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FROM LIFESTYLE INTERVENTIONS TO BARIATRIC SURGERY: AN OVERVIEW OF OBESITY TREATMENT MODALITIES

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ABSTRACT

Obesity is a chronic, multifactorial disease associated with serious metabolic, cardiovascular, psychological, and socioeconomic consequences. This review aims to synthesize current evidence on the contemporary treatment strategies for obesity: lifestyle interventions, pharmacotherapy, endoscopic therapies, and bariatric surgery.

Our findings indicate, that obesity develops through the interaction of genetic, metabolic, behavioral, and environmental factors, making simple lifestyle-based approaches insufficient for many patients. While multi-component lifestyle interventions remain the foundation of therapy, their long-term effectiveness is limited. The effectiveness strongly depends on patient's involvement, usually fluctuating between 2.4% and 10.8% of reduced total body weight per year. Modern drugs are the second stage of treatment. According to our results, the most effective is tirzepatide - dual incretin agonist - that demonstrates weight loss outcomes averaging up to 25.3% in 88 weeks follow-up. The next step of managing obesity is endoscopic treatment, that provide profound efficacy with favorable safety profiles. For example, endoscopically inserted intragastric balloons can lead to an average weight loss of around 25% within 12 months. Endoscopic methods seem to be a promising alternative for patients who are unwilling or unsuitable for surgical interventions. The most effective and durable treatment from many years remains bariatric surgery, offering substantial weight reduction and improvement in comorbidities. The most commonly performed is laparoscopic sleeve gastrectomy, averaging 35.14% total body weight loss after one year. However, we should remember that bariatric surgery also carries the highest risk of serious complications and it is the most invasive of all available obesity treatment methods.

KEYWORDS

Obesity, Weight Loss, Bariatric Surgery, Tirzepatide, Diabetes

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1. Introduction:

Obesity is a chronic, multifactorial disease characterized by an excessive accumulation of body fat that leads to negative effects on health. It is an alarmingly serious global problem, with its prevalence continuing to rise. According to the World Health Organization, in 2022 approximately one in eight people globally lived with obesity, and this number keeps growing (*Obesity and Overweight*, n.d.). Obesity is associated with a wide range of severe health consequences across multiple organs and systems. It significantly increases the risk of cardiovascular diseases, type 2 diabetes, various cancers, and respiratory disorders such as asthma and obstructive sleep apnea. Moreover, growing evidence links obesity to neurodegenerative diseases, autoimmune conditions, and a heightened susceptibility to infections, illustrating its profound impact on morbidity and mortality (Safaei et al., 2021). Obesity has also psychological consequences, contributing to poorer mental health. Research shows that patients experiencing obesity stigma are significantly more likely to develop depression, and perceived stigma is strongly linked to body-image dissatisfaction, lower quality of life, dysfunctional eating, and increased symptoms of depression and anxiety. Moreover, internalised stigma, when individuals adopt negative societal attitudes toward their own weight, produces similarly harmful psychological effects (Westbury et al., 2023).

2. Methodology:

This review examined current evidence on obesity from 2019 to 2025 and one randomized trial from 2012. Literature was searched in PubMed and Google Scholar using terms related to obesity pathogenesis, etiology, diagnosis, and treatment. We included clinical trials, observational studies, meta-analyses, and major international guidelines. Because the studies varied widely in design, findings were synthesized qualitatively rather than through formal meta-analysis. The collected evidence informed the summary of diagnostic frameworks and treatment strategies presented in the "Results" section.

3. Results:

3.1 Etiology and Risk Factors of Obesity

Obesity is a multifactorial condition resulting from the complex interaction of behavioral, environmental, genetic, and metabolic determinants. Lifestyle-related factors such as inadequate physical activity, excessive caloric intake, and unhealthy dietary behaviors contribute to chronic positive energy balance and fat accumulation. Moreover, socioeconomic context and environmental influences, such as impaired accessibility to healthy foods and lack of physical activity opportunities, shape behavioral patterns that increase obesity risk (Safaei et al., 2021). Beyond behavioral aspects, also biological mechanisms play an important role in the development of obesity. Genetic predisposition and epigenetic modifications, including DNA methylation, histone modification, and transgenerational epigenetic inheritance, affect metabolic regulation and energy homeostasis. Early-life nutritional exposures, parental health status, and postnatal environmental conditions can influence these processes and alter susceptibility to obesity across the lifespan. For example, a child with one obese parent has a three-times higher likelihood of becoming obese in adulthood, and this risk increases to ten-times when both parents are obese. Studies also show that family histories of cardiometabolic disease, frequent consumption of sugary foods and drinks, inadequate sleep, and reduced physical activity are significant contributors to childhood obesity (Lin & Li, 2021). In addition, the gut microbiome has emerged as an important mediator, affecting energy metabolism, inflammation, and insulin sensitivity. Experiments in mice without gut microflora demonstrate, that the gut microbiome has a direct, quantifiable impact on body fat and metabolism. In this study germ-free mice had 42% less total body fat despite eating 29% more food, but after colonization with gut microbes their body fat increased by 57%, but food intake dropped by 27%, indicating that microbial populations can drive greater energy harvest and fat deposition (Lin & Li, 2021). These findings underscore that obesity cannot be solely explained by lifestyle habits but represents a biologically complex disorder shaped by gene–environment interactions.

3.2 Diagnostic Criteria of Obesity

According to the World Health Organization, obesity is defined as an abnormal or excessive accumulation of body fat that presents a risk to health. In clinical and epidemiological practice, body mass index (BMI) remains the standard anthropometric indicator for classifying weight status. BMI is calculated as weight in kilograms divided by the square of height in meters (kg/m^2). Based on WHO criteria, overweight is diagnosed when BMI is equal to or greater than $25 \text{ kg}/\text{m}^2$, and obesity is defined as a BMI equal to or greater than $30 \text{ kg}/\text{m}^2$. Obesity is further categorized into three degrees of severity: Class I obesity (BMI 30.0 – $34.9 \text{ kg}/\text{m}^2$), Class II obesity (BMI 35.0 – $39.9 \text{ kg}/\text{m}^2$), and Class III obesity (BMI $\geq 40.0 \text{ kg}/\text{m}^2$), the latter also referred to as severe or morbid obesity (Safaei et al., 2021).

However, BMI provides imperfect estimation of body fat and does not adequately reflect the complex relationship between excess adiposity and health risk at the individual level. BMI-based classification can both underestimate and overestimate true adiposity, leading to potential misclassification of metabolic risk and inappropriate clinical decisions. Therefore, Rubino et al. in their review propose a refined diagnostic framework. While BMI remains a useful screening and epidemiological tool, it is recommended that individual diagnosis should be confirmed using direct or indirect assessments of adiposity, such as waist circumference, waist-to-hip ratio, or waist-to-height ratio, adjusted for age, sex, and ethnicity. The occurrence of clinical consequences such as alterations in the function of tissues, organs or the entire individual should also be taken into account (Rubino et al., 2025).

3.3 Clinical significance and comorbidities

Obesity represents a major global health burden, affecting more than two billion people and serving as a key driver of metabolic and chronic diseases. Its clinical significance lies not only in excess body weight but also in the distribution of adipose tissue, which clearly determines the risk of obesity-related comorbidities. Visceral adipose tissue, which is type of fat stored deep inside the abdominal cavity surrounding internal organs, has been identified as a central pathological component linking obesity to type 2 diabetes, non-alcoholic fatty liver disease (NAFLD) and cardiovascular disease (Zhang et al., 2023).

Epidemiological evidence indicates that obesity increases the risk of cancer at 13 different anatomical sites, including endometrial cancer, postmenopausal breast cancer, colorectal cancer, esophageal cancer, renal cancer, pancreatic cancer, cancer of the gastric cardia, liver cancer, ovarian cancer, gallbladder cancer, thyroid cancer, meningioma, and multiple myeloma. These associations are thought to be mediated by alterations in

hormones, insulin resistance, chronic inflammation, and other metabolic and molecular pathways linking obesity to carcinogenesis (Friedenreich et al., 2021).

It has been also linked to the development of neurodegenerative diseases, with studies showing higher rates of conditions such as Alzheimer's disease and Parkinson's disease among individuals with obesity. Evidence suggests that obesity-related metabolic dysfunctions, may initiate or accelerate neurodegenerative processes, thereby raising the long-term risk of cognitive decline and dementia (Safaei et al., 2021).

Obesity has also psychological consequences, clearly contributing to poorer mental health in patients living with obesity. For example it has been identified as a risk factor for depression, with studies showing that it increases the odds of developing depression by about 33%. Rising obesity rates appear to modestly elevate the overall prevalence of psychological distress in the population, contributing to worsening mental health trends over recent decades (Jokela & Laakasuo, 2023).

Taking all this into consideration, obesity represents a major and growing global health threat, responsible for a substantial proportion of premature mortality and disability. In 2019, high body mass index (BMI) accounted for approximately 8.5% of all global deaths and nearly 6% of total disability-adjusted life years (DALYs), reflecting its broad impact across populations. Between 1990 and 2019, deaths and DALYs associated with high BMI increased by 148% and 155.86% for men, and by 111.67% and 121.78% for women, respectively. Projections indicate a continued rise through 2035, underscoring the urgent need for global public health interventions to mitigate the escalating burden of obesity-related morbidity and mortality (Chen et al., 2024).

3.4 Treatment of obesity:

Effective management of obesity is essential due to its profound impact on morbidity, mortality, and overall quality of life. Given its multifactorial etiology and strong association with metabolic and cardiovascular complications, timely intervention is crucial to prevent disease progression and long-term health consequences. Current treatment strategies include lifestyle modification as the cornerstone of therapy, complemented by pharmacological interventions, endoscopic interventions and bariatric surgery, which together aim to achieve sustainable weight reduction and improve metabolic health.

3.4.1 Lifestyle and non-pharmacological approaches

The foundation of obesity treatment is lifestyle modification based on the principle of energy deficit (calories consumed < calories expended). A caloric deficit can be achieved in two ways: by increasing caloric expenditure, or by reducing caloric intake.

Evidence suggests that both aerobic exercise (Jayedi et al., 2024) and resistance training (Lopez et al., 2022), as well as increases in daily physical activity, such as walking more steps, enhance total energy expenditure, thereby promoting weight loss and supporting the management of obesity. These forms of activity contribute not only to caloric burn but also to improvements in body composition and metabolic health.

Reducing calorie intake can be achieved through various diets, which, however, vary in effectiveness. For example evidence from multiple randomized controlled trials and cohort studies show, that people following a Mediterranean diet experience greater weight reduction compared to those on other dietary patterns. Despite its moderate fat content, the Mediterranean diet rich in fruits, vegetables, legumes, whole grains, olive oil, and fish has demonstrated clear cardiovascular benefits and effective weight control, particularly when combined with physical activity (Dominguez et al., 2023).

Another example is low-calorie high-protein diet, which have been shown to effectively support weight loss and reduction of visceral fat in individuals with overweight, obesity, or glucose metabolism disorders. Clinical trials demonstrate that both animal- and plant-based high-protein diets result in comparable improvements in body composition, including an average weight loss of around 7–8 kg over six months, while also enhancing glucose metabolism and cardiometabolic health. These findings highlight the utility of high-protein dietary patterns as a practical strategy for obesity management and the reduction of associated metabolic risks (Rodrigo-Carbó et al., 2025).

Evidence consistently supports multi-component lifestyle interventions - combining dietary modification, increased physical activity, and behavioral therapy - as the most effective first-line strategy. One study evaluating the effects of a calorie-reduced low fat diet versus aerobic exercise versus a combination of both diet and exercise revealed, that populations eating a low fat, low-calorie diet and exercising at a moderate-intensity five times a week lost 10,8% of their body mass, while those only dieting or only exercising lost 8.5% and 2,4% body weight in one year, respectively (Foster-Schubert et al., 2012).

Obesity psychological interventions can be executed individually or in groups. Systematic reviews indicate that group-based interventions achieve greater average weight loss, compared to individual sessions.

Participants attending group multi-component lifestyle interventions lose on average 1.9 kg more weight than in one-to-one interventions at 12 months. The enhanced effectiveness of group settings probably results from peer support, shared accountability, and increased contact time, all of which reinforce behavioral change and adherence. Overall, these findings underscore that sustained behavioral modification supported by structured, multi-component approaches forms the foundation of effective, non-pharmacological obesity treatment (Abbott et al., 2021).

Meta-analysis published by Madigan et al. suggest that lifestyle-based weight management interventions delivered in primary care are effective in achieving clinically meaningful reductions in body weight and waist circumference. Such programs, implemented by general practitioners or non-medical professionals, typically result in an average weight loss of around 2–4 kg in 12-18 months, which even if modest, translates into significant metabolic benefits, including improvements in blood pressure, glucose regulation, and lipid profile. Greater effectiveness was observed in interventions that provided at least 12 patient contacts, which showed the importance of continuity and engagement in treatment. Importantly, non-medical practitioners (e.g., dietitians, health coaches) achieved comparable outcomes to physicians, suggesting that a multidisciplinary approach may enhance both accessibility and cost-effectiveness (Madigan et al., 2022).

3.4.2 Pharmacological treatment

Pharmacological treatment represents an important addition to lifestyle modification in the management of obesity, particularly for individuals who do not achieve sufficient weight loss through non-pharmacological approaches alone. Several anti-obesity medications are available, and their use should be individualized based on patient characteristics, comorbidities, treatment response, and personal preferences to ensure both efficacy and safety.

Guidelines suggest that most of pharmacotherapies for weight loss can be used for patients with BMI ≥ 30 kg/m² or BMI ≥ 27 kg/m² with adiposity-related complications, in combination with proper diet, physical activity and psychological interventions (Wharton et al., 2020).

a) GLP-1 receptor agonists

Glucagon-like peptide-1 receptor agonists represent one of the most effective pharmacologic approaches to obesity management, initially developed for type 2 diabetes, but now widely used for weight reduction. These agents, including liraglutide, semaglutide, dulaglutide, exenatide, and new oral formulations such as oral semaglutide and orforglipron, act by mimicking endogenous GLP-1, a gut-derived incretin hormone that enhances glucose-dependent insulin secretion by binding to GLP-1 receptors on pancreatic beta cells, which helps manage blood sugar levels, while reducing the risk of hypoglycemia. They also suppresses glucagon secretion from pancreatic alpha cells, thereby lowering hepatic glucose production and stabilizing blood sugar. GLP-1 receptor agonists delay gastric emptying, and promotes satiety through central nervous system pathways by acting on GLP-1 receptors in the hypothalamus (Patel et al., 2025). This combination of reduced appetite, slower gastric emptying, and improved glucose regulation leads to substantial decreases in caloric intake and sustained weight loss.

A comprehensive meta-analysis of 47 randomized controlled trials, which durations ranged widely from 4 to 104 weeks, encompassing over 23,000 participants demonstrated that treatment with GLP-1 receptor agonists resulted in a mean weight reduction of approximately 4.57 kg compared with placebo, alongside significant decreases waist circumference (Wong et al., 2025). The effects were consistent across agents and routes of administration, with semaglutide showing the highest efficacy. The benefits were observed in individuals with and without diabetes, but greater reductions were seen among non-diabetic participants. It suggests that metabolic alterations in diabetes may attenuate the full weight-lowering potential of GLP-1 receptor agonists. Moreover, treatment duration was a key determinant of success: longer periods of treatment (>1 year) were associated with continued weight loss beyond the typical plateau observed in other interventions (Wong et al., 2025).

In another systematic review and network meta-analysis of randomised controlled trials GLP-1 receptor agonists produced clinically meaningful weight loss, lowering body weight by an average of about 5.79% compared with lifestyle modification alone. Among different GLP-1 receptor agonists semaglutide showed the greatest effectiveness, achieving approximately 11.4% body-weight reduction, making it one of the most efficient GLP-1 based therapies for weight loss (Shi et al., n.d.). The differences in the results of the above studies also arise from the fact, that the meta-analyses include many studies of varying duration.

In addition to weight loss, GLP-1 agonists cause improvements in cardiometabolic health, including favorable effects on blood pressure, lipid profiles, and markers of inflammation. Evidence indicates a reduction in all-cause and cardiovascular mortality, positioning these drugs as valuable tools for mitigating obesity-

related comorbidities such as type 2 diabetes, cardiovascular disease, and chronic kidney disease. Additionally, data suggest that oral GLP-1 receptor agonists provide comparable efficacy to subcutaneous injections, potentially improving adherence due to greater convenience (Wong et al., 2025).

The therapeutic response to GLP-1 receptor agonists appear dose-dependent, with higher doses of liraglutide and semaglutide producing greater weight reduction, but at the cost of more frequent gastrointestinal side effects such as nausea and vomiting. Patient characteristics also influence efficacy: younger age, female sex, higher baseline BMI, and lower HbA1c predict better outcomes. Importantly, these agents are recommended primarily for individuals with BMI >30 kg/m² or BMI >27 kg/m² with obesity-related comorbidities, as the risks outweigh the benefits in normal-weight individuals (Wong et al., 2025).

Overall, GLP-1 receptor agonists offer a powerful and sustained pharmacologic option for obesity management, particularly when combined with lifestyle modification and physical activity. Their dual action on metabolic control and appetite regulation makes them a cornerstone of modern anti-obesity therapy, with ongoing research likely to refine their use and expand their indications in the coming years (Wong et al., 2025).

b) Dual incretin agonists (e.g., tirzepatide)

Tirzepatide represents one of the most promising recent developments in the pharmacological treatment of obesity. It is a dual incretin receptor agonist that simultaneously activates both glucose-dependent insulinotropic polypeptide (GIP) and glucagon-like peptide-1 (GLP-1) receptors, offering synergistic metabolic effects superior to those of traditional monotherapy with GLP-1 receptor agonists. Through this dual mechanism, tirzepatide has numerous beneficial actions, including suppression of appetite and caloric intake, slowing of gastric emptying, enhancement of glucose metabolism, and increased energy expenditure and thermogenesis (Galindo et al., 2025).

Initially approved for type 2 diabetes mellitus, tirzepatide has been also authorized by the U.S. FDA for long-term weight management in adults with obesity (BMI ≥ 30 kg/m²) or those who are overweight (BMI ≥ 27 kg/m²) and have at least one weight-related comorbidity such as hypertension, dyslipidemia, obstructive sleep apnea, or cardiovascular disease (Sallam et al., 2025).

Clinical evidence demonstrates that tirzepatide provides unprecedented weight loss outcomes among currently available pharmacological options. In some major clinical trials participants achieved up to 20.9% weight loss during 36-week treatment course. After that time, participants were randomly divided into 2 groups: the first one still using tirzepatide, and second one taking placebo. After 55 weeks the first group was still losing weight (on average -5.5%), while the placebo group regained 14.0% of the starting weight. At the end of a trial group using tirzepatide for 88 weeks continuously ended up losing on average 25.3% of initial weight. That results confirm the necessity of continuous treatment to maintain long-term benefits and prevent rebound weight gain (Aronne et al., 2024). Meta-analyses comparing tirzepatide to semaglutide and liraglutide found significantly higher odds of achieving ≥ 5 –20% weight loss, as well as improvements in BMI, waist circumference, blood pressure, and atherosclerotic cardiovascular disease risk profiles in favor of tirzepatide. Furthermore, patients reported enhanced quality of life, reflecting not only physical but also psychological benefits of sustained weight reduction (Sallam et al., 2025).

While tirzepatide's safety profile is generally favorable, gastrointestinal side effects, like nausea, constipation, and diarrhea are the most common, but typically mild to moderate, with fewer than 5% of patients rejecting treatment due to adverse events. Serious adverse reactions are rare. Importantly, current evidence shows that tirzepatide not only helps to control weight, but also contribute to cardiometabolic improvements, such as better insulin sensitivity, reduction in blood pressure and lipid levels. However, ongoing research is needed to confirm long-term safety, durability of effect, and comparative cost-effectiveness (Sallam et al., 2025).

c) Lipase inhibitors (orlistat)

Orlistat acts as a gastrointestinal lipase inhibitor, blocking the activity of gastric and pancreatic enzymes responsible for breaking down dietary triglycerides into absorbable fatty acids and monoglycerides. Typically it is taken three times a day with fat-containing meals. As a result, approximately 30% of consumed fat remains unabsorbed and is excreted in the feces, effectively reducing caloric intake and promoting weight loss. In addition to its local action in the digestive tract, orlistat has been shown to improve lipid profiles, particularly by lowering LDL cholesterol levels, while maintaining a low risk of systemic side effects due to minimal absorption (Patel et al., 2025).

To minimize gastrointestinal side effects such as oily stools, flatulence, and increased bowel movements, patients are advised to limit fat intake to less than 30% of total calories. Because orlistat interferes with the absorption of fat-soluble vitamins (A, D, E, and K), multivitamin supplementation is recommended, taken at

least two hours apart from the medication. Additionally, orlistat may interact with certain drugs, including cyclosporine and warfarin, requiring careful monitoring. Although most side effects are mild and temporary, rare but serious adverse events, such as liver injury and oxalate nephropathy, have been reported (Patel et al., 2025).

Clinical evidence supports modest effectiveness of orlistat in promoting weight loss, which depends mostly on diet. The average weight loss fluctuate between 5-10% in different studies. It was also proved that orlistat improves metabolic health among individuals with obesity (Caklili et al., 2023) (Patel et al., 2025).

d) Naltrexone/bupropion

The combination of naltrexone and bupropion promotes weight loss by acting on the central nervous system pathways involved in appetite regulation and reward. Bupropion, a norepinephrine and dopamine reuptake inhibitor, stimulates pro-opiomelanocortin (POMC) neurons in the hypothalamus, increasing the release of α -melanocyte-stimulating hormone (α -MSH), which suppresses appetite and promotes energy expenditure. However, this process also releases β -endorphin, which activates μ -opioid receptors and creates an autoinhibitory feedback loop that reduces POMC activity. Naltrexone, an opioid receptor antagonist, blocks this feedback inhibition, allowing for sustained POMC activation and continuous appetite suppression, thereby enhancing and maintaining weight loss more effectively than either drug alone (Liu et al., 2024).

Different studies confirm positive influence of naltrexone and bupropion on weight loss among patients with excessive BMI. In Wharton's et al. study, treatment with naltrexone/bupropion combined with lifestyle modification led to clinically significant weight loss in adults with obesity or overweight and related comorbidities. After six months, participants experienced an average weight reduction of 4.23 kg (approximately 4.05% of body weight). The most common side effects were nausea, constipation, and headache, though these were generally mild and manageable. Patients also reported decreased appetite, reduced cravings, and earlier satiety, contributing to healthier eating behaviors (Wharton et al., 2025).

Another review indicated that treatment with naltrexone/bupropion resulted in significantly greater weight loss compared with placebo, with participants losing on average 2.5 kg more over 12 months. However, naltrexone/bupropion group was associated with a higher incidence of adverse effects, such as gastrointestinal discomfort, insomnia, headaches, and palpitations, leading to more treatment discontinuations. Despite these side effects, overall dropout rates were similar between naltrexone/bupropion and placebo groups, likely due to greater weight-loss failure in the placebo arm (Onakpoya et al., 2020).

e) Phentermine/topiramate

The phentermine/topiramate combination acts synergistically to promote weight loss primarily through appetite suppression and reduced caloric intake. Phentermine functions as a sympathomimetic amine, increasing norepinephrine release in the hypothalamus, which stimulates β -adrenergic receptors and suppresses hunger signals. Topiramate, on the other hand, modulates GABA-A receptors and voltage-gated ion channels, contributing to appetite reduction and possible alterations in taste perception that decrease food intake. When combined, phentermine's noradrenergic activation and topiramate's GABA-mediated effects produce a stronger and more sustained anorectic response than either drug alone. This dual mechanism allows for enhanced efficacy at lower individual doses, improving tolerability while maintaining significant weight-reducing effects throughout the day (Kim et al., 2023).

In a 56-week randomized, double-blind, placebo-controlled trial participants receiving phentermine/topiramate extended-release experienced an average weight loss of 8.3% from baseline versus 2.3% with placebo. The treatment also resulted in decreases in visceral fat and body fat percentage, as well as improvements in glucose metabolism, highlighting its metabolic benefits beyond weight reduction. Although adverse events such as dizziness, paresthesia, and dry mouth occurred more frequently in the treatment group, most were mild to moderate in severity, and no fatal outcomes were reported. Overall, phentermine/topiramate extended-release proved to be an effective and generally well-tolerated pharmacological option for long-term obesity management (Hong et al., 2025).

Very similar conclusions were drawn from a systematic review and meta-analysis published in 2020 by Lei et al. Study demonstrated that phentermine/topiramate significantly reduced body weight compared with placebo, with the extent of weight loss correlating positively with dosage. On average, patients lost about 7.7 kg, along with improvements in cardiometabolic markers such as waist circumference, blood pressure, glucose, and lipid levels. The most common side effects like paresthesia, dry mouth, and constipation were generally mild, and most individuals maintained their weight loss over time (Lei et al., 2021).

3.4.3 Endoscopic treatment

Endoscopic bariatric and metabolic therapies (EBMTs) represent a rapidly advancing field that bridges the gap between lifestyle or pharmacological treatments and traditional bariatric surgery. These minimally invasive procedures are less risky than surgery, but generally more effective than medications and behavioral interventions. While long-term data remain limited, current evidence supports their safety and effectiveness, making EBMTs a promising alternative for patients who are unwilling or unsuitable for surgical interventions (Qureshi et al., 2023).

a) Intra-gastric balloons

Intra-gastric balloons are space-occupying devices inserted into the stomach to delay gastric emptying and promote early satiety, thereby reducing food intake. They are approved for patients with a BMI of 30–34.9 kg/m² and at least one obesity-related comorbidity who have not succeeded with lifestyle or medical interventions. Among various FDA-approved devices, the Orbera balloon is the most widely used, typically remaining in place for up to six months. Studies and meta-analyses have shown that Orbera treatment leads to an average excess body weight loss of about 25% at 12 months, demonstrating its effectiveness as a minimally invasive weight-loss option (Qureshi et al., 2023).

The most common adverse effects of intra-gastric balloon therapy are nausea, vomiting, and abdominal pain, occurring in up to 63%, 31%, and 5% of patients, respectively. Less frequent but notable complications include gastric ulceration, bleeding, and gastroesophageal reflux disease, with major complications reported in fewer than 1% of cases (Weitzner et al., 2023). This is significantly less than classic bariatric surgery, making them a safer method of weight loss.

b) Endoscopic sleeve gastroplasty

Endoscopic sleeve gastroplasty (ESG) is a minimally invasive, endoscopic alternative to laparoscopic sleeve gastrectomy (LSG), designed to reduce stomach volume by approximately 70%. Using an endoscopic suturing device, full-thickness sutures are placed along the lesser curvature of the stomach to create a narrow, tubular sleeve, which enhances satiety and delays gastric emptying (Qureshi et al., 2023). Compared to LSG, ESG results in slightly less total body weight loss (the 6-month follow-up on average ESG - 17.1% vs. LSG - 23.6% of total body weight loss) but offers a significantly lower rate of adverse events (5.2% vs. 16.9%) and new-onset GERD (1.9% vs 14.5%) (Fayad et al., 2019).

While ESG primarily induces mechanical restriction, it does not trigger the same hormonal changes seen with LSG, such as increased GLP-1 secretion or decreased ghrelin levels. However, combining ESG with pharmacologic therapies like liraglutide may enhance its weight loss effects. The most common adverse events are nausea, vomiting, abdominal pain, and mild procedural complications (Qureshi et al., 2023).

c) Primary Obesity Surgery Endoluminal (POSE)

The POSE (Primary Obesity Surgery Endoluminal) procedure involves the use of the Incisionless Operating Platform to create full-thickness plications in the gastric fundus, thereby reducing stomach volume and promoting satiety. Clinical studies have shown that POSE leads to an average total body weight loss (TBWL) of 12.68% at 12–15 months. The overall incidence of serious adverse events was 2.84% and included bleeding, hepatic abscess, severe pain, severe nausea, and severe vomiting (Singh et al., 2021).

3.4.4 Surgical treatment

The management of obesity typically follows a stepwise approach, beginning with lifestyle modifications such as dietary changes, increased physical activity, and behavioral interventions as first-line therapy. Subsequently, pharmacological treatment is considered as a second-line therapy. If that approaches fail, typically medicine offers an effective third-line option: bariatric surgery, offering significant and sustained loss of body weight and obesity-related comorbidities. There are four most common bariatric surgery procedures: the sleeve gastrectomy, Roux-en-Y gastric bypass, one-anastomosis gastric bypass and adjustable gastric banding.

The number of bariatric procedures performed and the popularity of specific surgical techniques, varies across countries and world regions. Worldwide data from 2021 show that a total of 598,834 bariatric procedures were performed in 57 countries that responded for data request. Sleeve gastrectomy accounted for 58.2% of all surgeries, Roux-en-Y gastric bypass represented 26.4% of procedures, while one-anastomosis gastric bypass represented 7.6% of operations globally (Angrisani et al., 2024).

For comparison, in 2023 in Poland 9,102 bariatric operations were performed, of which sleeve gastrectomy accounted for 82%, Roux-en-Y gastric bypass for 9.7%, and one-anastomosis gastric bypass for 3.9% (Janik et al., 2024). These data highlight how national trends can differ significantly from global patterns.

Eligibility for bariatric surgery is based on specific criteria to maximize safety and effectiveness. Current guidelines recommend considering surgery for individuals with a BMI ≥ 35 kg/m², regardless of comorbidities, or ≥ 40 kg/m² according to older standards (Wharton et al., 2020); those with a BMI of 30–34.9 kg/m² may also qualify if they have obesity-related diseases and have not achieved sufficient weight loss through lifestyle or pharmacological interventions. In Asian populations, the BMI threshold is lower: ≥ 27.5 kg/m², reflecting earlier onset of obesity-related complications. Before surgery, patients undergo comprehensive evaluations, including cardiac and pulmonary assessments and sleep apnea screening, to reduce perioperative risks and ensure optimal outcomes (Peri & Eisenberg, 2024).

a) Sleeve gastrectomy:

In recent years laparoscopic sleeve gastrectomy has been the most frequently performed bariatric procedure, with a continually growing popularity due to its safety, efficacy, and technical simplicity (Masry & Fiky, 2023).

In that procedure approximately 80% of the stomach is removed, leaving a narrow, tube-shaped “sleeve” that limits food intake and reduces hunger by lowering ghrelin production. It is considered less invasive and lower risk compared to gastric bypass, with fewer complications but slightly less overall weight loss. Common complications include bleeding, leaks, and gastroesophageal reflux, while long-term risks involve nutrient deficiencies and gallstones (Peri & Eisenberg, 2024).

Laparoscopic sleeve gastrectomy has proven to be a highly effective long-term treatment for severe obesity, with significant and sustained weight loss. In a large 11-year study including 892 patients, the mean total body weight loss reached was 35.14 % after one year, 32.51% after 5 years, and 30.91% after 11 years. Additionally, laparoscopic sleeve gastrectomy led to substantial improvement or complete resolution of obesity-related comorbidities, including dyslipidemia (97%), hypertension (66%), diabetes (61%), and sleep apnea (100%). Early postoperative complications were relatively rare, occurring in about 1.8% of patients, with a reoperation rate of 0.9% and mortality of 0.22%. Long-term weight regain was observed in a minority of patients, primarily among those with sedentary lifestyle and poor dietary habits. Overall, laparoscopic sleeve gastrectomy demonstrates durable efficacy and an acceptable safety profile compared to other bariatric procedures (Masry & Fiky, 2023).

b) Roux-en-Y gastric bypass

Roux-en-Y gastric bypass (RYGB) is a bariatric surgery in which the stomach is reduced to a small pouch and directly connected to the Roux limb of the small intestine, bypassing a portion of the duodenum. This procedure both restricts food intake and impairs nutrient absorption, leading to significant and sustained weight loss (Peri & Eisenberg, 2024). Studies have shown that patients typically achieve around 56.7% excess weight loss, with long-term maintenance of 27% body weight reduction even 15 years after surgery (O’Brien et al., 2019).

In another study on average patients achieved a maximum total weight loss of about 36% two years after surgery, with a sustained loss of approximately 28% still observed 15 years postoperatively (McClelland et al., 2023).

While RYGB is highly effective, it carries risks of both short- and long-term complications, including bowel obstruction, venous thromboembolism, gastrointestinal or intra-abdominal bleeding, anastomotic leak, infection, internal hernia, anastomotic stricture, marginal ulceration, cholelithiasis, incisional hernia, nutritional and vitamin deficiencies, dumping syndrome and malabsorption. (Peri & Eisenberg, 2024).

c) One-anastomosis gastric bypass

One-anastomosis gastric bypass is a simplified variation of the Roux-en-Y gastric bypass that uses a single gastrojejunostomy, eliminating the need for a second anastomosis and thereby reducing operative complexity and certain complications. The procedure involves creating a long, narrow gastric pouch and connecting it to a loop of jejunum approximately 200 cm from the ligament of Treitz. By avoiding a second anastomosis, one-anastomosis gastric bypass reduces risks such as internal herniation, additional anastomotic leaks, and bleeding from a second staple line (Karagul et al., 2024).

One-anastomosis gastric bypass can be performed with varying lengths of the biliopancreatic limb (BPL), typically ranging from 150 to 220 cm. Longer BPLs, such as 200 cm, tend to provide greater weight loss while maintaining comparable remission of comorbidities, but they are also associated with a higher risk of nutritional deficiencies (Onzi et al., 2024).

The YOMEGA trial compared one-anastomosis gastric bypass (OAGB) with standard Roux-en-Y gastric bypass (RYGB) in patients with morbid obesity over a two-year follow-up. The study demonstrated that OAGB is non-inferior to RYGB in terms of percentage excess BMI loss and metabolic improvement, with

mean excess BMI loss of 87.9% for OAGB versus 85.8% for RYGB. However, OAGB was associated with a higher incidence of nutritional complications, including diarrhea and steatorrhea, likely due to its 200 cm biliopancreatic limb and malabsorptive effect. Overall, OAGB appears effective for weight loss, but requires careful monitoring for nutritional deficiencies (Robert et al., 2019).

d) Gastric banding

Gastric banding, also known as the lap band, involves placing an adjustable silicone band around the upper part of the stomach to limit food intake and promote early satiety. The band can be tightened or loosened via subcutaneous access port, allowing individualized adjustments. Although the procedure carries a relatively low risk of short-term complications, long-term issues such as band slippage, erosion, and weight regain are common (Peri & Eisenberg, 2024).

Laparoscopic adjustable gastric banding (LAGB) was widely performed in the early 2000s but has sharply declined due to poor long-term weight loss and high complication and reoperation rates. That issues contribute to band removal in up to half of patients, with many requiring revisional surgery to address weight regain or recurrent comorbidities. Common revision options include Roux-en-Y gastric bypass (RYGB), laparoscopic sleeve gastrectomy (LSG), and more recently one-anastomosis gastric bypass (OAGB), which has shown promising weight-loss outcomes and high rates of comorbidity and GERD remission. Given the lack of consensus on the optimal revisional approach, further comparative studies are needed to guide individualized treatment decisions (Hany et al., 2024).

4. Discussion

Obesity is a complex disease driven by behavioral, genetic, metabolic, and environmental factors. The evidence reviewed here supports the view that this multifactorial nature requires individualized and long-term treatment strategies. Although BMI remains the standard diagnostic measure, it does not adequately reflect differences in adiposity or metabolic risk. Because cardiometabolic complications relate more to visceral fat and systemic inflammation than to total body mass, combining BMI with additional anthropometric and clinical markers, improves risk assessment and treatment selection (Rubino et al., 2025).

Obesity affects nearly every physiological system. It causes not only metabolic and cardiovascular complications, but growing evidence supports its role in carcinogenesis, neurodegenerative diseases, and psychological disorders. Its growing global burden, reflected in increased mortality and disability-adjusted life years, highlights the need for effective interventions. The rising levels of psychological distress associated with obesity shows the importance of adding mental health support to routine care.

Regarding treatment, the results presented in this review demonstrate that lifestyle modification remains the cornerstone of therapy, but rarely achieves substantial long-term weight loss when used alone. Multi-component lifestyle changes like low-calorie diet and increased physical activity show superior outcomes compared with single-modality programs. Evidence show that they can lower total body weight on average by 8.5% through diet only, by 2,4% through physical exercises only and by 10,8% through both in one year (Foster-Schubert et al., 2012). Weight loss effect can be even greater when patients attend group meetings because this enhance accountability and support (Abbott et al., 2021). Nevertheless, the limited effectiveness of non-pharmacological and non-invasive approaches underscores the need for supportive therapies.

Pharmacological options have expanded significantly in recent years, particularly with the development of incretin-based therapies. The most effective are GLP-1 receptor agonists (like semaglutide) and dual incretin agonists (such as tirzepatide) with total body weight loss averaging up to 11,4% and 25,3% respectively (Shi et al., n.d.) (Sallam et al., 2025). Their mechanisms, combining appetite suppression, delayed gastric emptying, and metabolic improvements, address core physiological drivers of obesity. However, medications mentioned above are relatively new, therefore further research is needed to fully assess their long-term safety and side effects.

Endoscopic bariatric therapies serve as an intermediate option, offering greater efficacy than pharmacotherapy but lower risk than surgery. For instance, studies show that endoscopically inserted intragastric balloons lead to an average excess body weight loss of about 25% at 12 months (Qureshi et al., 2023). Procedures like this demonstrate meaningful weight loss with favorable safety profiles, making them a useful alternative for patients who are not eligible for bariatric surgery.

The most effective and durable treatment for severe obesity is still bariatric surgery. Sleeve gastrectomy, currently the most common bariatric procedure globally, offers on average 35.14 % of total body weight loss after one year and improvement in comorbidities, though at the cost of potential complications such as GERD

and nutritional deficiencies (Masry & Fiky, 2023). Roux-en-Y gastric bypass and one-anastomosis gastric bypass can provide even greater metabolic benefits, but carry higher procedural risks.

A key finding of this review is the need to treat obesity as a long-term, chronic condition. Relapse is common, with weight regain frequently occurring after lifestyle changes, pharmacotherapy withdrawal, and even, in some cases, following bariatric surgery. Therefore effective care requires continuous monitoring, behavioral and nutritional support, and early management of metabolic risk. Future work should prioritize combination strategies: blending behavioral, pharmacologic, and endoscopic approaches to improve outcomes with less invasiveness. As these options expand, integrating them into routine care will be essential to address the global rise of obesity and its wide-ranging health effects.

5. Conclusions

Obesity is a chronic, multicausal disease, that significantly increases the risk of metabolic, cardiovascular, oncological, neurodegenerative, and psychological disorders. Because of rising prevalence, it becomes a major global health challenge, contributing to rising mortality and disability worldwide. Effective diagnosis and treatment requires an individualized, multifactorial approach, that takes into account the diverse causes and consequences of obesity. Lifestyle modification remains the foundation in obesity therapy but is insufficient for most individuals to achieve durable, clinically meaningful weight loss. Pharmacological advances, particularly incretin-based therapies, have transformed the therapeutic landscape, offering weight reductions previously achievable only with bariatric surgery. Endoscopic procedures provide an effective intermediary option, while bariatric surgery continues to offer the most substantial and sustainable results, especially for individuals with severe obesity or obesity-related comorbidities. Across all treatment modalities, long-term follow-up, behavioral reinforcement, and attention to mental health, are critical to maintain benefits and prevent relapse. Finally, addressing obesity requires a shift toward chronic disease management models, greater access to evidence-based therapies, and continued research into personalized treatment strategies. A comprehensive, integrated approach is essential to mitigate the growing global burden of obesity and improve patient outcomes.

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