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REVIEW ARTICLE

# Clinical evidence of low-calorie and ketogenic nutrological therapy before, during and after bariatric surgery: a systematic review

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## Abstract

**Introduction:** Obesity is a multifactorial disease that causes serious comorbidities. There are more than 2.2 billion overweight and obese people in the world. Obese patients tend to be predisposed to micronutrient deficiency even before bariatric surgery, therefore, it is imperative to supplement nutrients orally, enterally, or parenterally, according to the indications of each patient. **Objective:** It was highlighted the importance of low-calorie and ketogenic nutritional therapy before, during, and after bariatric surgery through the systematic analysis of clinical studies. **Methods:** The systematic review rules of the PRISMA Platform were followed. The search was conducted from June to July 2024 in the Scopus, PubMed, Science Direct, Scielo, and Google Scholar databases. The quality of the studies was based on the GRADE instrument and the risk of bias was analyzed according to the Cochrane instrument. **Results and Conclusion:** 119 articles were found. A total of 40 articles were fully evaluated and 34 were included and developed in the present systematic review study. Considering the Cochrane tool for risk of bias, the overall assessment resulted in 23 studies with a high risk of bias and 27 that did not meet GRADE and AMSTAR-2. Most studies presented homogeneity in their results, with $X^2$=76.5%>50%. It was concluded that nutrological therapy strategies could represent a possible alternative to other methodologies, especially when it is recommended to improve patient adherence to following the prescribed diet before bariatric surgery. Weight loss induced by the ketogenic diet before bariatric surgery has beneficial effects on reducing liver volume, metabolic profile, and intra- and postoperative complications. Knowledge of the type of bariatric surgery performed and an understanding of its anatomy and physiology are useful to provide optimal care to patients, especially in nutritional complications. Nutritional deficiencies and metabolic disorders result from "malabsorption" procedures such as RYGB. Immediate administration of thiamine is essential. Dextrose should be avoided in intravenous hydration until thiamine is adequately replaced. For all bariatric patients, a protein intake of 60-70 g/d and a multivitamin with iron and vitamin B12 supplementation is recommended. Daily calcium and vitamin D supplementation is also encouraged. In addition, serum micronutrient levels should be monitored regularly and additional supplementation should be prescribed as indicated.

**Keywords:** Bariatric surgery. Nutrological therapies. Ketogenic diet. Low-calorie diet.

## Introduction

Obesity is a multifactorial disease that causes serious comorbidities. There are more than 2.2 billion people who are overweight or obese in the world, and Brazil is in fifth place in the world ranking, with an estimated 18.0 million people, with a trend towards reaching 70.0 million individuals. It is estimated that by 2050, 15.4 million deaths will occur worldwide due to chronic non-communicable diseases, and the Brazilian population will contribute significantly to this scenario **[1]**.

In this scenario, obesity is considered one of the main causes of morbidity and mortality due to its strong association with several health risk factors, such as diabetes, hypertension, and hyperlipidemia. For patients with a body mass index (BMI) ≥ 40 kg/m$^2$, bariatric surgery is associated with a 42% reduction in cardiovascular risk and a 30% reduction in all-cause mortality **[1]**. In this context, it is important to note that most cases of early and late complications can quickly translate into micronutrient deficiency and malnutrition, especially when administered orally **[2–4]**. Obese patients tend to be predisposed to micronutrient deficiency even before surgery due to the obesogenic diet being calorie-dense but nutrient-depleted **[5-7]**.

Given this, nutrition support providers must have a better understanding of the complications that necessitate the use of nutritional support, as well as the best technique for nutrition delivery, including its efficacy and associated complications **[8-10]**. There is still a paucity of available data on the outcomes of parenteral and enteral administration as nutritional support after bariatric surgery **[11,12]**.

In this scenario, three case-control studies have demonstrated that parenteral nutrition (PN) administration can be used effectively to mitigate nutritional complications resulting from bariatric surgery, however, they report significant readmission rates **[1315]**. With enteral nutrition (EN), a case-control study in patients with leak after sleeve gastrectomy revealed benefit from EN administered via nasojejunal (NJ) tube combined with pigtail drainage catheters and stent placement. In this cohort, these surgical procedures were shown to improve obesity-related comorbidities.

Despite these advantages, the prevalence of post-surgical complications can be high, although improving with laparoscopic and advanced techniques. Studies show that complications can occur in up to 15% of patients with prevalence varying widely based on the type of procedure performed **[10,11]**.

Based on this, the present study highlighted the importance of low-calorie and ketogenic nutritional therapy before, during, and after bariatric surgery through systematic analysis of clinical studies.

## Methods

### Study Design

This study followed the international systematic review model, following the PRISMA (preferred reporting items for systematic reviews and meta-analysis) rules. Available at: http://www.prisma-statement.org/?AspxAutoDetectCookieSupport=1. It was accessed on: 07/20/2024. The AMSTAR-2 (Assessing the methodological quality of systematic reviews) methodological quality standards were also followed. Available at: https://amstar.ca/. It was accessed on: 07/20/2024.

### Data Sources and Search Strategy

The literature search process was carried out from June to July 2024 and developed based on Scopus, PubMed, Lilacs, Ebsco, Scielo, and Google Scholar, covering scientific articles from various periods to the present day. The following descriptors (DeCS / MeSH Terms) were used: “Bariatric surgery. Nutrological therapies. Ketogenic diet. Low-calorie diet”, and using the Boolean "and" between MeSH terms and "or" between historical findings.

### Study Quality and Risk of Bias

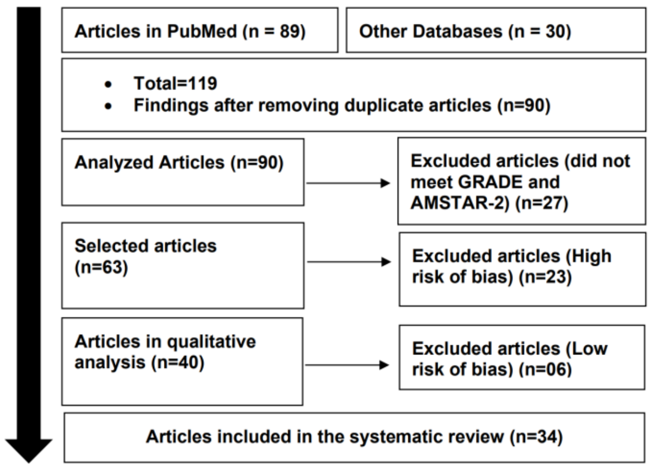
Quality was classified as high, moderate, low, or very low regarding the risk of bias, clarity of comparisons, precision, and consistency of analyses. The most evident emphasis was on systematic review articles or meta-analyses of randomized clinical trials, followed by randomized clinical trials. Low quality of evidence was attributed to case reports, editorials, and brief communications, according to the GRADE instrument. The risk of bias was analyzed according to the Cochrane instrument by analyzing the Funnel Plot graph (Sample size versus Effect size), using Cohen's d test.

## Results and discussion

### Summary of Findings

A total of 119 articles were found that were submitted to eligibility analysis, and 34 final studies were selected to compose the results of this systematic review. The studies listed were of medium to high quality (Figure 1), considering the level of scientific evidence of studies such as meta-analysis, consensus, randomized clinical, prospective, and observational. Biases did not compromise the scientific basis of the studies. According to the GRADE instrument, most studies presented homogeneity in their results, with $X^2 = 76.5\% > 50\%$. Considering the Cochrane tool for risk of bias, the overall assessment resulted in 23 studies with a high risk of bias and 27 studies that did not meet GRADE and AMSTAR-2.

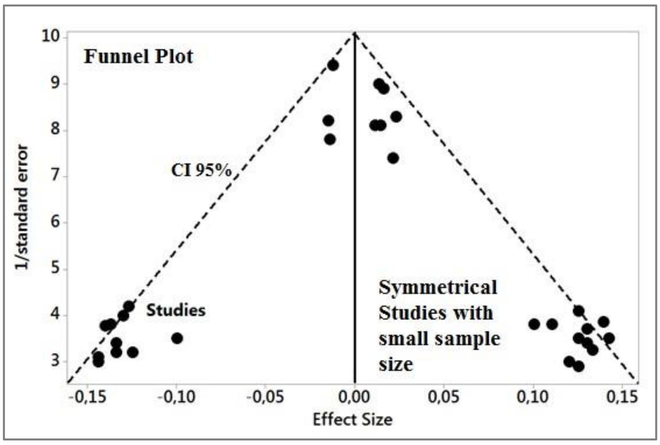
Figure 1. Flowchart showing the article selection process.




Source: Own Authorship.

Figure 2 presents the results of the risk of bias of the studies using the Funnel Plot, showing the calculation of the Effect Size (Magnitude of the difference) using Cohen's Test (d). Precision (sample size) was determined indirectly by the inverse of the standard error (1/Standard Error). This graph had a symmetrical behavior, not suggesting a significant risk of bias, both among studies with small sample size (lower precision) that are shown at the base of the graph and in studies with large sample size that are shown at the top.

Figure 2. The symmetrical funnel plot does not suggest a risk of bias among the studies with small sample size that are shown at the bottom of the graph. High confidence and high recommendation studies are shown above the graph (n=34 studies).




Source: Own Authorship.

### Nutritional Therapies and Bariatric Surgery

According to the literature findings, it has been observed that to achieve moderate weight loss and reduction of liver volume and steatosis before bariatric surgery, several dietary protocols have been introduced over time, among which low-calorie diets and ketogenic diets are widely prescribed **[16-20]**. In particular, Schiavo et al. **[21]** demonstrated that a 4-week preoperative ketogenic diet is safe and effective in reducing body weight (-10.3%, $p < 0.001$, in men; -8.2%, $p < 0.001$, in women) and left hepatic lobe volume (-19.8%, $p < 0.001$) in obese patients scheduled for bariatric surgery.

In addition, Albanese et al. **[22]**, aiming to compare surgical outcome and weight loss in two groups of patients who received two different types of preoperative diet (low-calorie and ketogenic diets), reported that ketogenic diets presented better results than low-calorie diets in surgical outcome, influencing drainage output, postoperative hemoglobin levels and hospital stay.

Evidence suggests that ketogenic diets can be effective tools to positively manage weight loss, glycemic control, and lipid profile changes **[22,23]**. However, these beneficial effects can be limited by poor adherence to the diet. In particular, cultural, religious, and economic barriers represent unique challenges to achieving nutritional compliance with ketogenic diets **[22,24]**. A potential solution is represented by enteral nutrition strategies.

In this sense, enteral nutrition strategies based on weight loss have been used in the treatment of obesity, showing promising results. In particular, Sukkar et al. **[25]**, evaluating the feasibility of a modified protein-sparing diet administered via nasogastric tube via enteral route (with continuous feeding) in the treatment of obesity, showed that 10 days of enteral nutrition treatment followed by 20 days of a low-calorie diet was safe and effective in reducing total body weight and abdominal circumference, and in improving the respiratory capacity of patients without major complications and side effects.

The authors Castaldo et al. [26] evaluated the effects of a carbohydrate-free diet provided via enteral nutrition for two weeks, followed by a nearly equivalent oral diet administered for another two weeks in 112 patients, and reported a significant reduction in BMI and waist circumference with improvement in blood pressure values and insulin resistance without major complications.

In this regard, weight loss induced by the ketogenic diet before bariatric surgery has beneficial effects on reducing liver volume, metabolic profile, and intra- and postoperative complications. However, these beneficial effects may be limited by poor adherence to the diet. A potential solution in patients with poor adherence to the prescribed diet could be represented by enteral nutrition strategies.

A recent study by the authors Castaldo et al. (2023) [27] evaluated the clinical impact, efficacy, and safety of enteral protein ketogenic nutrition (EKN) versus hypocaloric enteral nutritional (HEN) protocols in obese patients candidates for bariatric surgery. 31 patients with EKN were compared to 29 patients with NEI through a 1:1 randomization. Compared to baseline, BW, BMI, WC, WC, and NC were significantly reduced in both groups studied ($p < 0.001$). However, no significant difference was found between the EKN and HEN groups in terms of weight loss ($p = 0.559$), BMI ($p = 0.383$), WC ($p = 0.779$), and WC ($p = 0.559$), while a statistically significant difference was found in terms of NC (EKN, -7.1% vs. HEN, -4%, p=0.011). Furthermore, a significant improvement in the general clinical status was observed in both groups. However, a statistically significant difference was found in terms of glycemia (EKN, -16% vs. HEN, -8.5%, $p < 0.001$), insulin (EKN, -49.6% vs. HEN, -17.8%, $p < 0.0028$), HOMA index (EKN, -57.7% vs. HEN, -24.9%, $p < 0.001$), total cholesterol (EKN, -24.3% vs. HEN, -2.8%, $p < 0.001$), low-density lipoprotein (EKN, -30.9% vs. HEN, 1.96%, $p < 0.001$), apolipoprotein A1 (EKN, -24.2% vs. HEN, -7%, $p < 0.001$) and apolipoprotein B (EKN, -23.1% vs. HEN, - 2.3%, $p < 0.001$), while no significant difference was noted between the EKN and HEN groups in terms of aortomesenteric fat thickness (p=0.332), triglyceride levels ($p = 0.534$), degree of steatosis ($p = 0.616$) and left hepatic lobe volume ($p = 0.264$). Furthermore, EKN and HEN treatments were well tolerated and no major side effects were recorded.

Early oral feeding is the preferred mode of nutrition for surgical patients. Avoiding any nutritional therapy carries the risk of malnutrition during the postoperative period of major surgery. Considering that malnutrition and undernutrition are risk factors for postoperative complications, early enteral feeding is especially relevant for any surgical patient at nutritional risk, especially for those undergoing upper gastrointestinal surgery [28,29].

The authors Weimann et al. (2021) [30] wrote the ESPEN guideline that discussed both the nutritional aspects of the Enhanced Recovery After Surgery (ERAS) concept and the special nutritional needs of patients undergoing major surgery such as cancer and those who develop serious complications despite optimal perioperative care. From a metabolic and nutritional perspective, key aspects of perioperative care include the integration of nutrition into the overall patient care, avoiding long periods of preoperative fasting, reestablishing oral feeding as soon as possible after surgery, initiating nutritional therapy immediately if a nutritional risk becomes apparent, metabolic control such as blood glucose, reducing factors that exacerbate stress-related catabolism or impaired gastrointestinal function, minimizing the time from paralytic agents to ventilatory management in the postoperative period, and early mobilization to facilitate protein synthesis and muscle function.

Bariatric surgery is by far the most effective treatment option available for successfully achieving and maintaining weight loss in the obese population, but it can also be associated with complications leading to malnutrition. There is limited data on how enteral nutrition can be used to provide nutritional support in these cases. During the study period, 72 patients (86% women; mean age 50.3 ± 11.6) were initiated on home enteral nutrition (HEN) due to a complication of bariatric surgery. The most common bariatric surgery was Roux-en-Y (74%) and the most common indication for HEN was malnutrition/failure to thrive (33%). HEN was most commonly provided via nasojejunal feeding and resulted in a mean increase in patient body weight and BMI from 74.8 kg and 26.5 kg/m2, respectively, before HEN to 76.9 kg and 27.2 kg/$m^2$, at the end of the HEN period. Through HEN, patients received 22.2 ± 7.9 kcal/kg/day and 1.0 ± 0.3 g/kg/day of protein, achieving 94% ± 17% of their calories and 95% ± 29% of their protein goals. Vitamin deficiencies were observed in 69% of patients at the time of initiation of HEN, which improved to 10% after enteral feeding and adequate vitamin supplementation. Therefore, HEN is safe and effective in treating malnutrition and vitamin deficiencies that can occur as a complication of bariatric surgery, leading to the avoidance of parenteral nutritional support in most cases [31]. In particular, iron and vitamin D deficiencies are the most common. The importance of preoperative correction cannot be underestimated, as the absorption of iron, calcium, and vitamin D is reduced after bariatric procedures **[2]**. Other common preoperative micronutrient deficiencies include vitamin B12, folic acid, and thiamine **[10-13]**.

In this context, approximately 30% of patients undergoing bariatric surgery develop a nutrition-related complication, usually a macronutrient or micronutrient deficiency or both, at some point after the operation **[15]**. Specific nutrition-related complications include iron anemia, folate, vitamins B12, A, and E, copper; zinc, metabolic bone disease, calcium, vitamin D, protein-energy malnutrition, steatorrhea, Wernicke encephalopathy (thiamine), polyneuropathy and myopathy (thiamine, copper, vitamins B12 and E), visual disturbances (vitamins A and E, thiamine), skin rash (zinc, essential fatty acids, vitamin A) **[3,4]**.

The etiology of most nutritional deficiencies after bariatric surgery is multifactorial, with contributions from reduced dietary intake, altered food choices, and malabsorption. The number and severity of deficiencies are determined by the type of bariatric surgery performed, the patient's dietary habits, and the presence of other surgery-related gastrointestinal complications, such as nausea, vomiting, or diarrhea. For example, operations that result in the flow of nutrients bypassing the distal stomach, duodenum, and proximal jejunum may result in malabsorption of iron, calcium, folate, and vitamin B12 **[2,3]**.

Procedures such as Roux-en-Y gastric bypass (RYGB) may place patients at increased risk for deficiencies in fat-soluble vitamins, calcium, essential fatty acids, copper, and zinc. Although some deficiencies may develop rapidly, most are insidious in onset and may not be clinically apparent. Therefore, all bariatric surgery patients should adhere to lifelong vitamin and mineral supplementation and monitoring for deficiencies **[28,32,33]**.

Furthermore, it is important to recognize that anemia can also occur as a result of other micronutrient deficiencies or a combination of deficiencies. Deficiencies of vitamin B12 and folate can result in the development of macrocytic anemia. Deficiencies of copper and zinc and vitamins A and E are other potential causes of anemia in bariatric surgery patients. A deficiency of vitamin B12 can also result in a deficiency of folate. Significant deficiencies of vitamin B12 and folate can cause macrocytic anemia, pancytopenia, and glossitis **[34]**.

Also, neurological sequelae, including subacute combined degeneration of the dorsal and lateral spine, a rare complication of vitamin B12 deficiency, can also occur. Furthermore, the most potentially devastating micronutrient deficiency occurring in hospitalized post-bariatric surgery patients is thiamine (vitamin B1) deficiency **[12]**. Finally, humans cannot synthesize thiamine, which is absorbed primarily in the proximal small intestine, and thiamine stores in the body are low, making adequate dietary intake essential. Thiamine deficiencies after bariatric surgery can manifest clinically as Wernicke-Korsakoff syndrome and beriberi **[12]**. Protein-energy malnutrition is one of the most serious nutritional complications of bariatric surgery. This complication may be a consequence of reduced intake of proteins such as red meat, which is poorly tolerated after bariatric surgery, or the development of other gastrointestinal diseases that result in poor oral intake and excessive weight loss **[2]**.

## Conclusion

It was concluded that nutritional therapy strategies could represent a possible alternative to other methodologies, especially when it is recommended to improve patient adherence to the prescribed diet before bariatric surgery. Weight loss induced by the ketogenic diet prior to bariatric surgery has beneficial effects on reducing liver volume, metabolic profile, and intra- and postoperative complications. Knowledge of the type of bariatric surgery performed and an understanding of its anatomy and physiology are helpful in providing optimal patient care, especially in nutritional complications. Nutritional deficiencies and metabolic disorders are due to "malabsorption" procedures such as RYGB. Immediate administration of thiamine is essential. Dextrose should be avoided in intravenous hydration until thiamine is adequately replaced. For all bariatric patients, a protein intake of 60–70 g/d and a multivitamin with iron and vitamin B12 supplementation is recommended. Daily supplementation with calcium and vitamin D is also encouraged. In addition, serum micronutrient levels should be monitored regularly and additional supplementation measures prescribed as indicated.

## CRediT

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## References

1. World Health Organization. Factsheet: Obesity and overweight. Accessed at: June, 16, 2024. Available on: http://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight.
2. Silk DBA. Enteral nutrition in malnourished patients after bariatric surgery. JPEN J Parenter Enteral Nutr. 2022 Feb;46(2):272. doi: 10.1002/jpen.2301.
3. Fujioka K, DiBaise JK, Martindale RG. Nutrition and metabolic complications after bariatric surgery and their treatment. JPEN J Parenter Enteral Nutr. 2011 Sep;35(5 Suppl):52S-9S. doi: 10.1177/0148607111413600.
4. Bétry C, Disse E, Chambrier C, Barnoud D, Gelas P, Baubet S, Laville M, Pelascini E, Robert M. Need for Intensive Nutrition Care After Bariatric Surgery. JPEN J Parenter Enteral Nutr. 2017 Feb;41(2):258-262. doi: 10.1177/0148607116637935.
5. McMahon MM, Sarr MG, Clark MM, et al. Clinical management after bariatric surgery: value of a multidisciplinary approach. Mayo Clin Proc. 2006;81(suppl):S34-S45.
6. Drygalski AV, Andris DA. Anemia after bariatric surgery: more than just iron deficiency. Nutr Clin Pract. 2009;24:217-226.
7. Dalcanale L, Oliveira CP, Faintuch J, et al. Long-term nutritional outcome after gastric bypass. Obes Surg. 2010;20:181-187.
8. Brolin RE, Kenler HA, Gorman RC, et al. Are vitamin B12 and folate deficiency clinically important after Roux-en-Y gastric bypass? J Gastrointest Surg. 1998;2:436-442.
9. Slater GH, Ren CJ, Siegel N, et al. Serum fat-soluble vitamin deficiency and abnormal calcium metabolism after malabsorptive bariatric surgery. J Gastrointest Surg. 2004;8:48-55.
10. Goldner WS, O'Dorisio TM, Dillon JS, et al. Severe metabolic bone disease as a long-term complication of obesity. Obes Surg. 2002;12:685-692.
11. Johnson JM, Maher JW, Samuel I, et al. Effects of gastric bypass procedures on bone mineral density, calcium, parathyroid hormone, and vitamin D. J Gastrointest Surg. 2005;9:1106-1111.
12. Aasheim ET. Wernicke's encephalopathy after bariatric surgery. Ann Surg. 2008;248:714-720.
13. Lakhani SV, Shah HM, Alexander K, et al. Small intestinal bacterial overgrowth and thiamine deficiency after Roux-en-Y gastric bypass surgery in obese patients. Nutr Res. 2008;28:293-298.
14. Griffith DP, Liff D, Ziegler TR, et al. Acquired copper deficiency: a potentially serious and preventable complications following gastric bypass surgery. Obesity. 2009;17:827-831.
15. Scopinaro N, Gianetta E, Adami GF, et al. Biliopancreatic diversion for obesity at eighteen years. Surgery. 1996;119:261-268.
16. Schwartz ML, Drew RL, Chazin-Caldie M. Factors determining conversion from laparoscopic to open Roux-en-Y gastric bypass. Obes. Surg. 2004;14:1193–1197. Doi:

10.1381/0960892042386887.

17. Colangeli L, Gentileschi P, Sbraccia P, Guglielmi V. Ketogenic Diet for Preoperative Weight Reduction in Bariatric Surgery: A Narrative Review. Nutrients. 2022;14:3610. doi: 10.3390/nu14173610.
18. Leonetti F, Campanile F.C., Coccia F., Capoccia D., Alessandroni L., Puzziello A., Coluzzi I., Silecchia G. Very low-carbohydrate ketogenic diet before bariatric surgery: Prospective evaluation of a sequential diet. Obes. Surg. 2015;25:64–71. doi: 10.1007/s11695-014-1348-1.
19. Lorenzo PM, Sajoux I, Izquierdo AG, Gomez-Arbelaez D, Zulet MA, Abete I, Castro AI, Baltar J, Portillo MP, Tinahones FJ, et al. Immunomodulatory effect of a very-low-calorie ketogenic diet compared with bariatric surgery and a low-calorie diet in patients with excessive body weight. Clin. Nutr. 2022;41:1566–1577. doi: 10.1016/j.clnu.2022.05.007.
20. Schiavo L., De Stefano G., Persico F., Gargiulo S., Di Spirito F., Griguolo G., Petrucciani N., Fontas E., Iannelli A., Pilone V. A Randomized, Controlled Trial Comparing the Impact of a Low-Calorie Ketogenic vs a Standard Low-Calorie Diet on Fat-Free Mass in Patients Receiving an Elipse™ Intragastric Balloon Treatment. Obes. Surg. 2021;31:1514–1523. doi: 10.1007/s11695-020-05133-8.
21. Schiavo L., Pilone V., Rossetti G., Barbarisi A., Cesaretti M., Iannelli A. A 4Week Preoperative Ketogenic Micronutrient-Enriched Diet Is Effective in Reducing Body Weight, Left Hepatic Lobe Volume, and Micronutrient Deficiencies in Patients Undergoing Bariatric Surgery: A Prospective Pilot Study. Obes. Surg. 2018;28:2215–2224. doi: 10.1007/s11695-018-3145-8.
22. Albanese A., Prevedello L., Markovich M., Busetto L., Vettor R., Foletto M. Pre-operative Very Low Calorie Ketogenic Diet (VLCKD) vs. Very Low Calorie Diet (VLCD): Surgical Impact. Obes. Surg. 2019;29:292–296. doi: 10.1007/s11695-018-3523-2.
23. Kumar NK, Merrill JD, Carlson S, German J, Yancy WS, Jr. Adherence to Low-Carbohydrate Diets in Patients with Diabetes: A Narrative Review. Diabetes Metab. Syndr. Obes. Targets Ther. 2022;15:477–498. doi: 10.2147/DMSO.S292742.
24. Muscogiuri G, El Ghoch M., Colao A., Hassapidou M., Yumuk V., Busetto L. Obesity Management Task Force (OMTF) of the European Association for the Study of Obesity (EASO) European Guidelines for Obesity Management in Adults with a Very Low-Calorie Ketogenic Diet: A Systematic Review and Meta-Analysis. Obes. Facts. 2021;14:222–245. doi: 10.1159/000515381.
25. Sukkar SG, Signori A, Borrini C, Barisione G, Ivaldi C, Romeo C, Gradaschi R., Machello N., Nanetti E., Vaccaro A.L. Feasibility of protein-sparing modified fast by tube (ProMoFasT) in obesity treatment: A phase II pilot trial on clinical safety and efficacy (appetite control, body composition, muscular strength, metabolic pattern, pulmonary function test) Mediterr. J. Nutr. Metab. 2013;6:165–176. doi: 10.3233/s12349-013-0126-2.
26. Castaldo G., Monaco L., Castaldo L., Galdo G., Cereda E. An observational study of sequential protein-sparing, very low-calorie ketogenic diet (Oloproteic diet) and hypocaloric Mediterranean-like diet for the treatment of obesity. Int. J. Food Sci. Nutr. 2016;67:696–706. doi: 10.1080/09637486.2016.1186157.
27. Castaldo G, Schiavo L, Pagano I, Molettieri P, Conte A, Sarno G, Pilone V, Rastrelli L. Clinical Impact of Enteral Protein Nutritional Therapy on Patients with Obesity Scheduled for Bariatric Surgery: A Focus on Safety, Efficacy, and Pathophysiological Changes. Nutrients. 2023 Mar 20;15(6):1492. doi: 10.3390/nu15061492.
28. Byrne TK. Complications of surgery for obesity. Surg Clin North Am. 2001;81:1181-1193.
29. Heber D, Greenway FL, Kaplan LM, et al. Endocrine and nutritional management of the post-bariatric surgery patient: an Endocrine Society clinical practice guideline. J Clin Endocrinol Metab. 2010;95:4823-4843.
30. Weimann A, Braga M, Carli F, Higashiguchi T, Hübner M, Klek S, Laviano A, Ljungqvist O, Lobo DN, Martindale RG, Waitzberg D, Bischoff SC, Singer P. ESPEN practical guideline: Clinical nutrition in surgery. Clin Nutr. 2021 Jul;40(7):4745-4761. doi: 10.1016/j.clnu.2021.03.031.
31. Velapati SR, Schroeder SE, Schroeder DR, Buttar NS, Mohamed Elfadil O, Hurt RT, Mundi MS. Use of Home Enteral Nutrition in Malnourished Post-Bariatric Surgery Patients. JPEN J Parenter Enteral Nutr. 2021 Jul;45(5):1023-1031. doi: 10.1002/jpen.1973.
32. Skroubis G, Sakellaropoulos G, Pouggouras K, et al. Comparison of nutritional deficiencies after Roux-en-y gastric bypass and after biliopancreatic diversion with Roux-en-y gastric

bypass. Obes Surg. 2002;12:551-558.

**33.** Service GJ, Thompson GB, Service FJ, et al. Hyperinsulinemic hypoglycemia with nesidioblastosis after gastric bypass surgery. N Engl J Med. 2005;353:249-254.

**34.** McLaughlin T, Peck M, Hoist J, Deacon C. Reversible hyperinsulinemic hypoglycemia after gastric bypass: a consequence of altered nutrient delivery. J Clin Endocrinol Metab. 2010;95:1851-1855.