



Recurrent Weight Gain after Weight Loss Induced by Lifestyle Intervention, Metabolic and Bariatric Surgery, or Semaglutide in Adults with Obesity: A Systematic Review of Randomized Controlled Trials

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Abstract

Obesity management is challenged by high rates of recurrent weight gain following initial loss. We systematically reviewed 29 randomized controlled trials comparing long-term outcomes of lifestyle interventions, semaglutide, and metabolic and bariatric surgery (MBS). Databases were searched to March 2025, and data were synthesized using pairwise and network meta-analysis. Lifestyle interventions ranked highest in preventing recurrent weight gain, while semaglutide may support sustained weight reduction during ongoing therapy but is followed by rebound after discontinuation. MBS demonstrated relatively sustained weight loss (>10% maintained at 5–10 years), although RCT evidence was limited. These findings highlight the need for long-term, structured maintenance strategies and further high-quality trials with standardized outcomes.

Highlights

- Lifestyle interventions ranked highest for long-term weight maintenance, though outcomes varied by program intensity.
- Semaglutide may aid weight maintenance during active treatment but is followed by considerable rebound after discontinuation.
- Bariatric surgery sustained the largest weight loss over 5-10 years, but RCT evidence remains limited.

Keywords Recurrent weight gain · Weight cycling · Obesity · Lifestyle intervention · Metabolic and bariatric surgery · Semaglutide

Background

Obesity has become a widespread health concern worldwide [1], and it is closely associated with multiple chronic

illnesses, such as type 2 diabetes, hypertension, and cardiovascular disease [2]. Evidence also indicates that obesity plays a significant role in the growing burden of disability-adjusted life years (DALYs) [3]. According to clinical guidelines, a body mass index (BMI) of 30 kg/m² or higher [4] is linked to a markedly increased risk of mortality [5].

While short-term weight reduction is achievable through various interventions [6], long-term weight maintenance remains a major clinical challenge in the management of obesity [7]. Recurrent weight gain (RWG), defined as late weight regain following an initially successful weight loss, is normal after all types of interventions [8]. Over time, repeated cycles of weight loss and regain across multiple attempts to reduce body weight, defined as weight cycling [9], which has been associated

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with increased free fatty mass [10], adverse effects on the cardiovascular system [11], a higher incidence of type 1 and type 2 diabetes [12], and the progression of chronic inflammation [13].

Effective weight management requires a long-term, comprehensive approach that is personalized to individual goals and considers the risk-benefit balance of available treatments [14]. In individuals with obesity (BMI ≥ 30 kg/m²), existing studies have largely focused on promoting weight reduction through approaches such as lifestyle modification, pharmacotherapy, or metabolic and bariatric surgery (MBS) [15]. Lifestyle modification is widely regarded as the foundation of obesity treatment due to its favorable impact on health behaviors and cardiometabolic outcomes [16]. When lifestyle modification alone is insufficient for weight reduction, pharmacotherapy offers an alternative option for adults with overweight or obesity. GLP-1 receptor agonists are effective for weight loss, with semaglutide demonstrating greater efficacy than phentermine-topiramate, bupropion-naltrexone, orlistat, and liraglutide in recent meta-analyses [17], and recent trials have also provided long-term follow-up data showing RWG after treatment cessation [18]. Given its greater weight-loss effect, proven cardiometabolic benefits in long-term trials such as SELECT [19], and the convenience of once-weekly dosing that enhances adherence compared with daily liraglutide injections [20], semaglutide was selected as the representative pharmacotherapy in this review. Compared to non-surgical approaches, MBS yields more substantial and sustained weight loss [21]. At present, sleeve gastrectomy and Roux-en-Y gastric bypass constitute the majority of MBS globally, collectively representing around 90% of surgeries performed [22].

Although one prior review has addressed the long-term effects of lifestyle interventions, anti-obesity medications, and MBS in individuals with obesity, semaglutide was not included in the analysis [23]. Given that semaglutide has recently emerged as a highly effective pharmacologic agent for weight loss, its comparative effectiveness against lifestyle and surgical interventions in preventing RWG remains unclear. Only limited direct evidence exists comparing semaglutide, lifestyle, and MBS interventions; therefore, this review provides an indirect and qualitative comparison based on available data. To address this, the present systematic review aims to synthesize and compare current evidence on RWG following weight loss achieved through lifestyle intervention, semaglutide, and MBS in adults with obesity.

Method

This review adhered to the PRISMA guidelines for systematic reviews. The protocol was developed prior to data extraction and prospectively registered in PROSPERO.

Search Strategy

A systematic electronic search was conducted using PubMed, Embase, Web of Science, Cochrane CENTRAL, and Scopus databases in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. The search was completed on March 28, 2025, using a combination of relevant keywords and Boolean operators. Search terms included concepts related to “obesity”, “weight loss”, “weight regain”, “semaglutide”, “sleeve gastrectomy (SG)”, “Roux-en-Y gastric bypass (RYGB)”, and “lifestyle interventions”. The full search strategy is available in Supplementary Material Table S1. Only studies published in English were included.

Inclusion and Exclusion Criteria of the Retrieved Studies

Studies were included in this review if they met the following criteria: (1) patients were adults with obesity, defined as having a body mass index (BMI) ≥ 30 kg/m²; (2) interventions consisted of lifestyle-based weight loss programs, semaglutide treatment, or MBS such as sleeve gastrectomy (SG) or Roux-en-Y gastric bypass (RYGB); (3) included a comparator group receiving standard care or self-directed management; and (4) reported outcomes related to RWG or changes in body weight during the maintenance phase; (5) randomized controlled trial (RCT) design;

Studies were excluded if they met any of the following conditions: (1) Non-original research, such as case reports and reviews, (2) Publications that are duplicates or potentially include overlapping data, particularly those published by the same author, with identical data sources and intervention methods across overlapping timelines, (3) Publications where only abstracts are available and full texts are inaccessible, (4) Studies involving patients with severe physical illness, significant frailty, long-term bedridden state, training difficulties, or existing delirium at the time of admission, (5) Publications not written in English.

Data Extraction

Data extraction was independently performed by two reviewers (CHX and GXJ) using a standardized form. Extracted variables included: (1) study identifiers (author, year, and country); (2) design characteristics; (3) participant details (sample size, age, sex distribution, baseline BMI); (4) intervention types (lifestyle intervention, semaglutide, or MBS) and comparators; (5) duration of intervention and follow-up; and (6) outcomes: the primary outcomes were RWG reported in kilograms, the percentage of body weight regained, and the proportion of individuals who maintained their weight at or below baseline. Secondary outcomes were absolute weight change from baseline and the percentage of total weight loss (%TWL). We included trials regardless of the timing of randomization: at the start of weight loss induction or at the beginning of the weight maintenance phase. This variable was extracted for each study to allow interpretation of heterogeneity.

Quality Assessment of the Retrieved Studies

Two reviewers (CHX and GXJ), both experienced in systematic review methods, carried out the ROB2 assessments independently [24]. Differences were resolved through discussion, with a third reviewer consulted if consensus could not be reached.

Data Synthesis and Analysis

Analyses were performed in Stata 18 using the “network” suite and White’s commands [25]. For dichotomous outcomes, odds ratios (ORs) and 95% confidence intervals (CIs) were calculated. A pairwise meta-analysis was conducted to compare lifestyle interventions with usual care during the weight-loss maintenance phase. Network meta-analysis included outcomes reported in ≥ 3 studies with ≥ 2 interventions [26]. Heterogeneity was assessed via the I^2 statistic and Q-test. A random-effects model was used if $I^2 > 50\%$; otherwise, a fixed-effects model was applied [27]. The Q-test assesses if the observed differences surpass those anticipated by chance. Certainty of evidence for the primary and secondary outcomes was assessed using the GRADE approach, which considers study limitations, inconsistency, indirectness, imprecision, and publication bias [28].

To explore potential sources of heterogeneity, meta-regression analyses were performed using study-level covariates, including baseline BMI, mean participant age, country, and follow-up duration. Regression coefficients

(β) and corresponding 95% confidence intervals (CIs) were estimated using a random-effects model based on the restricted maximum likelihood (REML) method. Statistical significance was set at $p < 0.05$. These analyses were conducted in Stata 18 using the “metareg” command.

Results

Overview of Included Studies

A total of 4,901 records were identified through systematic database searching. After the removal of 1,466 duplicates, 3,435 titles and abstracts were screened, resulting in 412 full-text articles assessed for eligibility. Of these, 29 randomized controlled trials met the inclusion criteria and were included in the final synthesis (Fig. 1). The included studies comprised 16 trials evaluating lifestyle interventions [29–44], 2 investigating semaglutide as pharmacotherapy [18, 45], and 11 assessing MBS [46–56]. These studies were published between 2000 and 2024. Sample sizes varied from 36 to 1,311, yielding a total of 6,843 patients with obesity, most of whom had a baseline BMI ≥ 30 kg/m². The duration of weight loss interventions ranged from 6 weeks to 24 months, with follow-up durations ranging from 16 weeks to 10 years. Weight-related outcomes were reported using diverse metrics, including absolute weight change (kg), %TWL, percentage of excess weight loss (%EWL), and the magnitude of RWG at specified timepoints. Details of each intervention and weight-related outcomes can be found in Supplementary Material Table S2.

Network Meta-Analysis of Recurrent Weight Gain by Initial Weight-Loss Strategies

The network meta-analysis compared RWG (kg) among different initial weight-loss approaches, including lifestyle interventions, MBS, semaglutide, and usual care. Based on SUCRA ranking, lifestyle interventions were most effective in limiting RWG (SUCRA 77.7, PrBest 44.5%, MeanRank 1.7), followed by usual care (SUCRA 67.4, PrBest 27.5%, MeanRank 2.0) and MBS (SUCRA 52.2, PrBest 27.7%, MeanRank 2.4). Semaglutide ranked lowest (SUCRA 2.7, PrBest 0.3%, MeanRank 3.9). These findings suggest that lifestyle-based strategies as the initial weight-loss method are most consistently associated with better long-term weight maintenance, while evidence for MBS and semaglutide is limited by the small number of trials. The cumulative probability plot (Fig. 2) is used to rank the effectiveness of the interventions.

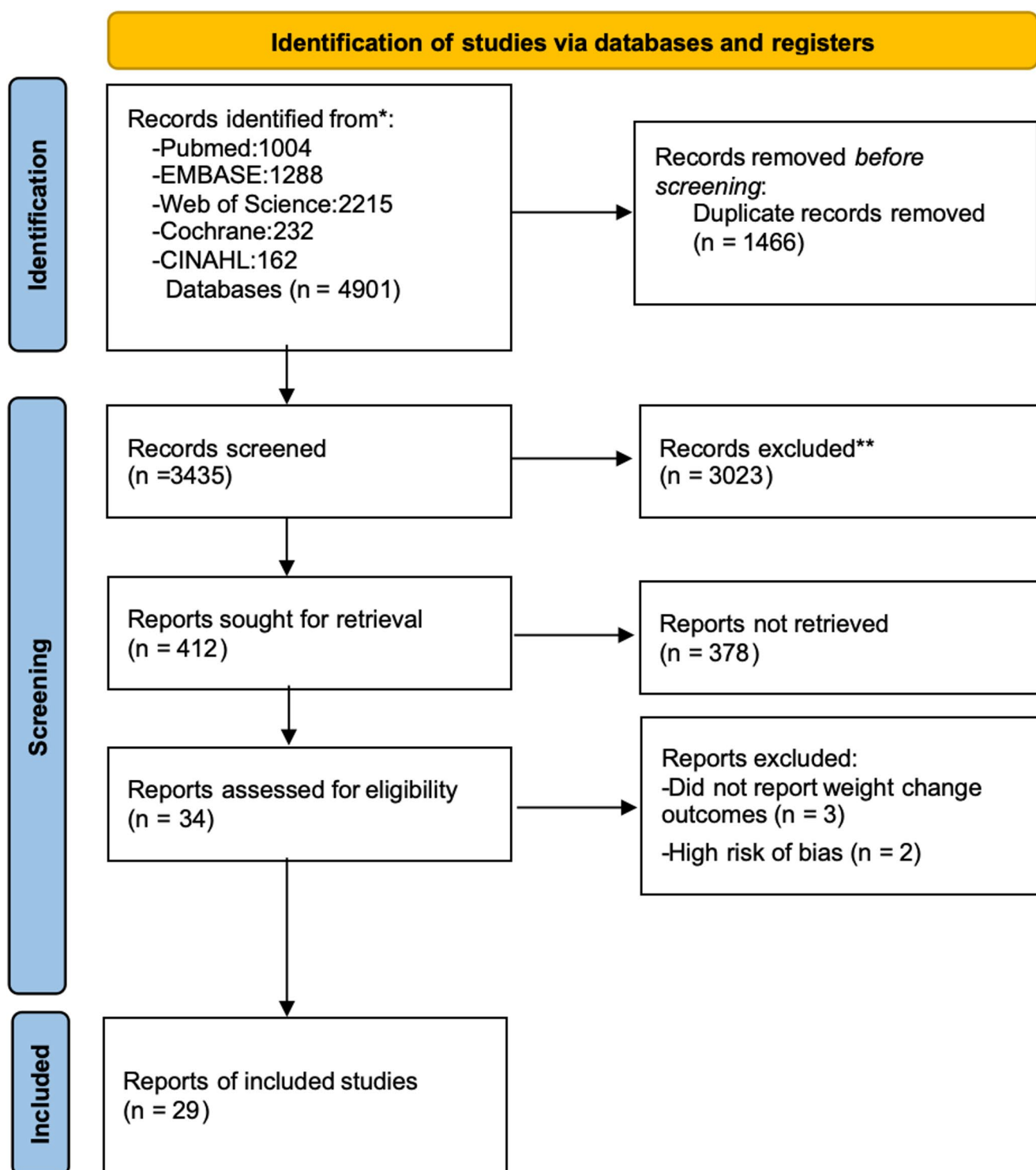


Fig. 1 PRISMA flow diagram

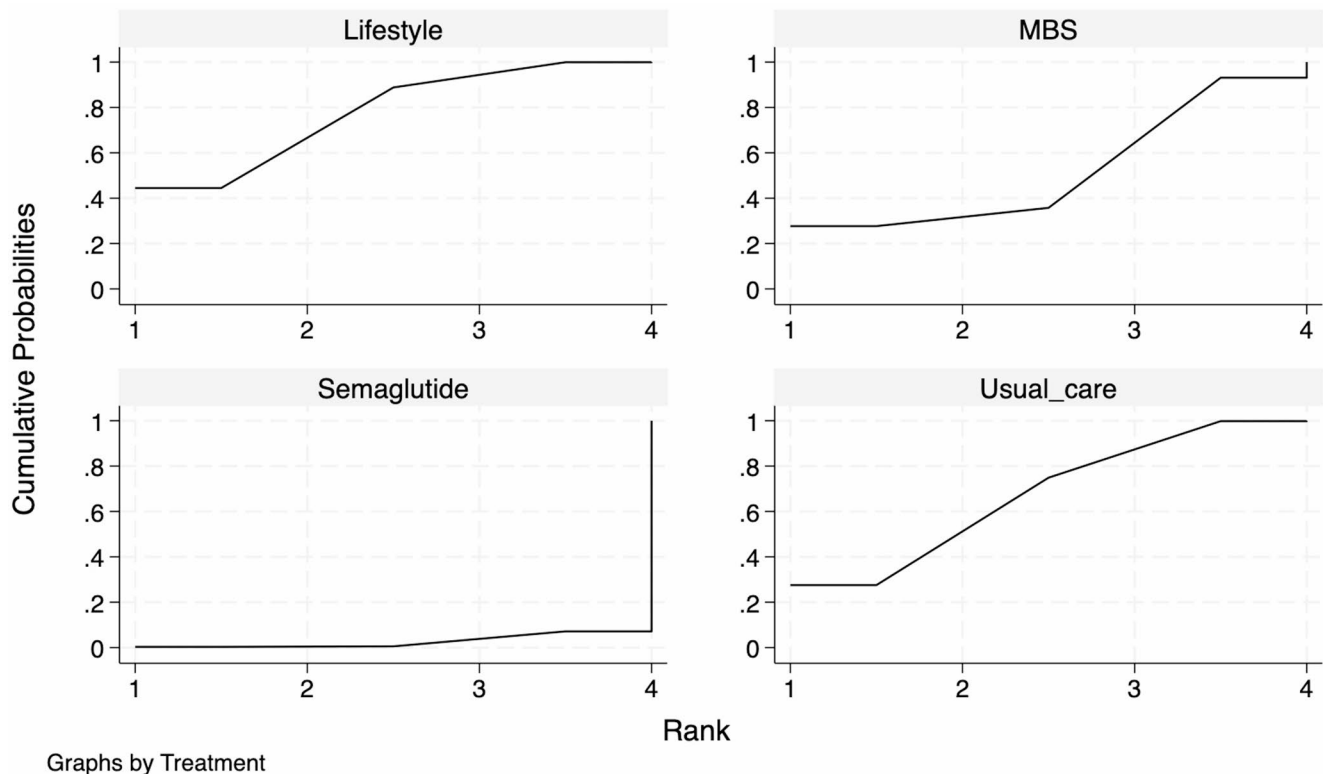


Fig. 2 Cumulative probability plots of interventions for preventing RWG

Network Meta-Analysis of Long-Term Weight Maintenance According to Initial Weight-Loss Intervention

The network meta-analysis indirectly compared lifestyle interventions and semaglutide using usual care as the common comparator. Figure 3 depicts Fig. 3 shows that semaglutide ranked highest for sustaining weight maintenance (SUCRA 100, PrBest 100%, MeanRank 1), followed by lifestyle intervention (SUCRA 47.2, PrBest 0%, MeanRank 2.1), while usual care ranked lowest (SUCRA 2.8, PrBest 0%, MeanRank 2.9).

Pairwise Meta-analysis

The pairwise meta-analysis included randomized trials comparing lifestyle interventions, semaglutide, and usual care.

For weight maintenance, lifestyle interventions were significantly more effective than usual care (OR=1.38, 95% CI 1.07–1.78; $I^2 = 47.6\%$) (Fig. 4). Subgroup analysis by initial weight-loss method showed that lifestyle-induced weight loss was associated with a significant maintenance benefit (OR=1.42, 95% CI 1.08–1.87; $I^2 = 49.9\%$), whereas surgery-induced weight loss showed no between-group difference (OR=0.99, 95% CI 0.51–1.93) (Fig. 5).

In addition, semaglutide showed a significantly higher likelihood of maintaining reduced body weight compared with usual care (OR=7.93, 95% CI 1.37–45.92; $I^2 = 96.3\%$) (Supplementary Fig. S3), while the comparison between lifestyle interventions and usual care based on weight regain (kg) showed no significant difference (SMD = -0.28, 95% CI -0.98 to 0.44; $I^2 = 95.3\%$) (Supplementary Fig. S4).

Meta Regression

Meta-regression indicated that participant age was significantly associated with weight-maintenance effects ($\beta=0.0566$, 95% CI 0.015–0.098, $p=0.014$). In contrast, baseline BMI, country, and follow-up duration were not significant predictors. For weight-regain outcomes, none of the examined study-level covariates showed statistically significant associations, and residual heterogeneity remained high ($I^2 > 90\%$). The detailed meta-regression results and residual statistics are presented in Supplementary Table S3.

Publication Bias and Sensitivity Analyses

Funnel plots for studies reporting weight maintenance and weight regain (kg) outcomes showed no evident asymmetry, and Egger's test for the 10 RCTs assessing weight maintenance indicated no small-study effects ($p=0.536$).

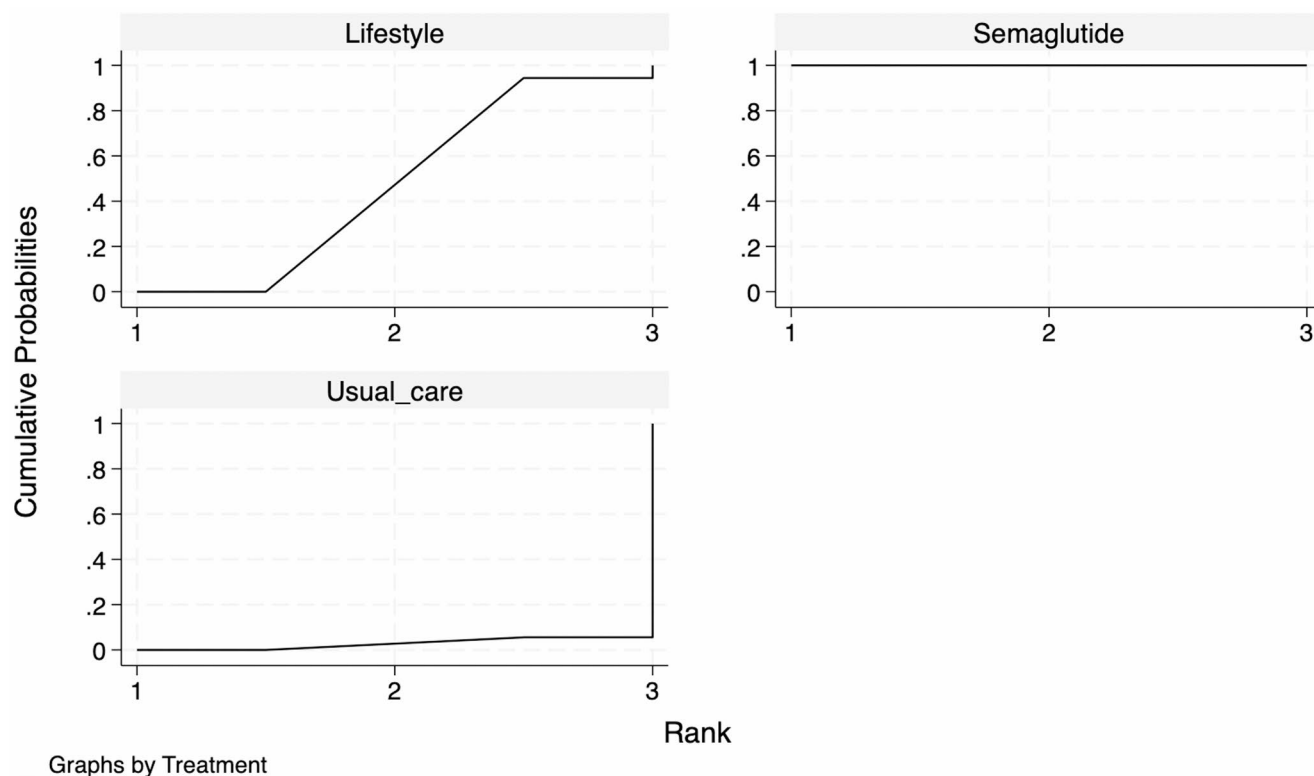


Fig. 3 Cumulative probability plots of interventions for sustaining long-term weight maintenance

Sensitivity analyses were conducted separately for pairwise meta-analyses of weight maintenance and weight regain (kg) to examine the robustness of pooled results. The exclusion of any single study did not materially change the pooled effect size or direction, indicating stable findings across analyses (Supplementary Fig. S5-8).

Risk of Bias Assessment

Figure 2 summarizes the ROB2 evaluation of the 29 included randomized controlled trials. Overall, seven studies were rated as low risk of bias and twenty-two as having some concerns, with no study judged high overall risk. The majority of concerns were concentrated in domain 2 related to deviations from intended interventions and domain 5 related to selective reporting, while other domains were largely assessed as low risk. These findings indicate that although most trials were methodologically sound, potential bias may have arisen from incomplete adherence and limited reporting transparency.

Certainty of Evidence

The GRADE evaluation indicated that the certainty of evidence was low for lifestyle interventions compared with

usual care due to some concerns in risk of bias and moderate heterogeneity. Evidence for MBS was rated very low, as only one small trial reported this outcome with wide confidence intervals. Evidence for semaglutide was graded as low, reflecting the limited number of available RCTs and imprecision in estimates. Overall, the certainty of evidence across interventions was low to very low. A detailed summary of findings table is provided in Supplementary Material Table S4.

Discussion

Key Findings

This review corroborates the well-documented challenges of sustaining weight loss, filling a gap in the literature where semaglutide had not previously been compared alongside lifestyle and surgical strategies [23]. Drawing on 29 randomized controlled trials, this review provides an integrated perspective on RWG patterns, revealing considerable heterogeneity in both extent and trajectory, as well as identifying modifiable factors influencing long-term outcomes.

The network meta-analyses showed that lifestyle interventions ranked highest in preventing recurrent weight gain

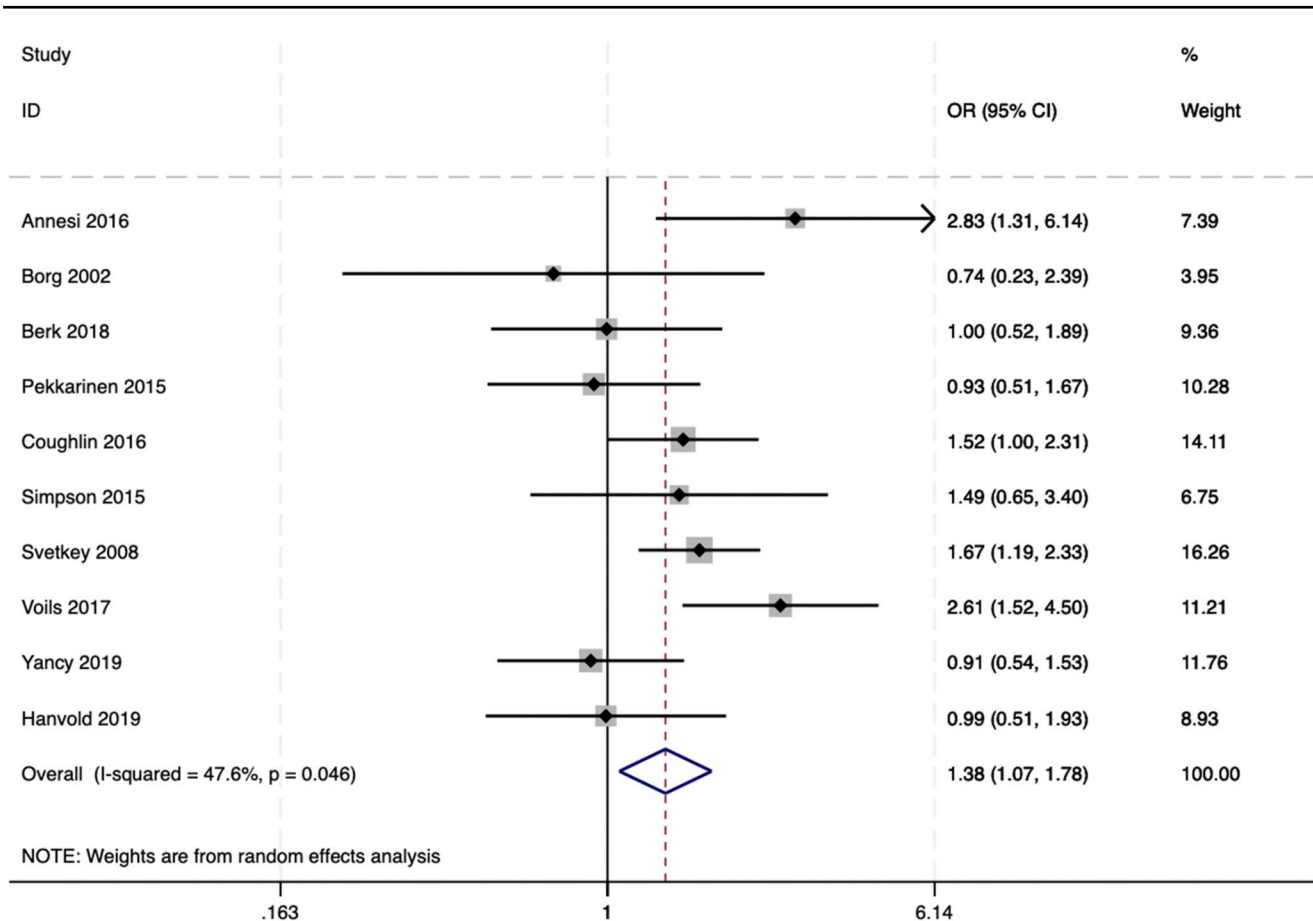


Fig. 4 Forest plot comparing lifestyle interventions with usual care for weight maintenance

(RWG), followed by usual care and MBS, while semaglutide ranked lowest. In contrast, for long-term weight maintenance during active treatment, semaglutide ranked highest, with lifestyle interventions providing moderate benefits and usual care the least effective. These findings suggest that the relative effectiveness of interventions differs across weight-management phases, highlighting the distinct roles of behavioral and pharmacologic strategies in sustaining outcomes.

MBS achieved comparatively sustained results, with >10% TWL maintained beyond 5 years. Lifestyle-based strategies provided moderate and variable results, largely dependent on the presence of structured follow-up. Semaglutide offered short-term effectiveness but was associated with substantial rebound upon discontinuation. Semaglutide also showed a favorable ranking for long-term weight maintenance, indicating its potential role in sustaining weight reduction beyond the active treatment phase.

Across the included studies, lifestyle interventions achieved short-term weight reductions of 8.5 kg (95% CI 7.9–9.1) within six months of intervention initiation [42] and 9.2 kg (95% CI 8.4–10.0) during the initial phase [30], but long-term maintenance varied, with regains of 4.0–5.5

kg observed within 30 months after intervention cessation (95% CI -2.4 to -0.6) [42]. Semaglutide 2.4 mg once weekly produced a mean weight loss of 17.3% (95% CI -16.5 to -14.1) after 68 weeks of treatment compared with placebo [45]. Following treatment withdrawal, participants regained 11.6% points of lost weight, leaving a net reduction of 5.6% (95% CI -12.0 to -8.6) from baseline within one year [18]. MBS demonstrated the relatively durable weight-loss outcomes. Across randomized trials, surgical procedures consistently produced and maintained large reductions in body weight, with total weight loss of 28.0% (95% CI, 25.2–30.8) at 3 years post-surgery [34] and 28.3% (95% CI, 25.4–31.3) at 5 years post-surgery [46]. Long-term follow-up confirmed sustained effects, showing 23.4% (95% CI, 22.1–24.7) after sleeve gastrectomy and 26.9% (95% CI, 25.6–28.2) after Roux-en-Y gastric bypass at 10 years postoperatively [56].

These findings reinforce the view that weight maintenance is physiologically and behaviorally distinct from initial weight loss [57, 58]. Although short-term weight loss is often achieved, long-term maintenance is hindered by persistent adaptive responses such as reduced resting metabolic rate and altered appetite regulation, which may last for years and complicate sustained outcomes [57]. This review

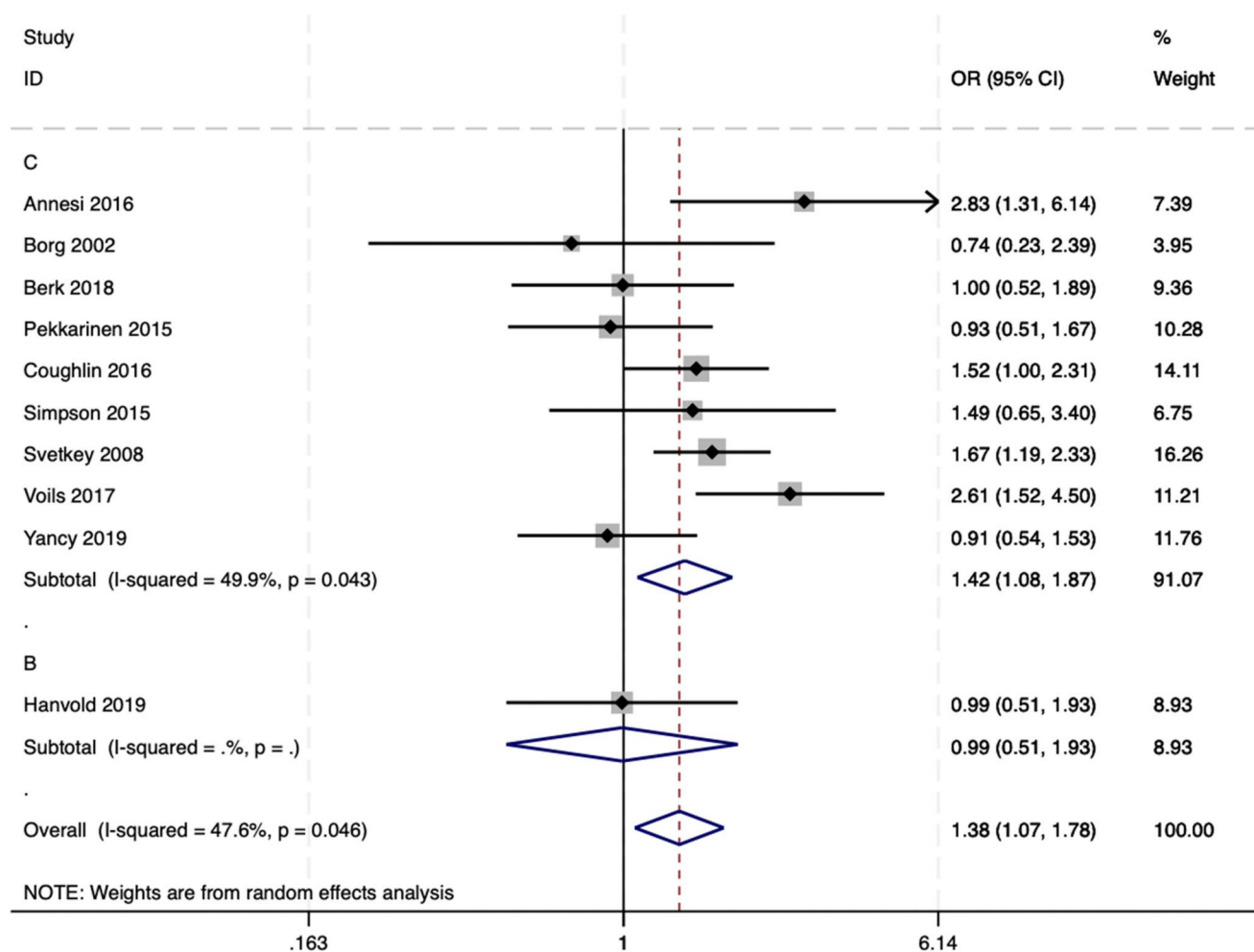


Fig. 5 Forest plot of subgroup analyses stratified by initial weight-loss method for lifestyle interventions versus usual care in long-term weight maintenance

primarily captures acute RWG following an induced weight loss episode, rather than chronic weight cycling across multiple attempts. This distinction is important for interpreting the findings, as strategies to prevent initial regain may differ from those aimed at breaking recurrent cycles of loss and regain.

It is important to interpret these findings with caution, as only limited direct evidence exists comparing semaglutide, lifestyle, and MBS interventions. The present results therefore reflect an indirect comparison derived from the available randomized evidence, and potential differences in study populations and designs should be taken into account when interpreting relative effects.

Metabolic and Bariatric Surgery: Durable but not Infallible

In the network meta-analysis of RWG, lifestyle interventions ranked highest for preventing RWG, while MBS

showed intermediate effectiveness, though the available RCT evidence was limited. In the pairwise analyses, MBS was examined only in a subgroup that included a single trial, which found no significant difference compared with lifestyle interventions. This restricted evidence base underscores the need for additional long-term randomized trials to more reliably evaluate the sustained benefits of surgery.

Among the evaluated strategies, MBS demonstrated the relatively durable weight loss outcomes, with several studies showing >10% total weight loss maintained over 5 to 10 years. These findings are consistent with current evidence suggesting that the efficacy of MBS is driven by multiple mechanisms, including alterations in gut hormone secretion, changes in gut microbiota composition, and bile acid metabolism [23, 59].

Despite its superior long-term effectiveness, RWG remains a concern, particularly in the absence of structured postoperative support. Longitudinal evidence indicates that behavioral reinforcement after surgery can significantly

attenuate weight rebound [46]. Additionally, adjunctive use of anti-obesity pharmacotherapy such as GLP-1 receptor agonists has been proposed as a beneficial strategy for individuals at high risk of postoperative weight recurrence [60].

Semaglutide: Effective but Dependent

Semaglutide demonstrated strong short-term efficacy, inducing up to 17.3% weight loss within 68 weeks [18]. However, substantial RWG upon discontinuation raised concerns regarding its sustainability as monotherapy [45]. In the network meta-analysis, semaglutide ranked lowest in limiting RWG when compared across initial weight-loss strategies, but ranked highest in maintaining reduced body weight during the follow-up phase, indicating that its performance depends heavily on whether active pharmacological treatment is continued. Evidence from recent studies underscores the necessity of extended pharmacological intervention or adjunctive strategies to maintain long-term efficacy [61].

These findings suggest that while semaglutide can effectively support long-term weight maintenance under ongoing therapy, discontinuation without behavioral reinforcement often results in significant rebound. As semaglutide primarily modulates appetite without inducing permanent behavioral or metabolic adaptations, its cessation frequently leads to weight rebound unless supported by concurrent lifestyle interventions. While this review focused on semaglutide, it is noteworthy that RWG after treatment discontinuation has also been documented with other anti-obesity medications such as liraglutide [62]. This indicates that the phenomenon may extend to pharmacotherapy as a class, although the magnitude of effects varies across agents.

Lifestyle Interventions: Heterogeneity and Predictors of Success

Pooled pairwise meta-analysis showed that lifestyle interventions were not significantly more effective than usual care in sustaining weight below baseline, although subgroup analysis suggested a potential advantage when structured lifestyle programs were implemented. The subgroup finding that lifestyle-induced weight loss led to greater maintenance success supports the value of continuous behavioral engagement.

Lifestyle interventions demonstrated the most pronounced diversity in long-term effectiveness. Programs integrating structured behavioral strategies—such as cognitive behavioral therapy (CBT), nutritional counseling, and physical activity support—were consistently associated with better outcomes, often limiting RWG to less than 3 kg over 18 to 24 months [29, 30]. This suggests that maintaining weight loss may rely on a set of behavioral strategies that differ from those used during the initial weight reduction phase [58].

Moreover, the network meta-analysis showed that lifestyle interventions ranked highest in preventing RWG, which supports the role of structured behavioral support in sustaining outcomes. Specific nutritional and activity-related predictors were also identified. Protein intake and fruit/vegetable consumption were inversely associated with regain [32], while structured walking interventions resulted in significant reductions in rebound weight [36]. These findings align with prior evidence identifying sustained environmental and behavioral modifications as crucial components of long-term weight maintenance [57].

Nevertheless, lifestyle-based strategies remain vulnerable to contextual and psychosocial influences. As the withdrawal of behavioral support following intervention often coincides with RWG, as evidenced in previous long-term follow-up studies [63]. Future interventions must address this gap by integrating long-term, scalable behavioral reinforcement models.

Implications for Clinical Practice and Future Research

This review reinforces the need to reconceptualize weight maintenance as a distinct therapeutic phase requiring tailored interventions. Clinical protocols should consider early incorporation of maintenance strategies, including long-term follow-up, adjunct pharmacotherapy, and behavioral reinforcement. Moreover, personalized medicine approaches integrating phenotypic, genotypic, and environmental factors may optimize sustainability [58].

From a clinical perspective, strategies should distinguish between preventing initial RWG and managing chronic weight cycling. The prevention of early rebound primarily requires structured behavioral programs, dietary relapse prevention, and, where appropriate, prolonged pharmacologic support to stabilize post-intervention weight. By contrast, chronic weight cycling often involves complex physiological and psychological mechanisms such as metabolic adaptation, emotional eating, and environmental triggers [9, 64]. These patients may therefore benefit from integrated, multidisciplinary management that combines CBT [30], metabolic monitoring, and sustained behavioral coaching to address underlying drivers of relapse.

Further research is warranted to explore the mechanistic underpinnings of RWG, particularly the roles of metabolic adaptation, gut-brain axis signaling, and environmental context. Emerging insights from microbiome and neuroendocrine studies offer promising directions for novel intervention targets [59].

Notably, the GRADE assessment underscored that the certainty of evidence remains low to very low, particularly

for semaglutide and surgical interventions, emphasizing the need for additional high-quality randomized trials with standardized outcome reporting.

Finally, systematic comparison of hybrid strategies such as combining pharmacotherapy with behavioral support or integrating lifestyle intervention pre-and post-surgery could yield new pathways to durable weight control. It should also be noted that in most of the included trials, patients underwent only a single episode of induced weight loss followed by subsequent regain. While these outcomes are more accurately described as RWG, the broader construct of weight cycling remains relevant when considering repeated episodes over the life course. Future research should explicitly distinguish between interventions targeting the prevention of first-time RWG and those designed to break ongoing weight cycling, as these may require different clinical approaches.

Limitations

This review has several limitations. First, the exclusive focus on randomized controlled trials strengthened internal validity but limited generalizability, particularly for bariatric surgery. Many long-term insights into post-surgical RWG, especially beyond five to ten years, are derived from large observational cohorts and registry studies, which were not included here. As a result, the durability of surgical outcomes may be overestimated, since trial patients typically receive more intensive follow-up than routine clinical populations. Second, the number of eligible RCTs was limited for some interventions, especially semaglutide, restricting the robustness of comparisons. While RCTs have evaluated each intervention individually, direct head-to-head evidence remains scarce; thus, this review provides indirect synthesis based on the available data. Third, although meta-regression identified age as a potential contributor to between-study variability, other population and design-related factors such as baseline BMI and follow-up duration remained unexplained. Fourth, weight-related outcomes were reported using diverse metrics, complicating direct comparisons. Finally, although this review referred to weight cycling, the evidence mainly reflects RWG, that is, one episode of regain after initial loss rather than multiple recurrent cycles. The findings therefore reflect acute RWG rather than chronic cycling, which should be taken into account when interpreting clinical implications.

Conclusions

This review found that lifestyle interventions were most effective in limiting RWG, underscoring the importance of structured behavioral support for long-term weight

management. Semaglutide may produce substantial initial weight loss and shows potential advantages in maintaining reduced body weight, although weight regain commonly occurs after discontinuation. MBS appears to achieve the relatively durable long-term outcomes, yet randomized evidence remains limited compared with the extensive data from observational studies. These findings suggest that durable weight control likely requires integrated and sustained maintenance strategies that combine behavioral, pharmacological, and surgical approaches. Future trials with standardized outcomes are needed to better clarify the durability of pharmacological interventions and to confirm the long-term sustainability of MBS.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s11695-025-08415-1>.

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Data Availability All data generated or analyzed during this study are included in this published article and its supplementary information files.

Declarations

Ethical Approval Not applicable. This study is a systematic review of previously published literature.

Competing Interests The authors declare no competing interests.

References

1. Bray GA, Kim KK, Wilding JPH. Obesity: a chronic relapsing progressive disease process. A position statement of the world obesity federation. *Obes Rev.* 2017;18(7):715–23.
2. Afshin A, Forouzanfar MH, Reitsma MB, Sur P, Estep K, Lee A, et al. Health effects of overweight and obesity in 195 countries over 25 years. *N Engl J Med.* 2017;377(1):13–27.
3. Galih W, Susi K. Cancers attributable to obesity in indonesia: A prevalence based study using disability adjusted life years. *Global J Health Sci.* 2018;10(8):21.
4. WHO Expert Consultation. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *Lancet.* 2004;363(9403):157–63.
5. Global BMIMC, Di Angelantonio E, Bhupathiraju Sh N, Wormser D, Gao P, Kaptoge S, et al. Body-mass index and all-cause mortality: individual-participant-data meta-analysis of 239 prospective studies in four continents. *Lancet.* 2016;388(10046):776–86.
6. Mamalaki E, Poulimeneas D, Tsiampalis T, Kouvari M, Karipidou M, Bathrellou E, et al. The effectiveness of technology-based

- interventions for weight loss maintenance: A systematic review of randomized controlled trials with meta-analysis. *Obes Rev.* 2022;23(9):e13483.
7. Liu M, Zhang M, Chen X, Zhang X. Weight gain increases plasma levels of uric acid in adults in China. *Minerva Endocrinol.* 2019;44(3):326–8.
 8. Haddad A, Suter M, Greve JW, Shikora S, Prager G, Dayyeh BA, et al. Therapeutic options for recurrence of weight and obesity related complications after metabolic and bariatric surgery: an IFSO position statement. *Obes Surg.* 2024;34(11):3944–62.
 9. Sanaya N, Janusaite M, Dalamaga M, Magkos F. The physiological effects of Weight-Cycling: A review of current evidence. *Curr Obes Rep.* 2024;13(1):35–50.
 10. Cornejo MA, Ortiz RM. Body mass cycling and predictors of body mass regain and its impact on cardiometabolic health. *Metabolism.* 2021;125:154912.
 11. Bangalore S, Fayyad R, Laskey R, Demicco DA, Messerli FH, Waters DD. Body-weight fluctuations and outcomes in coronary disease. *N Engl J Med.* 2017;376(14):1332–40.
 12. Zou H, Yin P, Liu L, Duan W, Li P, Yang Y, et al. Association between weight cycling and risk of developing diabetes in adults: A systematic review and meta-analysis. *J Diabetes Investig.* 2021;12(4):625–32.
 13. Bernecker M, Lin A, Feuchtinger A, Molenaar A, Schriever SC, Pfluger PT. Weight cycling exacerbates glucose intolerance and hepatic triglyceride storage in mice with a history of chronic high fat diet exposure. *J Transl Med.* 2025;23(1):7.
 14. Perdomo CM, Cohen RV, Sumithran P, Clément K, Frühbeck G. Contemporary medical, device, and surgical therapies for obesity in adults. *Lancet.* 2023;401(10382):1116–30.
 15. Jacob E, Moura A, Avery A. A systematic review of physical activity and nutritional interventions for the management of normal weight and overweight obesity. *Nutr Metab Cardiovasc Dis.* 2024;34(12):2642–58.
 16. Bray GA, Heisel WE, Afshin A, Jensen MD, Dietz WH, Long M, et al. The science of obesity management: an endocrine society scientific statement. *Endocr Rev.* 2018;39(2):79–132.
 17. Overholser A, Czech E, Speer L, Wilson J, Overholser A. Comparison of GLP-IRAs vs other pharmacotherapy for obesity: a clinical review. Translation [Internet]. 2025 [cited 2025 Dec 3]: 13(1). Available from: <http://openjournals.utoledo.edu/index.php/translation/article/view>.
 18. Wilding JPH, Batterham RL, Davies M, Van Gaal LF, Kandler K, Konakli K, et al. Weight regain and cardiometabolic effects after withdrawal of semaglutide: the STEP 1 trial extension. *Diabetes Obes Metab.* 2022;24(8):1553–64.
 19. Ryan DH, Lingvay I, Deanfield J, Kahn SE, Barros E, Burguera B, et al. Long-term weight loss effects of semaglutide in obesity without diabetes in the SELECT trial. *Nat Med.* 2024;30(7):2049–57.
 20. Xie Z, Yang S, Deng W, Li J, Chen J. Efficacy and safety of liraglutide and semaglutide on weight loss in people with obesity or overweight: a systematic review. *Clin Epidemiol.* 2022;14:1463–76.
 21. Gloy VL, Briel M, Bhatt DL, Kashyap SR, Schauer PR, Mingrone G et al. Bariatric surgery versus non-surgical treatment for obesity: a systematic review and meta-analysis of randomised controlled trials. *BMJ.* 2013;347:f5934.
 22. Sharaiha RZ, Shikora S, White KP, Macedo G, Toouli J, Kow L. Summarizing consensus guidelines on obesity management: a joint, multidisciplinary venture of the international federation for the surgery of obesity & metabolic disorders (IFSO) and world gastroenterology organisation (WGO). *J Clin Gastroenterol.* 2023;57(10):967–76.
 23. Kheniser K, Saxon DR, Kashyap SR. Long-Term weight loss strategies for obesity. *J Clin Endocrinol Metab.* 2021;106(7):1854–66.
 24. Sterne JAC, Savović J, Page MJ, Elbers RG, Blencowe NS, Boutron I, et al. RoB 2: a revised tool for assessing risk of bias in randomised trials. *BMJ.* 2019;366:l4898.
 25. White IR, Barrett JK, Jackson D, Higgins JP. Consistency and inconsistency in network meta-analysis: model Estimation using multivariate meta-regression. *Res Synth Methods.* 2012;3(2):111–25.
 26. Jansen JP, Fleurence R, Devine B, Itzler R, Barrett A, Hawkins N, et al. Interpreting indirect treatment comparisons and network meta-analysis for health-care decision making: report of the ISPOR task force on indirect treatment comparisons good research practices: part 1. *Value Health.* 2011;14(4):417–28.
 27. Stogiannis D, Siannis F, Androulakis E. Heterogeneity in meta-analysis: a comprehensive overview. *Int J Biostat.* 2024;20(1):169–99.
 28. Guyatt GH, Oxman AD, Vist GE, Kunz R, Falck-Ytter Y, Alonso-Coello P, et al. GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. *BMJ.* 2008;336(7650):924–6.
 29. Annesi JJ, Johnson PH, Tennant GA, Porter KJ, McEwen KL. Weight loss and the prevention of weight regain: evaluation of a treatment model of exercise Self-Regulation generalizing to controlled eating. *Perm J.* 2016;20(3):15–146.
 30. Berk KA, Buijks HIM, Verhoeven AJM, Mulder MT, Özcan B, van 't Spijker A, et al. Group cognitive behavioural therapy and weight regain after diet in type 2 diabetes: results from the randomised controlled POWER trial. *Diabetologia.* 2018;61(4):790–9.
 31. Borg P, Kukkonen-Harjula K, Fogelholm M, Pasanen M. Effects of walking or resistance training on weight loss maintenance in obese, middle-aged men: a randomized trial. *Int J Obes Relat Metab Disord.* 2002;26(5):676–83.
 32. Champagne CM, Broyles ST, Moran LD, Cash KC, Levy EJ, Lin PH, et al. Dietary intakes associated with successful weight loss and maintenance during the weight loss maintenance trial. *J Am Diet Assoc.* 2011;111(12):1826–35.
 33. Coughlin JW, Brantley PJ, Champagne CM, Vollmer WM, Stevens VJ, Funk K, et al. The impact of continued intervention on weight: Five-year results from the weight loss maintenance trial. *Obes (Silver Spring).* 2016;24(5):1046–53.
 34. Courcoulas AP, Belle SH, Neiberg RH, Pierson SK, Eagleton JK, Kalarchian MA, et al. Three-year outcomes of bariatric surgery vs lifestyle intervention for type 2 diabetes mellitus treatment a randomized clinical trial. *JAMA Surg.* 2015;150(10):931–40.
 35. Fanning J, Rejeski WJ, Leng I, Barnett C, Lovato JF, Lyles MF, et al. Intervening on exercise and daylong movement for weight loss maintenance in older adults: A randomized, clinical trial. *Obes (Silver Spring).* 2022;30(1):85–95.
 36. Fogelholm M, Kukkonen-Harjula K, Nenonen A, Pasanen M. Effects of walking training on weight maintenance after a very-low-energy diet in premenopausal obese women: a randomized controlled trial. *Arch Intern Med.* 2000;160(14):2177–84.
 37. Lopes Gomes D, Moehlecke M, Lopes da Silva FB, Dutra ES, D'Agord Schaan B, Baiocchi de Carvalho KM. Whey protein supplementation enhances body fat and weight loss in women long after bariatric surgery: a randomized controlled trial. *Obes Surg.* 2017;27(2):424–31.
 38. Madjd A, Taylor MA, Delavari A, Malekzadeh R, Macdonald IA, Farshchi HR. Effects of replacing diet beverages with water on weight loss and weight maintenance: 18-month follow-up, randomized clinical trial. *Int J Obes.* 2018;42(4):835–40.
 39. Pekkarinen T, Kaukua J, Mustajoki P. Long-term weight maintenance after a 17-week weight loss intervention with or without a one-year maintenance program: a randomized controlled trial. *J Obes.* 2015;2015:651460.

40. Pereira V, Barreiros-Mota I, Cortez F, Castela I, Teixeira D, Calhau C, et al. A randomized controlled trial of a weight loss maintenance program in adults with obesity: the WLM3P study. *Eur J Clin Nutr.* 2024;78(8):694–702.
41. Simpson SA, McNamara R, Shaw C, Kelson M, Moriarty Y, Randell E, et al. A feasibility randomised controlled trial of a motivational interviewing-based intervention for weight loss maintenance in adults. *Health Technol Assess (Winchester Eng).* 2015;19(50):v–vi. xix–xxv, 1–378.
42. Svetkey LP, Stevens VJ, Brantley PJ, Appel LJ, Hollis JF, Loria CM, et al. Comparison of strategies for sustaining weight loss: the weight loss maintenance randomized controlled trial. *JAMA.* 2008;299(10):1139–48.
43. Voils CI, Olsen MK, Gierisch JM, McVay MA, Grubber JM, Gaillard L, et al. Maintenance of weight loss after initiation of nutrition training: A randomized trial. *Ann Intern Med.* 2017;166(7):463–71.
44. Yancy WS Jr., Shaw PA, Reale C, Hilbert V, Yan J, Zhu J, et al. Effect of escalating financial incentive rewards on maintenance of weight loss: A randomized clinical trial. *JAMA Netw Open.* 2019;2(11):e1914393.
45. Rubino D, Abrahamsson N, Davies M, Hesse D, Greenway FL, Jensen C, et al. Effect of continued weekly subcutaneous semaglutide vs placebo on weight loss maintenance in adults with overweight or obesity: the STEP 4 randomized clinical trial. *JAMA.* 2021;325(14):1414–25.
46. Bellicha A, Ciangura C, Roda C, Torcivia A, Aron-Wisniewsky J, Poitou C et al. Effect of exercise training after bariatric surgery: a 5-year follow-up study of a randomized controlled trial. *PLoS ONE.* 2022;17(7):e0271561.
47. Elder CR, Gullion CM, Debar LL, Funk KL, Lindberg NM, Ritenbaugh C, et al. Randomized trial of Tapas acupuncture technique for weight loss maintenance. *BMC Complement Altern Med.* 2012;12:19.
48. Grönroos S, Helmiö M, Juuti A, Tiusanen R, Hurme S, Löyttyniemi E, et al. Effect of laparoscopic sleeve gastrectomy vs Roux-en-Y gastric bypass on weight loss and quality of life at 7 years in patients with morbid obesity: the SLEEVEPASS randomized clinical trial. *JAMA Surg.* 2021;156(2):137–46.
49. Hanvold SE, Vinknes KJ, Loken EB, Hjartaker A, Klungsoyr O, Birkeland E, et al. Does lifestyle intervention after gastric bypass surgery prevent weight regain? A randomized clinical trial. *Obes Surg.* 2019;29(11):3419–31.
50. Ikramuddin S, Korner J, Lee WJ, Bantle JP, Thomas AJ, Connett JE, et al. Durability of addition of Roux-en-Y gastric bypass to lifestyle intervention and medical management in achieving primary treatment goals for uncontrolled type 2 diabetes in mild to moderate obesity: A randomized control trial. *Diabetes Care.* 2016;39(9):1510–8.
51. Ikramuddin S, Korner J, Lee WJ, Thomas AJ, Connett JE, Bantle JP, et al. Lifestyle intervention and medical management with vs without roux-en-y gastric bypass and control of hemoglobin a1c, Ldl cholesterol, and systolic blood pressure at 5 years in the diabetes surgery study. *JAMA - J Am Med Association.* 2018;319(3):266–78.
52. Kalarchian MA, Marcus MD, Courcoulas AP, Lutz C, Cheng Y, Sweeny G. Structured dietary intervention to facilitate weight loss after bariatric surgery: A randomized, controlled pilot study. *Obes (Silver Spring).* 2016;24(9):1906–12.
53. Lundholm MD, Hu B, Kirwan JP, Patti ME, Cummings DE, Kashyap S. Long-term outcomes of metabolic surgery vs. medical/lifestyle therapy on nonalcoholic fatty liver disease in adults with obesity and type 2 diabetes. *Diabetes.* 2023;72(Supplement_1):372-OR.
54. Marc-Hernández A, Ruiz-Tovar J, Aracil A, Guillén S, Moya-Ramón M. Effects of a High-Intensity exercise program on weight regain and Cardio-metabolic profile after 3 years of bariatric surgery: A randomized trial. *Sci Rep.* 2020;10(1):3123.
55. Pajeci D, Dantas ACB, Dos Santos Pinheiro MC, Corsi GC, Dias MCG, Santo MA. SLEEVE GASTRECTOMY VERSUS ROUX-EN-Y GASTRIC BYPASS FOR TREATING OBESITY IN ELDERLY PATIENTS: 3-YEAR OUTCOMES OF A RANDOMIZED TRIAL. *Obes Surg.* 2023;33:298.
56. Salminen P, Grönroos S, Helmiö M, Hurme S, Juuti A, Jussela R, et al. Effect of laparoscopic sleeve gastrectomy vs Roux-en-Y gastric bypass on weight Loss, Comorbidities, and reflux at 10 years in adult patients with obesity: the SLEEVEPASS randomized clinical trial. *JAMA Surg.* 2022;157(8):656–66.
57. Flanagan EW, Spann R, Berry SE, Berthoud HR, Broyles S, Foster GD et al. New insights in the mechanisms of weight-loss maintenance: summary from a Pennington symposium. *Obesity (Silver Spring).* 2023;31(12):2895–908.
58. Rosenbaum M, Foster G. Differential mechanisms affecting weight loss and weight loss maintenance. *Nat Metab.* 2023;5(8):1266–74.
59. Akalestou E, Miras AD, Rutter GA, le Roux CW. Mechanisms of weight loss after obesity surgery. *Endocr Rev.* 2022;43(1):19–34.
60. Cohen RV, Park JY, Prager G, Bueter M, le Roux CW, Parmar C et al. Role of obesity-management medications before and after metabolic bariatric surgery: a systematic review. *Br J Surg.* 2024;111(12):znae284.
61. Moiz A, Levett JY, Filion KB, Peri K, Reynier P, Eisenberg MJ. Long-Term efficacy and safety of Once-Weekly semaglutide for weight loss in patients without diabetes: A systematic review and Meta-Analysis of randomized controlled trials. *Am J Cardiol.* 2024;222:121–30.
62. Lofton HF, Maranga G, Hold R, Fielding G, Youn H, Gujral A, et al. A randomized, double-blind, placebo-controlled trial of weight loss using liraglutide 3.0 mg for weight recurrence after Roux-en-Y gastric bypass. *Surg Obes Relat Dis.* 2025;21(2):135–45.
63. O’Neil PM. Long-term maintenance of weight loss. *Lancet Public Health.* 2022;7(10):e806–7.
64. Li W, Wang D, Chen H, Liu Y, Dong S, Sun M et al. The relationship between psychological distress and weight maintenance in weight cycling: mediating role of eating behavior. *BMC Public Health.* 2024;24(1):894.

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