–15 rep, free weight/elastic band, etc. 3 days/week	- Chest press - Shoulder press - Lateral pull down - Leg press - Squat - Lunge
Stretching	Stretching especially large muscles, 4 repetitions, with 10–30 s holding	Not specific time sites far from surgery location immediately after surgery in a pain-free range of motion	Modified stretching, increase the time of holding and repetition an on regular basis	A static stretch for 10–30 s to the point of tightness or slight discomfort without pain, most of the days/week	- Hamstring stretching - Quadriceps stretching
Core stability	Core stability as routine in patient's tolerance range	Taking deep breaths, the day after surgery and start to draw in pain-free range whenever she/he is ready	Slowly increase exercises in a symptom-free range	2–5 times/day core stability exercises on a regular basis, keep the ideal body posture	- Draw in (supine and in daily living activities) - Single knee to chest - Pelvic tilt
Abdominal	As tolerated according to patient capacity	Weeks 8–12	Similar to core exercises	Similar to core exercises, gradually increasing the level of training and repetition	- Crunch - Alternative leg lift - Partial sit up
Leisure time	As usual	2–4 weeks after surgery, mild intensity	Increase activity by increasing daily intensity and duration	Increase activity by increasing daily intensity and duration	- Outdoor activities
Sport-specific	As usual	Not determined, depending on the patient in the pain-free range	Progress slowly depending on body status and symptoms	Moderate to vigorous, 2–3 days/week	- Football - Tennis - Jogging

*Borg scale is a relative scale which is specified by numbers from 6 to 20 in order to assess how hard one feels when he/she is exercising

**Max HR = $(220 - \text{age}) \times 0.85$

Table 7 Micronutrient assessments and supplementation recommendations pre and post bariatric surgery

Micronutrients		Recommendations according to surgery methods
Vitamin B1 (thiamin)	Presurgery assessment	Recommended for all patients. (Grade C, BEL 3)
	Post-surgery assessment	Routine screening is recommended in high-risk groups: [Patients with risk factors for thiamin deficiency, females, Blacks, patients not attending a nutritional clinic after surgery, patients with GI symptoms (intractable nausea and vomiting, jejunal dilation, megacolon, or constipation), patients with concomitant medical conditions such as cardiac failure (especially those receiving furosemide)]. (Grade B, BEL2) also, 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 months, then every 3–6 months until symptoms resolve. (Grade B, BEL2)
	Post-surgery recommendation	All post-WLS patients should take at least 12 mg thiamin daily (grade C, BEL3) and preferably a 50-mg dose of thiamin from a B-complex supplement or multivitamin once or twice daily. (Grade D, BEL4)
	Post-surgery treatment	Practitioners should treat post-WLS patients with suspected thiamin deficiency before or in the absence of laboratory confirmation of deficiency and monitor and evaluate the resolution of signs and symptoms. (Grade C, BEL3) • Oral therapy: 100 mg 2–3 times daily until symptoms resolve. (Grade D, BEL4) • IV therapy: 200 mg 3 times daily to 500 mg once or twice daily for 3–5 days, followed by 250 mg/day for 3–5 days or until symptoms resolve, then consider treatment with 100mg/day orally, usually indefinitely or until risk factors have been resolved. (Grade D, BEL4) • IM therapy: 250 mg once daily for 3–5 days or 100–250 mg monthly. (Grade C, BEL3) *Simultaneous administration of magnesium, potassium, and phosphorus should be given to patients at risk for refeeding syndrome. (Grade C, BEL3)
Vitamin B12 (cobalamin)	Presurgery assessment	Recommended for all patients (methylmalonic acid is the choice assay). (Grade B, BEL 2)
	Post-surgery assessment	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 months) 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 the risk of B12 deficiency: nitrous oxide, neomycin, metformin, colchicine, proton pump inhibitors, and seizure medications. (Grade B, BEL2) *Serum B12 may not be adequate to identify B12 deficiency.
	Post-surgery recommendation	All post-WLS patients should take vitamin B12 supplementation. (Grade B, BEL2) • Orally by disintegrating tablet, sublingual, or liquid: 350–500 mg daily • Nasal spray as directed by the manufacturer • Parenteral (IM or SQ): 1000 mg monthly.
Folate (folic acid)	Post-surgery treatment	• 1000 mg/day to achieve normal levels and then resume dosages recommended to maintain normal levels. (Grade B, BEL2)
	Presurgery assessment	Recommended for all patients. (Grade B, BEL 2)
	Post-surgery assessment Post-surgery recommendation	Routine post-WLS screening recommended. (Grade B, BEL 2) • 400–800 mg oral folate daily from their multivitamin. (Grade B, BEL2) • Women of childbearing age should take 800–1000 mg oral folate daily. (Grade B, BEL2)

Table 7 (continued)

Micronutrients		Recommendations according to surgery methods
Iron	Post-surgery treatment	<ul style="list-style-type: none"> • 1000 mg of folate daily to achieve normal levels and then resume the recommended dosage to maintain normal levels. (Grade B, BEL2) * Folate supplementation above 1 mg/day is not recommended in post-WLS patients because of the potential masking of vitamin B12 deficiency. (Grade B, BEL2)
	Presurgery assessment	Recommended for all patients (Ferritin level is used for iron status screening, but not for iron deficiency diagnosing. A combination of tests including, serum iron, serum transferrin saturation, and total iron-binding capacity is recommended for diagnosing iron deficiency). (Grade B, BEL 2)
	Post-surgery assessment	Routine post-WLS screening of iron status is recommended within 3 months after surgery, then every 3–6 months until 12 months, and annually for all patients. (Grade B, BEL2)
	Post-surgery recommendation	<ul style="list-style-type: none"> • Low-risk patients (males and patients without a history of anemia) for post-WLS iron deficiency should receive at least 18 mg of iron from their multivitamin. (Grade C, BEL3) • 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, BEL3)
Vitamin D and calcium	Post-surgery treatment	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, BEL3)
	Presurgery assessment	Recommended for all patients (Combination tests: Vit D, 25-OH, serum alkaline phosphatase, PTH, 24-h urinary calcium...). (Grade A, BEL 1)
	Post-surgery assessment	Routine post-WLS screening recommended. (Grade B, BEL 2)
	Post-surgery recommendation	<p>All post-WLS patients should take calcium supplementation. (Grade C, BEL3)</p> <p>The appropriate dose of daily calcium from all sources varies by surgical procedure:</p> <ul style="list-style-type: none"> • BPD/DS: 1800–2400 mg/day, LAGB, SG, RYGB: 1200–1500 mg/day. <p>The recommended preventative dose of vitamin D in post-WLS patients should be based on serum vitamin levels:</p> <ul style="list-style-type: none"> • Recommended vitamin D3 dose is 3000 IU daily until blood levels of 25(OH)D are greater than sufficient (30 ng/ml). (Grade D, BEL4)
Vitamins A, E, and K	Post-surgery treatment	<p>Vitamin D levels must be repleted if deficient or insufficient to normalize calcium. (Grade C, BEL3)</p> <p>All post-WLS patients with vitamin D deficiency or insufficiency should be repleted with the following doses:</p> <ul style="list-style-type: none"> • Vitamin D3 at least 3000 IU/day and as high as 6000 IU/day, or 50,000 IU vitamin D2 1–3 times weekly. (Grade A, BEL1) • 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, BEL1) • The recommendations for repletion of calcium deficiency vary by surgical procedure (Grade C, BEL3): BPD/DS: 1800–2400 mg/day calcium, LAGB, SG, RYGB: 1200–1500 mg/day calcium.
	Presurgery assessment	Recommended for all patients (Use physical signs and symptoms and labs for Vit A deficiency: Retinol-binding protein and ↓plasma retinol, Vit E deficiency: ↓plasma α -tocopherol and Vit K deficiency: ↑DCP). (Grade C, BEL 3)
	Post-surgery assessment	Post-WLS patients should be screened for vitamin A deficiency within the first post-operative year, particularly those who have undergone BPD/DS, regardless of symptoms; in addition, vitamin A should be measured in patients who have undergone RYGB and BPD/DS, particularly

Table 7 (continued)

Micronutrients	Recommendations according to surgery methods
Post-surgery recommendation	<p>in those with evidence of protein-calorie malnutrition. (Grade B, BEL2)</p> <p>Vitamin E and K deficiencies are uncommon after WLS, symptomatic patients should be screened. (Grade B, BEL2)</p> <p>Post-WLS patients should take vitamins A, E, and K, with dosage based on the type of procedure:</p> <ul style="list-style-type: none"> • LAGB: vitamin A 5000 IU/day and vitamin K 90–120 µg/day, (Grade C, BEL3) • RYGB and SG: Vitamin A 5000–10,000 IU/day and vitamin K 90–120 µg/day, (Grade D, BEL4) • DS: vitamin A 10,000 IU/day and vitamin K 300 µg/day, (Grade B, BEL2) • LAGB, SG, RYGB, BPD/DS: vitamin E 15 mg/day. (Grade D, BEL4) <p>*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, BEL4)</p> <p>*Special attention should be paid to post WLS supplementation of vitamin A and K in pregnant women. (Grade D, BEL3)</p>
Post-surgery treatment	<p>Vitamin A</p> <ul style="list-style-type: none"> • Vitamin A deficiency without corneal changes: a dose of vitamin A 10,000–25,000 IU/day should be administered orally until clinical improvement is evident (1–2 weeks). (Grade D, BEL4) • With corneal changes: a dose of vitamin A 50,000–100,000 IU should be administered IM for 3 days, followed by 50,000 IU/day IM for 2 weeks (Grade D, BEL4) <p>*Patients should also be evaluated for concurrent iron and copper deficiencies because these can impair the resolution of vitamin A deficiency. (Grade D, BEL4)</p> <p>Vitamin E</p> <p>*The optimal therapeutic dose of vitamin E in post-WLS patients has not been clearly defined. There is potential for antioxidant benefits of vitamin to be achieved with supplements of 100–400 IU/day. This recommendation is higher than the amount typically found in a multivitamin; thus, additional vitamin E supplementation may be required for repletion. (Grade D, BEL4)</p>
Zinc	<p>Presurgery assessment</p> <p>Recommended before RYGB or BPD/DS (use physical signs and symptoms and labs: ↓serum or urinary zinc or RBC zinc). (Grade D, BEL 3)</p> <p>*Zinc assays in pre-WLS patients should be interpreted because patients with obesity have lower serum zinc levels and lower concentrations of zinc in plasma and erythrocytes than leaner patients. Thus, depletion of zinc is indicated when signs and symptoms are evident, and zinc assays are severely low. (Grade C, BEL3)</p> <p>Post-surgery assessment</p> <p>Screening is recommended at least annually for zinc deficiency in Post-RYGB and post-BPD/DS patients (Serum and plasma zinc are the most appropriate biomarkers for zinc screening of post-WLS patients). (Grade C, BEL3).</p> <p>*Zinc should be evaluated in all post-WLS patients when the patient is symptomatic for iron deficiency anemia but</p>

Table 7 (continued)

Micronutrients	Recommendations according to surgery methods	
Copper	Post-surgery recommendation	<p>screening results for iron deficiency anemia is negative. (Grade C, BEL3)</p> <p>*Post-WLS patients who have chronic diarrhea should be evaluated for zinc deficiency. (Grade D, BEL4)</p> <p>All post-WLS patients should take > RDA zinc, with dosage based on the type of procedure:</p> <ul style="list-style-type: none"> • BPD/DS: Multivitamin with minerals containing 200% of the RDA (16–22 mg/day) • RYGB: Multivitamin with minerals containing 100–200% of the RDA (8–22 mg/day) • SG/LAGB: Multivitamin with minerals containing 100% of the RDA (8–11 mg/day) <p>*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, BEL3)</p>
	Post-surgery treatment	<p>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.</p> <p>*Zinc status should be routinely monitored using consistent parameters throughout treatment. (Grade C, BEL3)</p>
	Presurgery assessment	<p>Recommended before RYGB or BPD/ DS (Serum copper and ceruloplasmin are recommended, but they are acute phase reactants, so erythrocyte superoxide dismutase is preferred assay if available). (Grade D, BEL 4)</p>
	Post-surgery assessment	<p>Routine screening is recommended at least annually after RYGB or BPD/ DS (serum copper and ceruloplasmin). (Grade C, BEL4)</p>
	Post-surgery recommendation	<p>All post-WLS patients should take > RDA copper as part of routine multivitamin and mineral supplementation:</p> <ul style="list-style-type: none"> • BPD/DS or RYGB: 200% of the RDA (2 mg/day), SG or LAGB: 100% of the RDA (1 mg/day). <p>*In post-WLS patients, supplementation with 1 mg copper is recommended for every 8–15 mg of elemental zinc to prevent copper deficiency.</p> <p>*In post-WLS patients, copper gluconate or sulfate is recommended. (Grade C, BEL3)</p>
	Post-surgery treatment	<p>The recommended regimen for repletion of copper will vary with the severity of the deficiency:</p> <ul style="list-style-type: none"> • Mild to moderate deficiency (including low hematologic indices): treat with 3–8 mg/day oral copper gluconate or sulfate until indices return to normal, • Severe deficiency: 2–4 mg/day intravenous copper can be initiated for 6 days or until serum levels return to normal and neurologic symptoms resolve, <p>*Once copper levels are normal: monitor copper levels every 3 months. (Grade C, BEL3)</p>

“Routine post-surgery screening” refers to performing a nutrient assessment every 3–6 months in the first year and annually thereafter, unless otherwise specified

LAGB laparoscopic adjustable gastric banding, *RYGB* Roux-en-Y gastric bypass, *SG* laparoscopic sleeve gastrectomy, *BPD* biliopancreatic diversion, *BPD/DS* biliopancreatic diversion/duodenal switch, *Grade* grades of evidence A through D (strongest to weakest), *BEL* best evidence level, *SBBO* small bowel bacterial overgrowth, *DCP* des-gamma carboxy prothrombin

adherence to daily physical activity. Previous studies emphasized the importance of exercise programs in promoting post-operative weight loss. It seems that surgery candidates who are physically active before and after the

operation experience a greater weight loss and their quality of life increases effectively [71, 73].

After weight loss surgery, the human body starts to burn unused muscle mass in order to compensate for calorie

restriction [74]. It is highly recommended to weight loss surgery candidates to start physical activity before surgery and continue daily exercise afterwards to keep their lean body mass, improve their cardiometabolic risk factors such as insulin sensitivity and blood lipid profile, and increase cardiovascular capacity and also aerobic performance [74, 75].

A summary of the importance of physical activity in patients undergoing bariatric surgery is presented in Table 4.

Physical Activity Assessments Before Bariatric Surgery

Before recommending any exercise program to surgery candidates, the patient's current physical activity level, mobility level, functional capacity, body composition, and potential needs for medical assessments should be assessed [76].

Current Physical Activity Level

Assessment can be done both subjectively (by questionnaires such as International Physical Activity Questionnaire (IPAC), ESM 1 or Baecke Physical Activity Questionnaire, ESM 2) or objectively using armbands or accelerometers/pedometers for 7 days [72, 76].

Mobility Level

Based on subjective mobility assessment, patients are categorized into three groups, and appropriate exercise is recommended for each group:

1. Patients who cannot walk
2. Patients who can walk with some restrictions
3. Patients who have no mobility restrictions [76]

Functional Level

In order to assess the functional level, both functional strength and aerobic capacity should be considered. Functional strength can be measured by one-repetition maximum test (1RM) for upper (e.g., arm curl) and lower limbs (e.g., leg press) or sit-to-stand test [74, 75, 77]. Aerobic capacity can be assessed by cardiopulmonary exercise test, preferably on a cycle ergometer, 6-min walk test, or 12-min walk-run test [75–78].

Body Composition

Anthropometric data can be collected by body impedance analysis (BIA), dual-energy X-ray absorptiometry (DEXA), hydrostatic weighing, etc. to evaluate the total body mass, fat-free mass, percent body fat, and lean body mass [75, 79, 80].

Assessment of Potential Need for Medical Testing

Medical tests, such as cardiac stress tests, pulmonary function tests, and musculoskeletal assessments, should be considered based on the patient's symptoms and the general indications for each one [76]. Figure 1 presents the recommended assessments before exercise prescription and recommendations for their evaluation in order to prescribe individualized exercise programs.

Exercise Prescription (Frequency, Intensity, Time, and Type: FITT) Based on Preoperative Assessments

There is no specific guideline for physical activity prescription before and/or after bariatric surgery. However, based on general guidelines, at least 150 min/week moderate to vigorous physical activity (equivalent 3–6 METs) or 10,000 steps/day is recommended for improving the general health, 150–250 min/week equivalent to 1200–2000 kcal/week for preventing weight regain, and more than 300 min/week for weight maintenance after weight loss. The more active person is, the more weight loss occurs [72, 80, 81]. The type of exercise according to the intensity and some examples are summarized in Table 5 [82].

Although there is not enough evidence to support that using resistance training will promote weight loss [83], it seems that a combination of aerobic exercises with resistance training, besides diet restrictions before and after bariatric surgery, leads to better weight loss results. In addition, prevention of weight regain with some positive effects on anthropometric indices such as decreased fat mass and stable or improved fat-free mass as well as cardiometabolic fitness are the other benefits [74, 75].

Exercise prescription could be done based on the patient's mobility. For example, therapists can prescribe aquatic plus upper body exercises in those who cannot walk, or physicians should consider walking in the range that the patients can afford plus swimming sessions and arm exercises in patients with walking limitations. Finally, all types of exercises could be prescribed in those without any limitations [84].

When to Start the Physical Activity After Bariatric Surgery?

Individuals should be encouraged to start physical activity from the day of the surgery by leaving the bed and walking short distances. Then, they should increase their physical activity gradually by walking further on the next days. Two weeks after laparoscopic surgery, patients can start daily exercise up to pain threshold under the surgeon's permission. This time may be longer in open surgery. During the first 4 weeks, recommended physical activity programs include walking around, taking deep

breaths, and doing normal daily activities. During 4–6 weeks, patients can gradually increase their activity with the surgeon's permission and supervision. Lifting weights more than 15 lbs during the first 6 weeks after surgery and abdominal exercise during the first 8–12 weeks should be avoided. During the first few months after surgery, the patients should increase their activity level gradually under supervision in a pain-free range and avoid high-intensity exercise. Therefore, bariatric patients should be well guided to set realistic goals and consider their healing process to prevent any damages or injuries. They should simultaneously be encouraged to avoid longtime rest and immobilization [85]. The physical activity step-by-step prescription is presented in Table 6.

Most of the previous studies have emphasized the potential effects of aerobic and resistance training after bariatric surgery, but there is no determined guideline for stretching nor core exercises. However, it seems safe to stretch to warm up and cool down. There is no contraindication for pain-free stretching of the sites away from the surgery site. If there is a problem in stretching due to the patient's condition after the operation, the exercise could be modified, for example, by getting help from a chair for hamstring or quadriceps stretching.

As mentioned before, there is no precise advice for starting core exercises after bariatric surgery. However, according to general guidelines, patients can start taking deep breaths the day after surgery and continue with doing simple exercises such as abdominal draw in. Core exercises should be done in a pain free range and increase gradually. The duration of training highly depends on the patient's overall condition. Return to sport and sport-specific exercises are not determined as well and may take a long time based on the surgical method and patient's condition [74, 75, 77].

Micronutrient Assessments and Recommendations Before and After Bariatric Surgery

The prevalence of micronutrient deficiencies is increasing while monitoring of patients in the follow-up period is decreasing [86]. Table 7 provides a practical guideline for micronutrient assessments before and after surgery including vitamins B1 and B12; folate; iron; vitamins A, E, and K; calcium; vitamin D; copper; and zinc. It also includes the recommended dose of micronutrient supplementation for the prevention and treatment of deficiency. These recommendations are based on the last update of "American Society for Metabolic and Bariatric Surgery" in 2016–2017 [87].

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical Approval Statement This article does not contain any studies with human participants or animals performed by any of the authors.

Informed Consent Statement Formal consent is not required for this type of study.

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