

Six-year Follow-Up of Nonpharmacological and Nonsurgical Obesity Treatments

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Purpose: The prevalence of obesity and its cardiometabolic consequences are increasing worldwide. Scalable and affordable methods to obtain and maintain weight loss and prevent comorbidities such as type 2 diabetes (T2D) are major goals for obesity care. We performed a long-term follow-up study based on self-report after attending different nonpharmacological weight loss treatments at a university center when modern obesity drugs were not yet available.

Patients and Methods: A total of 1,130 subjects were invited. Response rate was 67% and treatment and follow-up times were 1.4 ±0.04 and 6.1±0.1 years (mean±SEM), respectively. The treatment groups were: Individual therapy (IT; n=156); Group-based behavioral therapy (GT; n=285); GT initiated by low-calorie diet (LCD-GT; n=136); and bariatric surgery (BS) at any time after attending the center (n=152). A total of 145 subjects had T2D at baseline.

Results: 57.8% (95% CI 54.1–61.5) and 36.4% (32.9–40.0) of subjects achieved >5% and >10% body weight loss, respectively. At follow-up, this translated into 96.7 (92.5–98.9) and 92.1% (86.6–95.9) of subjects who went on to BS achieving >5% and >10% weight loss compared to 48.1 (43.9–52.4) and 30.9% (27.1–34.9) in the non-surgery (NS) subgroups. The LCD-GT subgroup experienced the largest weight loss, but also the greatest weight regain among the NS subgroups; 56.7 (47.9–65.2) and 41.8% (33.3–50.6) maintaining a >5% and >10% loss of weight at follow-up. Incident T2D was lower (2.6% [0.5–7.4] vs 9.2% [6.7–12.2], $p=0.02$) and remission of T2D was greater (52.8% [35.5–69.6] vs 9.3% [4.5–16.4]; $p<0.0001$) after BS than after NS, where the lowest T2D incidence and greatest remission were observed in LCD-GT; 5.6% (2.1–11.7) and 17.9% (6.1–36.9), respectively.

Conclusion: In real-world practice, bariatric surgery fulfils the promise of academic trials. However, nonsurgical and nonpharmacological treatments can also have a long-term impact on both weight loss and diabetes prevention and remission. This is important because modern obesity drugs and bariatric surgery are not available or affordable for most obese people.

Keywords: weight loss, weight maintenance, type 2 diabetes remission, real-world evidence, clinical practice

Introduction

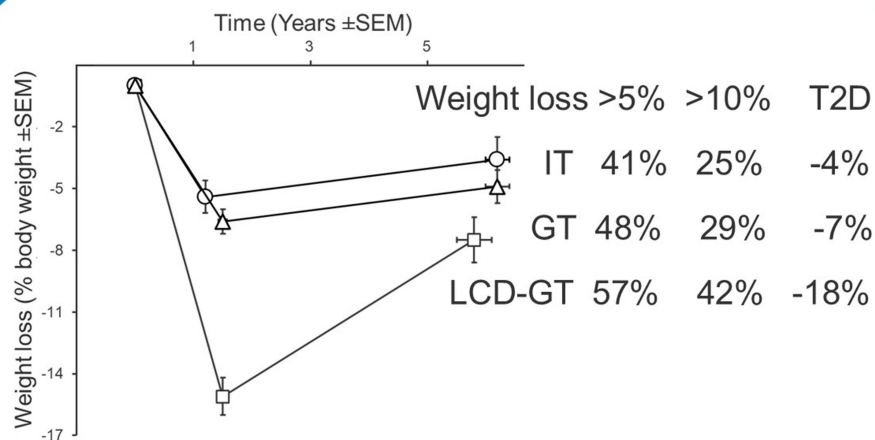
In recent decades, the prevalence of obesity has increased worldwide, and it is now the second leading cause of preventable death, primarily through its association with cardiovascular risk factors, such as hypertension, dyslipidemia, and type 2 diabetes (T2D).^{1–3} Greater weight reduction has greater benefits, but even moderate intentional weight loss (5 to 10%) is sufficient to decrease these risks if weight loss is maintained.^{4,5} The successful effects of bariatric surgery^{6–8} and incretin-based pharmacological treatments⁹ on short- and long-term weight loss, morbidity, and mortality are becoming increasingly well documented.

There is much less documentation of the long-term effects of nonsurgical and nonpharmacological treatments. Most nonsurgical, nonpharmacological long-term follow-up studies address the active treatment period, some also the first couple of years after treatment, and when more long-term typically have limited sample sizes.¹⁰ The results have often been disappointing.^{10–13} This is a serious knowledge gap since surgery and modern drug therapy are not available to most obese people.



Graphical Abstract

Self-reported 6-year follow-up of non-pharma/non-surgical weight loss treatments; 729 responders (67%): Individual Therapy (IT; 156), Group Therapy (GT; 285), LCD-initiated GT (LCD-GT; 136), Bariatric surgery controls (152).



Conclusion: Non-pharma/non-surgical treatments work long-term. Important message since drugs and surgery will not be available to most who could benefit from them.

Here, we present data from a retrospective, questionnaire-based, six-year follow-up study on adult obese subjects who initiated different kinds of surgical and nonsurgical weight reduction treatments when modern obesity drug therapy was not yet available, with a particular focus on weight maintenance and the incidence and remission of T2D.

Methods and Materials

Study Participants

Patients attending the obesity outpatient unit of the Department of Endocrinology, Skåne University Hospital, Malmö and Lund, Sweden, between 1999 and 2010 ($n=1.339$) received a follow-up questionnaire by mail. The inclusion criteria for the current analysis were having at least two appointments at the clinic and having met with a physician or nurse to discuss weight reduction strategies at least once. 1.130 subjects were included in the analysis (Figure 1). Patients were sent up to two reminders and were then considered non-responders. The response rates were 67%, 64% and 68% in males and females, respectively ($p=0.2$). 23 responders returned blank questionnaires, had never initiated treatment at the center, or were unable to answer, leaving 729 responders that were included. Responders were older at start of treatment (44 ± 0.5 vs. 39 ± 0.7 years; $p<0.0001$) and showed a slightly more pronounced weight loss during treatment (8.7 ± 0.5 vs. 7.2 ± 0.8 kg; $p=0.04$) compared to non-responders but there was no difference in weight prior to treatment. Summary statistics for responders and non-responders are presented in [Supplementary Table S1](#).

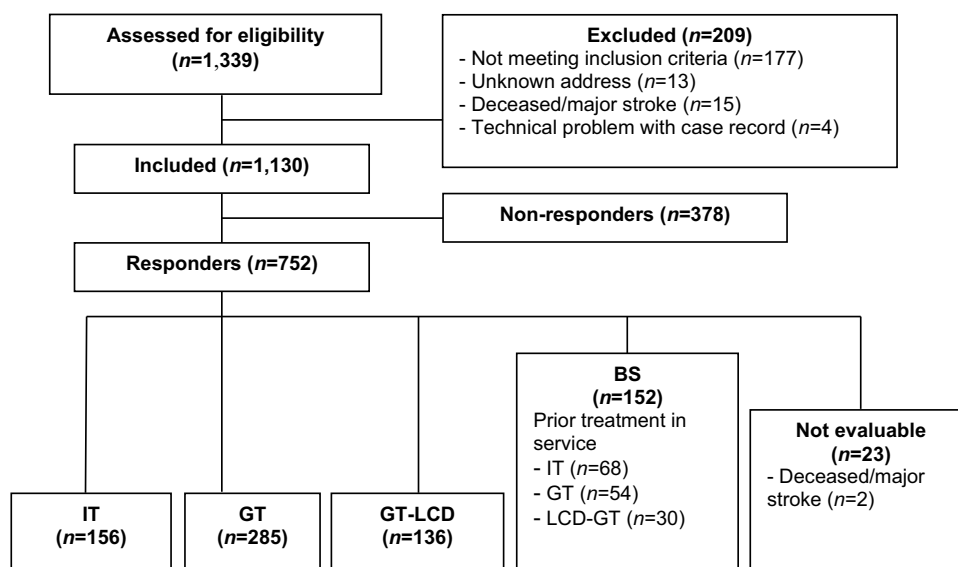


Figure 1 Flow-chart showing patients eligible for evaluation of the long-term effects of weight loss at a university hospital out-patient unit.

Abbreviations: IT, individual treatment; GT, group treatment based on behavioral modification principles; GT-LCD, GT initiated by a low-calorie diet; BS, bariatric surgery.

Treatments at the Center

The obesity treatment alternatives proposed to patients were based on patient preference and medical history and was carried out either as group therapy (GT) or individual therapy (IT). Eligible patients were referred for bariatric surgery (BS) at any time during or after completing a program. A more detailed description of the programs is available upon request.^{14,15} In brief, patients were evaluated by a specialist physician and/or nurse (depending on pre-treatment comorbidities) at least once during their treatment. GT programs (10–12 subjects in each group) typically ran over the course of seven to 12 months with 14–17 evenly spaced 1 hour and 45-minute group sessions with specific themes related to diet, physical activity and lifestyle change. IT would include one or several of the same themes for the individual 30–60-minute sessions. Whenever possible, GT would be initiated by a three-month period on low calorie diet (LCD; milk protein based; 800–880 kcal/day [protein 25–30 E%, carbohydrates 49–55 E%, fat 20–21 E%]) including six group sessions transitioning to a food-based hypocaloric diet with graduated physical activity goals and ongoing GT support (LCD-GT). Subjects with a history of a recent myocardial infarction (within six months), malignancy, type 1 diabetes or decompensated heart failure were excluded from LCD-treatment.

The common intention for all treatment alternatives was to obtain lifestyle changes leading to long lasting weight reduction. Treatments were based on behavioral modification principles focusing on barriers to lifestyle changes and were led by a specially trained nurse or dietician. Strategies included goal setting, self-monitoring, dietary and physical activity changes, stimulus control and relapse prevention. Subjects had the possibility of individual sessions with a specially trained nurse, dietician, physical therapist, social worker, or with their physician during treatment. Monitoring support involved in-clinic weigh-ins, self-report logs, and dietitian review. Between-visit contacts included optional phone/email check-ins and ad hoc weigh-ins where available. Upon completion of the treatment programs, patients were referred to their primary health care physician for optional follow-up. No center-based treatment follow-up was offered.

Prescription of orlistat, sibutramine and rimonabant, the obesity drugs available at the time, was allowed. 51.3% and 16.5% of the patients had tried these prior to or did so during treatment, respectively. This sporadic use was significantly more common ($p < 0.0001$) for BS (29.6%) and IT (23.1%) than for GT (10.9%) and LCD-GT (5.9%) but did not affect the outcomes as per sensitivity analysis ([Supplementary Table S2–S5](#)).

Questionnaire

The study questionnaire, available on request, consisted of questions on previous and current weight, type of treatment received at the clinic, pre- and post-obesity treatment efforts, for instance, “Were you receiving treatment for diabetes?”

and “Are you receiving treatment for diabetes”, and questions related to other previous and current common complications of obesity.

Endpoints

The objective of this study was to investigate long-term weight change and T2D outcomes in adults initiating clinic-based obesity care. The primary endpoint was the follow-up maintenance of achieved weight loss at the service for patients in the nonsurgical group (NS). This was defined as the difference between the reported pretreatment weight, the weight registered after treatment at the service, and the reported follow-up weight, with follow-up defined as when answering the questionnaire. When a pretreatment weight was missing in the questionnaire, the first registered weight at the service was used instead ($n=79$). The correlation between the reported pre-treatment and the first registered weight for all subjects was strong ($r=0.91$, $p<0.001$).

Our estimand of outcomes by treatment received at the center was operationalized via a hierarchical classification, assuming that some treatments were more effective than others, to be able to investigate long-term differences. The first level of hierarchy was individuals categorized as BS, regardless of having received other treatments at the center. The second level was individuals receiving LCD-GT, regardless of having received other treatment modalities apart from BS. The third level was receiving GT, regardless of other treatment support apart from BS or LCD-GT. And the final hierarchy level was those receiving IT only. In addition, subjects belonging to LCD-GT, GT, or IT were grouped as nonsurgical (NS) for comparisons with BS. These comparisons are presented as descriptive rather than causal, given differences in exposure timing. A sensitivity analysis presenting short- and long-term data for subjects referred to BS from the center ($n=46$) or later from elsewhere ($n=106$), ie. with shorter exposure, is presented for the same reason ([Supplementary Table S6](#)).

Statistics and Ethical Considerations

Clinical characteristics were described as either mean \pm standard error of the mean (SEM) for numeric values or as percentage (n [%] and 95% confidence interval, where applicable [95% CI]) for categorical variables. Continuous variables were analyzed using non-parametric Wilcoxon’s signed rank test for paired comparisons, and Mann–Whitney U -test or Kruskal–Wallis for unpaired comparisons, as appropriate. Categorical variables were analyzed using the Chi-square test. Univariate correlations were tested using the Spearman’s test. Statistical significance was set at p -value <0.05 . Statistical calculations were performed using the Number Cruncher Statistical System 2004 software (NCSS, Kaysville, USA).

The study was a retrospective questionnaire-based analysis of routine clinical practice. Subjects gave their written informed consent through the questionnaires prior to being enrolled in the analysis. The study was approved by the Regional Institutional Ethics Board, Lund University, Lund, Sweden (Dnr 2013/138). The study was conducted in accordance with the Declaration of Helsinki.

Results

Study Participants

Baseline, post-treatment, and follow-up characteristics are summarized in [Tables 1](#) and [2](#). There was no difference in baseline BMI between males and females, regardless of a slight difference in age (46.2 ± 0.9 and 43.0 ± 0.6 years, respectively; $p=0.003$). Of the 729 responders, 152 reported that they had undergone BS between baseline and follow-up. Time from surgery to follow-up was 2.5 ± 0.3 years ranging from 0.8 to 3.0 years (lower to upper quartile). The participants attending NS were older and less obese than those in the BS group ([Table 1](#)). There were also slightly more males in the NS group (28.7 vs 21.2%; $p=0.06$). Most subjects in the BS group had received some form of NS treatment at the center prior to surgery ($n=126$; 83%). There was no difference in the treatment compliance between the NS and BS groups ([Table 1](#)). Mean follow-up time (from the first visit to the service to answering the questionnaire) was 6.1 ± 0.1 years.

Table 1 Clinical Characteristics and Treatment Outcome in Subjects Receiving Nonsurgical and Surgical Treatment

	NS (n=577)	BS (n=152)	p-value	All (n=729)
Age at start of treatment (years)	45.4±0.5	37.8±1.0	<0.0001	43.8±0.5
Gender (m/f [%males])	165/410 (28.7)	33/119 (21.7)	ns (0.08)	198/529 (27.2)
IT (%)	27.0	44.7	0.0001	30.7
GT (%)	49.4	35.5		46.5
LCD-GT (%)	23.6	19.7		22.8
Pre-treatment weight (kg)	117.8±1.1	133.3±2.0	<0.0001	121±1.0
Pre-treatment BMI (kg/m ²)	40.9±0.3	46.0±0.6	<0.0001	42.0±0.3
Center treatment duration (years)	1.4±0.05	1.1±0.1	0.002	1.4±0.04
Completers (%)	75.2	73.3	ns (0.6)	74.8
Post-treatment weight (kg)	107.5±1.0	119.0±2.0	<0.0001	109.8±0.9
Post-treatment BMI (kg/m ²)	37.3±0.3	41.1±0.6	<0.0001	38.1±0.3
Treatment weight loss (kg)	10.4±0.6	13.4±1.2	0.04	11.0±0.5
Treatment weight loss (%)	8.3±0.5	9.7±0.9	ns (0.2)	8.6±0.4
>5% treatment weight loss (%)	56.9 (52.7–60.9)	61.6 (53.2–69.6)	ns (0.3)	57.8 (54.1–61.5)
>10% treatment weight loss (%)	35.2 (31.3–39.3)	41.1 (33.0–49.5)	ns (0.2)	36.4 (32.9–40.0)
Follow-up (years)	6.1±0.1	6.2±0.2	ns (0.7)	6.1±0.1
Follow-up weight (kg)	111.0±1.1	93.8±2.1	<0.0001	107.4±1.0
Follow-up BMI (kg/m ²)	38.6±0.3	32.2±0.6	<0.0001	37.2±0.3
Follow-up weight loss (kg)	6.8±0.7	39.6±1.4	<0.0001	13.8±0.8
Follow-up weight loss (%)	5.2±0.6	29.3±1.1	<0.0001	10.3±0.6
Follow-up weight regain (kg)	3.7±0.7	–25.2±1.3	<0.0001	–2.3±0.7
Follow-up weight regain (%)	4.0±0.6	–20.5±1.2	<0.0001	–1.1±0.6
>5% follow-up weight loss (%)	48.1 (43.9–52.4)	96.7 (92.5–98.9)	<0.0001	58.5 (54.8–62.1)
>10% follow-up weight loss (%)	30.9 (27.1–34.9)	92.1 (86.6–95.9)	<0.0001	43.9 (40.2–47.6)

Abbreviations: NS, nonsurgical; BS, bariatric surgery.

Short- and Long-Term Weight Outcomes

Weight changes during treatment at the center and follow-up are shown in [Tables 1 and 2](#) and [Figure 2](#). Treatment at the center for those who later underwent BS was as effective as for the NS group in terms of relative weight loss. During follow-up, subjects who had undergone surgery showed the greatest weight loss compared to baseline (29.3±1.0% of body weight; 92.1% achieving >10% weight loss; [Table 1](#)). Based on weight loss, there was no difference in surgical success between males and females (29.4±2.4% vs 29.3±1.2%; $p=0.9$) or between having attended different NS alternatives at the center prior to surgery (IT 28.7±1.8%, GT 29.9±1.7%, LCD-GT 28.0±2.3%; ANOVA $p=0.8$).

Weight Outcomes for Nonsurgical Treatments

The participants in the LCD-GT group were more obese than those in the IT and GT groups at baseline ([Table 2](#)). Compliance was lower for IT than for GT and LCD-GT ($p<0.001$). This difference was attenuated when the analysis was restricted to males (IT: 68.3%; GT: 76.4%; LCD-GT: 77.1%; $p=0.57$). There was a mean weight regain of 3.7±0.7 kg during follow-up and the proportion of patients achieving a >5% loss of body weight decreased from 56.9 post-treatment to 48.1% at follow-up. Both weight loss and weight regain were unevenly distributed among NS alternatives ([Table 2](#)). LCD-GT was the most effective treatment, with 84.3% and 65.7% of the patients achieving >5% and >10% weight loss, respectively, followed by GT and IT, which were equally effective ($p=0.35$ when comparing weight loss at the service). At follow-up there was a 9.5±1.3 kg ($p<0.001$) weight regain in the LCD-GT group ([Figure 2](#)). Compared to baseline, LCD-GT was still the most effective NS alternative, eg. based on percent weight loss, with 56.7% and 41.8% maintaining >5% and >10% loss of body weight, respectively ([Figure 2](#)).

Table 2 Clinical Characteristics and Treatment Outcome in Subjects Receiving Nonsurgical Treatment Alternatives

	IT (n=156)	GT (n=285)	LCD-GT (n=136)	p-value
Age at start of treatment (years)	43.5±1.1	46.9±0.8	44.7±1.2	0.03
Gender (m/f [%males])	42/114 (26.9)	73/210 (25.8)	50/86 (36.8)	ns (0.06)
Pre-treatment weight (kg)	113.4±2.0	116.2±1.5	126.0±2.1	<0.0001
Pre-treatment BMI (kg/m ²)	39.8±0.5	40.6±0.4	42.9±0.6	<0.0001
Center treatment duration (years)	1.2±0.09	1.5±0.07	1.5±0.1	0.003
Completers (%)	62.9	78.1	82.8	0.0002
Post-treatment weight (kg)	106.7±2.0	108.2±1.4	106.9±2.1	ns (0.2)
Post-treatment BMI (kg/m ²)	37.4±0.5	37.8±0.4	36.3±0.6	0.03
Treatment weight loss (kg)	6.8±1.0	8.1±0.8	19.4±1.1	<0.0001
Treatment weight loss (%)	5.4±0.8	6.6±0.6	15.1±0.9	<0.0001
>5% treatment weight loss (%)	47.4 (39.3–55.6)	48.9 (42.9–54.9)	84.3 (77.0–90.0)	<0.0001
>10% treatment weight loss (%)	22.7 (16.4–30.2)	27.5 (22.3–33.1)	65.7 (57.0–73.7)	<0.0001
Follow-up (years)	6.2±0.2	6.2±0.2	5.8±0.3	ns (0.4)
Follow-up weight (kg)	108.5±2.1	109.8±1.6	116.3±2.3	ns (0.06)
Follow-up BMI (kg/m ²)	38.1±0.6	38.4±0.5	39.5±0.7	ns (0.1)
Follow-up weight loss (kg)	5.0±1.3	6.3±1.0	10.0±1.4	0.003
Follow-up weight loss (%)	3.6±1.1	4.9±0.8	7.5±1.1	0.007
Follow-up weight regain (kg)	1.6±1.1	2.0±0.8	9.5±1.2	<0.0001
Follow-up weight regain (%)	2.3±1.1	2.3±0.8	9.7±1.2	<0.0001
>5% follow-up weight loss (%)	40.9 (33.1–48.7)	48.0 (42.0–54.1)	56.7 (47.9–65.2)	0.028
>10% follow-up weight loss (%)	24.7 (18.1–32.3)	29.1 (23.8–34.8)	41.8 (33.3–50.6)	0.0048

Abbreviations: IT, individual therapy; GT, group therapy; LCD-GT, GT initiated by low calorie diet.

Remission and Incidence of Type 2 Diabetes

Weight loss in subjects with baseline T2D was comparable to that in subjects without T2D for all the treatment alternatives (data not shown). Subjects with baseline T2D receiving NS were older than those without diabetes (52.4 ± 1.0 vs 43.8 ± 0.6 years, $p < 0.001$) and maintained their weight loss to follow-up (Table 3), while subjects without T2D regained some weight (from BMI 37.3 ± 0.3 to 38.7 ± 0.4 kg/m², $p < 0.001$).

For all subjects, there was a non-significant increase in the prevalence of T2D from baseline to follow-up, from 19.9% (17.1–23.0) to 22.2% (19.2–25.3) ($p = 0.29$). However, these individuals were not the same ($p < 0.0001$). Overall, 20.1% (13.9–27.6) of those with baseline T2D reported no longer being treated for T2D at follow-up, and 7.9% (5.8–10.4) of those without baseline T2D reported that they were now treated for T2D at follow-up (Figure 3A and B). Incident T2D was less common (2.6% [–3.5–5.4] vs 9.2% [6.6–11.8], $p = 0.02$), and remission was more common (52.8% [35.6–69.9] vs 9.2% [6.5–11.1], $p < 0.001$) in BS than in NS (Figure 3A and B). T2D remission rates at follow-up were 17.2% (2.6–31) and 7.0% (1.8–13.9) in the LCD-GT ($p < 0.001$) and GT ($p = 0.04$) subgroups, respectively (Figure 3B).

As stated in the Methods section, it is important to stress that exposure times differed between groups, particularly regarding the timing and follow-up after BS. A sensitivity analysis comparing subjects referred to BS from the center with longer exposure, and subjects being referred to BS after having finished their treatment center showed no differences in outcomes or total follow-up time (Supplementary Table S6), illustrating that the effect of BS on weight loss and for instance diabetes remission occurs already within the first couple of years.⁶

Discussion

The current global obesity epidemic demands affordable, scalable strategies for long-term weight maintenance and prevention of cardiometabolic diseases such as T2D. Although bariatric surgery^{6–8} and GLP-1 receptor agonists⁹ cause significant weight loss, they are inaccessible to most patients. In addition, while all weight loss strategies rest on lifestyle

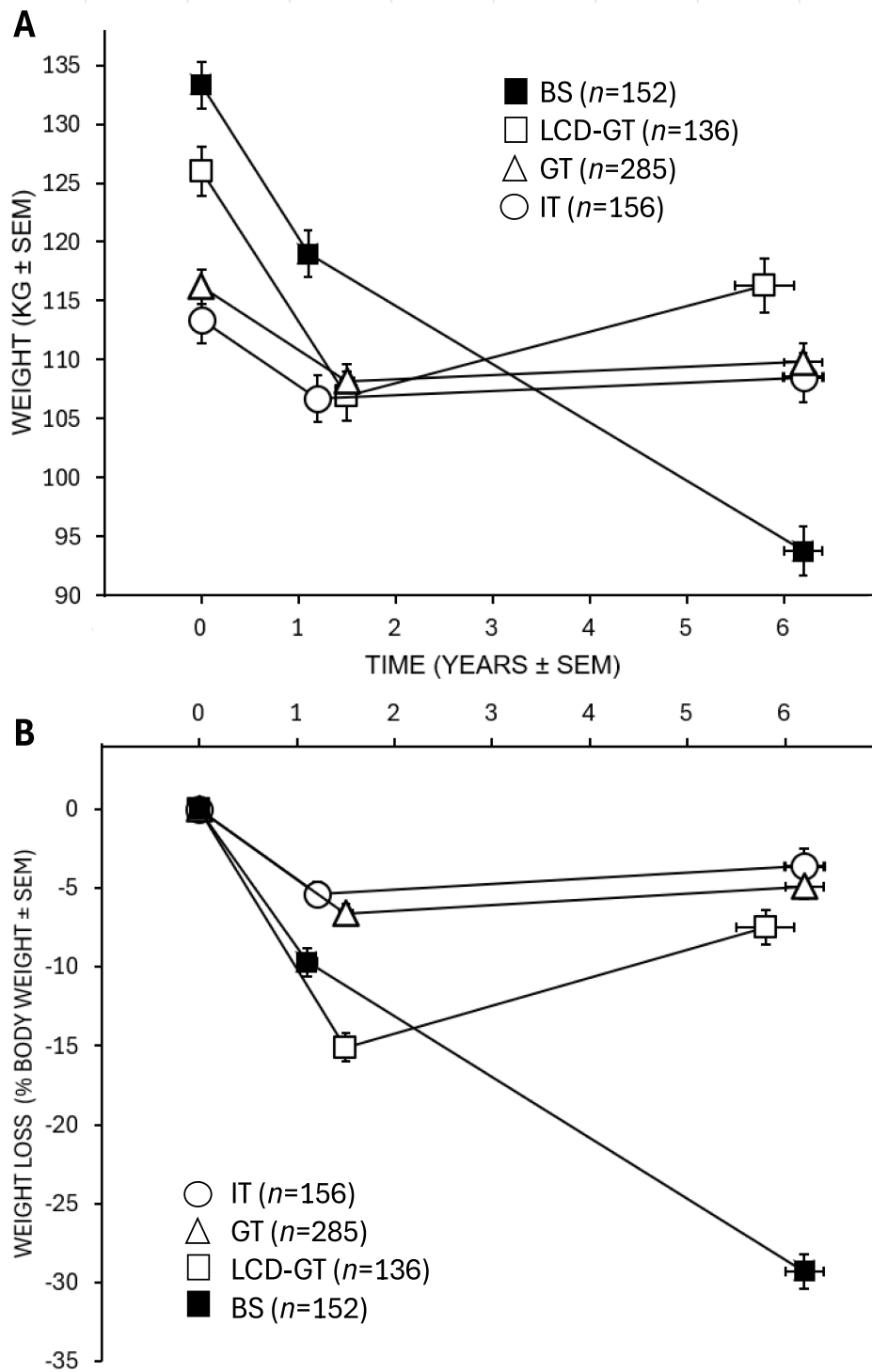


Figure 2 Long-term weight development after attending different obesity treatments. Data are shown for bariatric surgery (filled box), group treatment based on behavioral modification principles (GT; open triangle), GT initiated with a low-calorie diet (open box), and individual treatment (open circle) before and after treatment at the clinic (at approximately 1 year) and at follow-up (at approximately 6 years). Data are shown as mean \pm SEM for weight loss as (A) kg and (B) % of body weight.

changes that may be successful in academic trials, the general perception is that weight loss is rarely sustained in the long term.^{10–13} This encouraged us to perform this long-term follow-up study on nonsurgical, primarily nonpharmacological treatments in a real-world setting conducted before GLP-1 receptor agonists were available.

Table 3 Clinical Characteristics and Treatment Outcome in Subjects with Type 2 Diabetes Receiving Nonsurgical and Surgical Treatment

	NS (n=109)	BS (n=36)	p-value	All (n=145)
Age at start of treatment (years)	52.4±1.0	43.2±1.8	<0.0001	50.2±1.0
Gender (m/f [%males])	35/73 (32.4)	7/29 (31.8)	ns (0.16)	42/102 (29.2)
IT (%)	22.0	36.1	ns (0.1)	25.5
GT (%)	52.3	36.1		48.3
LCD-GT (%)	25.7	26.3		26.2
Pre-treatment weight (kg)	116.9±2.1	130.8±3.7	<0.0005	120.3±1.9
Pre-treatment BMI (kg/m ²)	40.6±0.6	45.0±1.0	<0.001	41.7±0.5
Center treatment duration (years)	1.8±0.14	1.3±0.3	0.013	1.7±0.1
Completers (%)	81.9	86.1	ns (0.6)	83.0
Post-treatment weight (kg)	107.3±2.0	116.5±3.5	0.0055	109.5±1.8
Post-treatment BMI (kg/m ²)	37.2±0.5	40.1±1.0	0.0085	37.9±0.5
Treatment weight loss (kg)	9.6±1.3	14.2±2.2	ns (0.07)	10.8±1.1
Treatment weight loss (%)	7.5±1.0	10.5±1.8	ns (0.1)	8.3±0.9
>5% treatment weight loss (%)	54.2 (44.3–63.9)	65.7 (47.8–80.9)	ns (0.23)	57.0 (48.5–65.3)
>10% treatment weight loss (%)	31.8 (23.1–41.4)	48.6 (31.4–66.0)	ns (0.07)	35.9 (28.0–44.4)
Follow-up (years)	6.0±0.3	5.9±0.5	ns (1.0)	6.0±0.3
Follow-up weight (kg)	109.0±2.0	91.9±3.5	<0.0001	104.7±1.9
Follow-up BMI (kg/m ²)	37.9±0.5	31.2±0.9	<0.0001	36.3±0.5
Follow-up weight loss (kg)	7.9±1.4	38.9±2.4	<0.0001	15.6±1.6
Follow-up weight loss (%)	6.0±1.1	29.5±2.0	<0.0001	11.8±1.3
Follow-up weight regain (kg)	2.1±1.4	–25.1±2.4	<0.0001	–4.6±1.5
Follow-up weight regain (%)	2.5±1.2	–20.8±2.1	<0.0001	–3.2±1.4
>5% follow-up weight loss (%)	52.3 (42.5–61.9)	100.0 (90.3–100.0)	<0.0001	64.1 (55.8–71.9)
>10% follow-up weight loss (%)	35.8 (26.8–45.5)	91.7 (77.5–98.2)	<0.0001	49.7 (41.2–58.1)

Abbreviations: NS, nonsurgical; BS, bariatric surgery.

We asked two main questions. First, can weight loss be maintained for several years, given that most studies last only one year? Second, what are the effects of these treatments on T2D remission and incidence? Beyond the expected benefits of bariatric surgery,^{16,17} we found that nonsurgical and primarily lifestyle change-based approaches achieved surprisingly durable weight loss and clinically significant effects on T2D prevention and remission.

Typically, approximately 20% of overweight individuals maintain a 10% weight loss for one year in nonsurgical, nonpharmacological intervention studies.¹² Our six-year data implies that this can be sustained for much longer: 25–40% of participants in nonsurgical programs maintained a weight loss of >10%. Group therapy with an initial LCD phase yielded the greatest early weight loss, but also the most regain, consistent with prior studies showing approximately 10% weight loss and then some regain when followed up until one year.^{10,13} It will be important to focus on known factors that can positively influence weight maintenance, such as regular and consistent eating patterns, physical activity, and self-monitoring of weight after such treatments, as it seems that weight maintenance might be easier over time.^{12,13}

It has been consistently shown that weight loss due to bariatric surgery may result in long-term remission of diabetes.^{6,16–18} The extent of this response depends on factors such as age, sex, degree of obesity, and duration and severity of diabetes as well as on the definition of remission itself.^{19,20} In essence, our observations confirm these data. Bariatric surgery remains the most effective intervention, with approximately half of the patients achieving diabetes remission within 2.5 years post-surgery in our study. Interestingly, the presurgical program type attended by most of the subjects who underwent bariatric surgery did not influence surgical outcomes.

Nonsurgical treatments showed lower T2D remission rates (4.4–17.9%), which were the highest in the LCD-based therapy group. These results align with studies such as DIRECT and Look AHEAD.^{21–23} In the DIRECT study, people with T2D were randomized to a weight management program with substantial weight loss or best practice, both in a primary care setting.²¹ T2D remission after one year in the DIRECT weight management arm was 46% with a clear

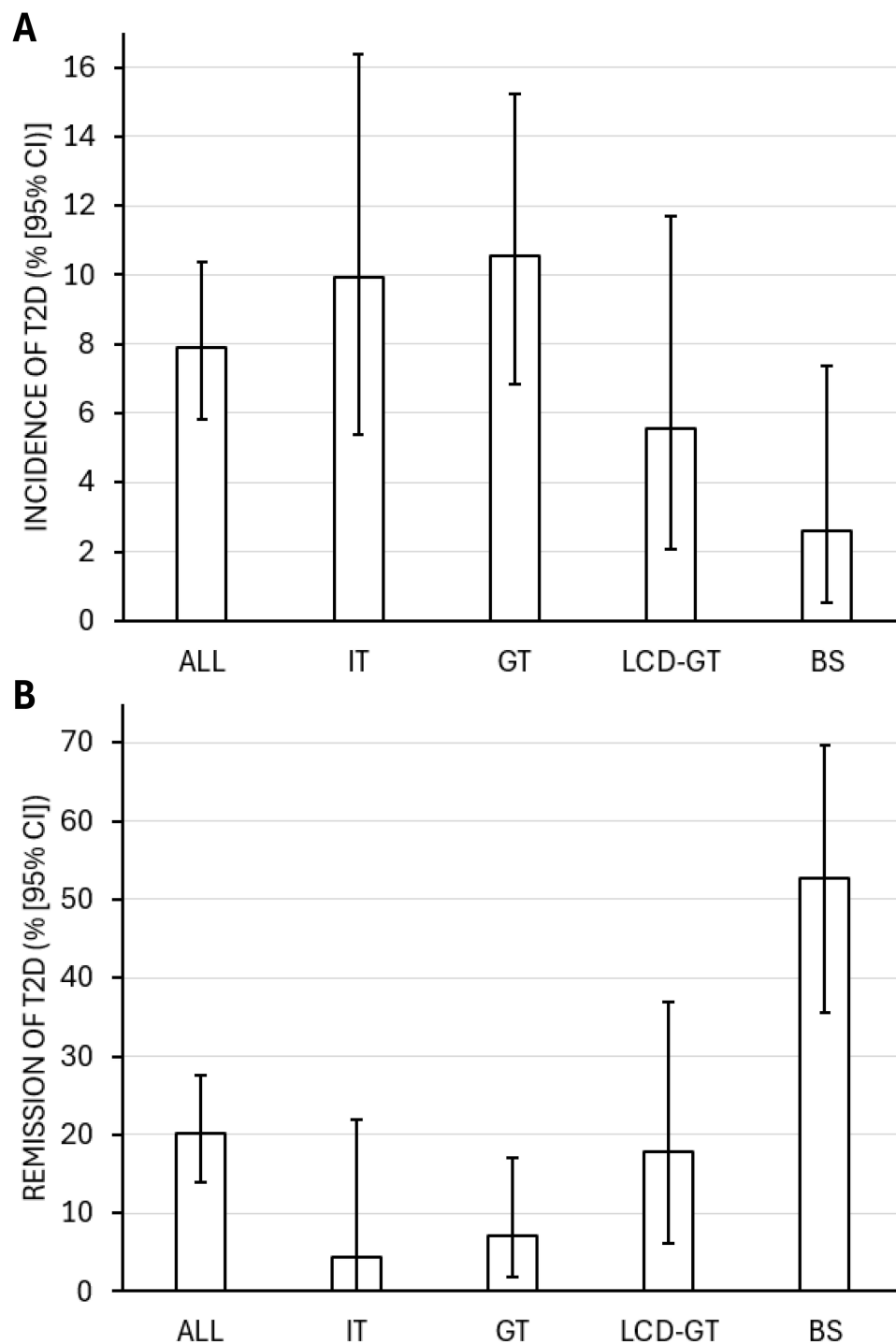


Figure 3 Diabetes incidence (A) and remission (B) in patients six years after attending different obesity treatments.

Abbreviations: IT, individual treatment; GT, group treatment based on behavioral modification principles; LCD-GT, GT initiated by low calorie diet; BS, bariatric surgery.

dose-response effect, at a 2-year follow-up 36%, and after 5 years 13%.²² Contrary to DIRECT, where subjects were followed up with low-intensity support, we have no information on subsequent treatment attempts, other than that the responders in our study did not undergo bariatric surgery, and the fact that diabetes drugs positively affecting weight were not available at the time of our investigation. Another useful comparison regarding T2D might be the results of the Look AHEAD, in which subjects in the intensive lifestyle arm achieved a weight loss of 4.7% and diabetes remission of 7.3% after four years.²³

We also found that the effect of obesity treatment was equal in subjects with and without T2D, and that subjects with T2D experienced less weight regain than others. This was not expected because people with T2D often lose less weight compared to people without diabetes, but may be explained by their older age, which has been shown to be a predictor of weight loss.²⁴ Greater sustained weight loss in older individuals has been observed previously in, for instance, the long-term follow-up of the Finnish Diabetes Prevention Study (DPS).²⁵ Other than being older, subjects with T2D in our study had similar clinical baseline characteristics.

Two important conclusions can be made from these observations. First, T2D remission is dependent on the magnitude of weight loss, and second, weight loss is at least an as effective opportunity for subjects with T2D, as it is for those without. This message is also important when considering Look AHEAD being stopped, since the intensive lifestyle arm treatment did not lead to a significant reduction in cardiovascular outcomes.²³

Preventing T2D hinges on weight reduction, supported by evidence from lifestyle, drug, and surgical interventions.^{25–31} Two key studies in lifestyle-based T2D prevention – DPS and the U.S. Diabetes Prevention Program (DPP) – provide important comparisons to our findings.^{25–28} Both enrolled high-risk individuals with prediabetes and randomized them to control/placebo or intensive lifestyle intervention targeting modest weight loss (5–7%) and increased physical activity (>150 minutes/week).^{26,27} DPP also included a metformin arm.²⁷ Each study offered an initial intensive support phase (6–12 months) followed by ongoing follow-up, initially for about three years. Both achieved comparable early lifestyle outcomes (for instance 43–50% reaching weight loss goals) and reported the same 58% short-term reduction in T2D risk, with 6-year diabetes incidences of ~25% in intervention groups vs ~40% in controls and sustained effects for much longer despite weight regain.^{25,28} These rates are substantially higher than in our non-controlled NS cohort, despite similar weight loss as our IT and GT groups. This likely reflects population differences: participants in DPS/DPP were older (51–55 vs 45 years), less obese (BMI 31–34 vs 41 kg/m²), yet at very high and documented diabetes risk. Notably, despite strong effects on T2D incidence, neither study has demonstrated improvements in long term all cause or cause specific mortality, underscoring the importance of continued long term follow up in both academic trials and real-world studies.²⁹

A potentially more comparable population to our study is the control arm of the Swedish Obese Subject study (SOS), matched to be similar to those undergoing bariatric surgery but not eligible for surgery themselves.⁶ They were of similar age (48 vs 45 years), gender distribution (30 vs 29% males), and BMI (40 vs 41 kg/m²) as our NS study population. In addition to the robust results on weight loss, T2D remission and prevention seen in the surgery arm of SOS, subjects in the control arm, who all had the intention to lose weight and were managed through standard obesity care at the time, also did very well. After 10 years about 27% had lost more than 5% of their initial weight, and 4% more than 20% of their weight. The incidence of T2D was 8 and 24% after 2 and 10 years, respectively, with a corresponding remission rate of T2D of 21 and 13%, respectively. These numbers are far from what surgery achieved (for instance a 36% T2D remission rate after 10 years)⁶ but are still strikingly good compared to the results of DPS and DPP, be that in populations of greater risk, and aligned with what we observed after six years. Our data, taken together with those of among others DIRECT, Look AHEAD, DPS, DPP and SOS, underscores the importance of considering nonpharmacological programs. We also conclude that treatments that have been worked out and investigated in academic trials do seem to work when implemented in clinical practice.

This study has some important limitations. Its observational design makes it impossible to fully compare treatment alternatives due to inherent selection bias and causal interpretation is difficult. Rather, the outcomes observed here represent what can be expected when different modalities are offered to a heterogeneous obese population, and the choice of treatment is based on the clinical evaluation and patient preference. Reporting bias is another important limitation of this study. We partly view this as minor, since the response rate was as high as 67%. Self-reported data should be interpreted with caution. However, comparing self-reported pretreatment body weights to weights registered at the center showed very high congruence, indicating robustness and validity. Similarly, the observed differences between questionnaire responders and non-responders were minor. Notably, 25% of responders reported not completing the treatment program they started, indicating that success reporting bias might not be a significant problem, although this can never be ruled out.¹⁰

Diabetes diagnosis constitutes a particular case since there was no validation of diagnosis, lack of diagnosis, or diabetes remission, introducing the risk for recall bias and misclassification. There was no consensus on the remission criteria at the time, and the patient's opinion may still be valid in clinical practice. Although non-comparable to the 2021

ADA consensus remission criteria which postdated the treatment era of our cohort, the exact phrasing of the question put to the study participants as “were/are you being treated for diabetes” is aligned with the current definition of diabetes remission.¹⁹ An apparent strength of this study is the very long-term follow-up time compared to previous studies and the fact that modern obesity drugs were not available during the observation period and could not inflate or dilute the results that may serve as a baseline.

Conclusion

To date, bariatric surgery has been the most effective obesity treatment in terms of weight loss and diabetes prevention and remission, followed by modern obesity drugs. However, in the face of the global obesity epidemic, only a minority of patients will receive surgery or modern obesity drugs. For these patients, nonpharmacological and nonsurgical treatments may offer long-term effectiveness. These results are encouraging, particularly concerning the prevention and potential treatment of diabetes.

Data Sharing Statement

The data in our study are available upon request from the corresponding authors.

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Author Contributions

M.J.E. and M.R.: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Project administration; Visualization; Writing – original draft; Writing – review & editing. M.R.: Funding acquisition; Resources; Supervision. All authors gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Disclosure

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References

1. Malik VS, Willet WC, Hu FB. Nearly a decade on - trends, risk factors and policy implications in global obesity. *Nat Rev Endocrinol.* 2020;16(11):615–616. doi:10.1038/s41574-020-00411-y
2. NCD Risk Factor Collaboration (NCD-RisC). Worldwide trends in underweight and obesity from 1990 to 2022: a pooled analysis of 3663 population-representative studies with 222 million children, adolescents, and adults. *Lancet.* 2024;403(10431):1027–1050. 10.1016/S0140-6736(23)02750-2.
3. Xie F, Xiong F, Yang B, et al. Global, regional, and national burden of mortality and DALYs attributable to high body mass index from 1990 to 2021 with projections to 2036. *BMC Public Health.* 2025;25(1):2053. doi:10.1186/s12889-025-23237-7
4. Strelitz J, Lawlor ER, Wu Y, et al. Association between weight change and incidence of cardiovascular disease events and mortality among adults with type 2 diabetes: a systematic review of observational studies and behavioural intervention trials. *Diabetologia.* 2022;65(3):424–439. doi:10.1007/s00125-021-05605-1
5. Strandberg TE, Strandberg AY, Jyväkorpi S, et al. Weight loss in midlife, chronic disease incidence, and all-cause mortality during extended follow-up. *JAMA Network Open.* 2025;8(5):e2511825. doi:10.1001/jamanetworkopen.2025.11825
6. Sjöström L, Lindroos AK, Peltonen M, et al; Swedish Obese Subjects Study Scientific Group. Lifestyle, diabetes, and cardiovascular risk factors 10 years after bariatric surgery. *N Engl J Med.* 2004;351(26):2683–2693. doi:10.1056/NEJMoa035622
7. Sjöström L, Narbro K, Sjöström CD, et al. Swedish Obese Subjects Study. Effects of bariatric surgery on mortality in Swedish obese subjects. *N Engl J Med.* 2007;357(8):741–752. doi:10.1056/NEJMoa066254

8. Courcoulas AP, Daigle CR, Arterburn DE. Long term outcomes of metabolic/bariatric surgery in adults. *BMJ*. 2023;383:e071027. doi:10.1136/bmj-2022-071027
9. Yao H, Zhang A, Li D, et al. Comparative effectiveness of GLP-1 receptor agonists on glycaemic control, body weight, and lipid profile for type 2 diabetes: systematic review and network meta-analysis. *BMJ*. 2024;384:e076410. doi:10.1136/bmj-2023-076410
10. Nordmo M, Danielsen YS, Nordmo M. The challenge of keeping it off, a descriptive systematic review of high-quality, follow-up studies of obesity treatments. *Obes Rev*. 2020;21(1):e12949. doi:10.1111/obr.12949
11. Wadden TA, Butryn ML, Byrne KJ. Efficacy of lifestyle modification for long-term weight control. *Obes Res*. 2004;12:151S–62S. doi:10.1038/oby.2004.282
12. Wing RR, Phelan S. Long-term weight loss maintenance. *Am J Clin Nutr*. 2005;82(1 Suppl):222S–225S. doi:10.1093/ajcn/82.1.222S
13. Johansson K, Neovius M, Hemmingsson E. Effects of anti-obesity drugs, diet, and exercise on weight-loss maintenance after a very-low-calorie diet or low-calorie diet: a systematic review and meta-analysis of randomized controlled trials. *Am J Clin Nutr*. 2014;99(1):14–23. doi:10.3945/ajcn.113.070052
14. Melin I, Rössner S. Practical clinical behavioral treatment of obesity. *Patient Educ Couns*. 2003;49(1):75–83. doi:10.1016/s0738-3991(02)00049-6
15. Ekman MJ, Klintonberg M, Björck U, Norström F, Ridderstråle M. Six-minute walk test before and after a weight reduction program in obese subjects. *Obesity*. 2013;21(3):E236–43. doi:10.1002/oby.20046
16. Scherthaner G, Brix JM, Kopp HP, Scherthaner GH. Cure of type 2 diabetes by metabolic surgery? A critical analysis of the evidence in 2010. *Diab Care*. 2011;34:S355–60. doi:10.2337/dc11-s253
17. Mingrone G, Panunzi S, De Gaetano A, et al. Bariatric surgery versus conventional medical therapy for type 2 diabetes. *N Engl J Med*. 2012;366(17):1577–1585. doi:10.1056/NEJMoa1200111
18. Schauer PR, Kashyap SR, Wolski K, et al. Bariatric surgery versus intensive medical therapy in obese patients with diabetes. *N Engl J Med*. 2012;366(17):1567–1576. doi:10.1056/NEJMoa1200225
19. Riddle MC, Cefalu WT, Evans PH, et al. Consensus report: definition and interpretation of remission in type 2 diabetes. *Diab Care*. 2021;44(10):2438–2444. doi:10.2337/dci21-0034
20. Taheri S. Type 2 diabetes remission: a new mission in diabetes care. *Diab Care*. 2024;47(1):47–49. doi:10.2337/dci23-0062
21. Lean ME, Leslie WS, Barnes AC, et al. Primary care-led weight management for remission of type 2 diabetes (DiRECT): an open-label, cluster-randomised trial. *Lancet*. 2018;391(10120):541–551. doi:10.1016/S0140-6736(17)33102-1
22. Lean ME, Leslie WS, Barnes AC, et al. 5-year follow-up of the randomised diabetes remission clinical trial (DiRECT) of continued support for weight loss maintenance in the UK: an extension study. *Lancet Diab Endocrinol*. 2024;12(4):233–246. doi:10.1016/S2213-8587(23)00385-6
23. Gregg EW, Chen H, Wagenknecht LE, et al. Association of an intensive lifestyle intervention with remission of type 2 diabetes. *JAMA*. 2012;308(23):2489–2496. doi:10.1001/jama.2012.67929
24. Thorning TK, Fabre O, Legrand R, Astrup A, Hjorth MF. Weight loss and weight loss maintenance efficacy of a novel weight loss program: the retrospective RNPC[®] cohort. *Obes Med*. 2018;10:16–18. doi:10.1016/j.obmed.2018.05.001
25. Lindström J, Ilanne-Parikka P, Peltonen M, et al; Finnish Diabetes Prevention Study Group. Sustained reduction in the incidence of type 2 diabetes by lifestyle intervention: follow-up of the Finnish Diabetes Prevention Study. *Lancet*. 2006;368(9548):1673–1679. doi:10.1016/S0140-6736(06)69701-8
26. Tuomilehto J, Lindström J, Eriksson JG, et al; Finnish Diabetes Prevention Study Group. Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. *N Engl J Med*. 2001;344(18):1343–1350. doi:10.1056/NEJM200105033441801
27. Knowler WC, Barrett-Connor E, Fowler SE, et al; Diabetes Prevention Program Research Group. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *N Engl J Med*. 2002;346(6):393–403. doi:10.1056/NEJMoa012512
28. Group DPPR, Knowler WC, Fowler SE, et al. 10-year follow-up of diabetes incidence and weight loss in the diabetes prevention program outcomes study. *Lancet*. 2009;374(9702):1677–1686. doi:10.1016/S0140-6736(09)61457-4
29. Lee CG, Heckman-Stoddard B, Dabelea D, et al. Diabetes prevention program research group; diabetes prevention program research group: effect of metformin and lifestyle interventions on mortality in the diabetes prevention program and diabetes prevention program outcomes study. *Diab Care*. 2021;44(12):2775–2782. doi:10.2337/dc21-1046
30. Hamman RF, Wing RR, Edelstein SL, et al. Effect of weight loss with lifestyle intervention on risk of diabetes. *Diab Care*. 2006;29(9):2102–2107. doi:10.2337/dc06-0560
31. Carlsson LM, Peltonen M, Ahlin S, et al. Bariatric surgery and prevention of type 2 diabetes in Swedish obese subjects. *N Engl J Med*. 2012;367(8):695–704. doi:10.1056/NEJMoa1112082

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