The efficacy of energy-restricted diets in achieving preoperative weight loss for bariatric patients: A systematic review.

Abstract

In bariatric practice, a preoperative weight loss of at least 5% is recommended. However, the hypocaloric diets prescribed vary and no consensus exists. This study examined the efficacy of preoperative diets in achieving 5% weight loss. From a systematic literature search, eight randomised controlled trials (n=862) were identified. Half of the trials used a "Very-low-calorie diet" whilst the rest employed a "Low-calorie diet". Only five diets achieved ≥5% weight loss over varying durations and energy intake. By inference, compliance with a 700-1050kcal (2929-4393kJ) diet, consisting of moderate carbohydrate, high protein and low/moderate fat, for three weeks is likely to achieve 5% weight loss. A low CHO diet (<20g/day) may achieve this target within a shorter duration. Additional research is required to validate these conclusions.

Keywords

Obesity

Bariatric surgery

Metabolic surgery

Low-calorie diet

Very-low-calorie diet

Introduction

Obesity is a major global health issue both in terms of its increasing trajectory and as one of the leading causes of morbidity and mortality (1–5). Presently, bariatric surgery is accepted as the most effective treatment for the management of morbid obesity (6–8). It is also termed “metabolic surgery” since the weight loss mechanisms extend beyond food restriction and nutrient malabsorption by altering physiological and metabolic processes to induce larger amounts of sustainable weight loss (9,10).

However, bariatric surgery is not entirely risk-free and carries potential complications ranging from 5 to 20% (11). Consequently, bariatric guidelines (12–15) support an intentional preoperative weight loss to reduce the liver volume (13,14) and risk of perioperative complications (12,13,15). It is particularly challenging for surgeons to elevate the left lobe of a large or fatty liver (16,17), especially during laparoscopic Roux-en-y gastric bypass surgery (RYGB), thereby, increasing the risk of liver injury and intraoperative bleeding (18). Furthermore, an enlarged liver contributes to an estimated 50% of minimally invasive laparoscopic RYGB procedures transitioning to an open procedure (19,20) making the surgery more invasive and increasing the risk of wound infections, length of hospital stay and recovery time (13). Nevertheless, with advances in technique and technology, when bariatric surgeons encounter a large liver, they may choose to either postpone the surgery or execute a simpler procedure of second choice such as the sleeve gastrectomy.

A total weight loss (%TWL) of at least 5% (21–23) has been shown to achieve the general liver volume reduction target of approximately 10% (18,24). Furthermore, losing at least 5%TWL has also been recommended for the treatment of non-alcoholic fatty liver disease (25). This is compatible with the general consensus that, regardless of a scheduled bariatric surgery, a modest weight loss, defined as 5-10 %TWL, has

benefits on existing comorbidities (25,26) such as ameliorating hyperglycaemia or cardiovascular risk factors which are associated with increased perioperative risks (27,28).

The most recent bariatric guidelines (14,15) and literature (24,29–33) are in favour of energy-restricted diets to achieve rapid preoperative weight reduction. However, there is significant heterogeneity in the type of energy-restricted dietary regimes being prescribed (34). For example, an observational study, involving one-third of the bariatric centres in the United Kingdom found extensive variability in the type of energy-restricted diets prescribed preoperatively (35).

Given this lack of consensus amongst bariatric professions, there is a need to systematically review the highest level of evidence to determine the magnitude, macronutrient composition and duration of energy-restricted diets that may optimally achieve a preoperative weight loss of at least 5%.

Methods

The Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) checklist (36) was used as a basis for this review.

Eligibility criteria

The PICO (population, intervention, comparator, outcomes) formula (37,38) was adopted to develop the clinical question and eligibility criteria as follows:

Review question	Can preoperative energy-restricted diets for bariatric patients incur significant weight loss?
Population	Human subjects of any age with any degree of obesity who are scheduled for bariatric surgery.
Intervention	English-language randomised controlled trials exploring the efficacy of preoperative energy-restricted diets on weight loss. Trials published from 2013 onwards.
Comparator	Comparison of energy-restricted diets, standard diets, other weight loss strategies, macronutrient composition, varying durations, no dietary intervention or placebo.
Outcomes	Primary outcomes: Body weight, Body Mass Index (BMI), % excess weight loss, % total body weight lost. Secondary outcomes: Any positive or adverse health outcomes and observed changes in: ▪ Biochemical and clinical variables. ▪ Liver volume. ▪ Visceral fat. ▪ Length of hospital stay. ▪ Duration of surgery. ▪ Surgery-related complications. ▪ Mortality.
Setting	Hospital wards, bariatric centres, outpatient settings, home. No restrictions.

Information sources

Literature specific to the review question was identified by searching the following electronic databases from 2013 to June 2017: PubMed, CINAHL, Cochrane Library, Web of Science and Science Direct.

In addition to performing citation searches on key articles, hand searching the bibliographies of relevant retrieved articles and contacting authors for missing details, the search was supplemented with the following alternative sources: ClinicalTrials (http://clinicaltrials.gov), Clinical UK trials (https://www.ukctg.nihr.ac.uk/), PROSPERO (https://www.crd.york.ac.uk/PROSPERO/) and National Institute for Health and Care Excellence's evidence search website (https://www.evidence.nhs.uk/).

Search strategy

The search strategy incorporated truncation and speech marks for phrases to capture variation in terminology, where possible. Boolean logic operators was utilised for the electronic search engines. The following key words and/or Medical Index Subject Headings and related synonyms were used: ("Clinical efficacy" OR "treatment outcome*" OR "body weight" OR "blood glucose" OR "glycosylated hemoglobin" OR "glycosylated haemoglobin" OR "blood pressure" OR Liver OR Fat OR Adipos* OR "Inter-abdominal") AND (Preoperative OR "Before surgery" OR "Pre-surgery") AND ("Weight loss diet*" OR "Diet reducing" OR "Weight reduction diet*" OR "Very Low Calorie Diet*" OR "Caloric restriction" OR "Low Calorie Diet*" OR "Very Low Energy Diet*" OR "Low Energy Diet*" OR VLCD OR LCD OR "Liquid Diet*" OR "Meal replacement*") AND ("Bariatric surgery" OR "Weight Loss Surgery" OR "Metabolic surgery" OR "Sleeve gastrectomy" OR "Gastric bypass" OR "Laparoscopic Adjustable Gastric Banding").

Data management

The literature search results were uploaded to EndNote (39) to facilitate the management of identified records and allow easy identification of duplicate studies.

Selection process

In the first stage of study selection, one reviewer independently screened the titles and abstracts as per predetermined eligibility criteria. In the second stage, full articles were retrieved if adequate information was unavailable from the abstracts. Any uncertainties were clarified and discussed with the supervisor in-charge (OF) of this review.

Data collection process and data items

One reviewer extracted data independently from eligible articles using a standardized template as per Centre for Reviews and Dissemination Guidelines (CRDG) (40).

Assessing bias and quality of selected studies

The methodological quality of the trials was appraised using the Downs and Blacks Checklist (41). Any lack of clarity was discussed with OF. For the purpose of clarity, the last question on power was modified to two options whereby one point was assigned if the trial had conducted a power calculation and zero points if not. Therefore, this simplified version has a maximum score of 28. Additionally, scores less than 14 were graded "poor", 14 to 18 as "fair", 19-23 as "good" and 24-28 as "excellent" quality. This method has been adopted by a previous study (42).

Data synthesis

Relevant details are presented as a systematic narrative synthesis in the following order to highlight key findings: trials characteristics, details of energy-restricted diets,

weight loss and secondary outcomes. A meta-analysis could not be conducted due to the heterogeneity of the data.

Confidence in cumulative estimate

The strength of the evidence was determined using the CRDG's hierarchy of evidence level (40).

Results

Selected RCTs

The literature search results are summarised in Figure 1.

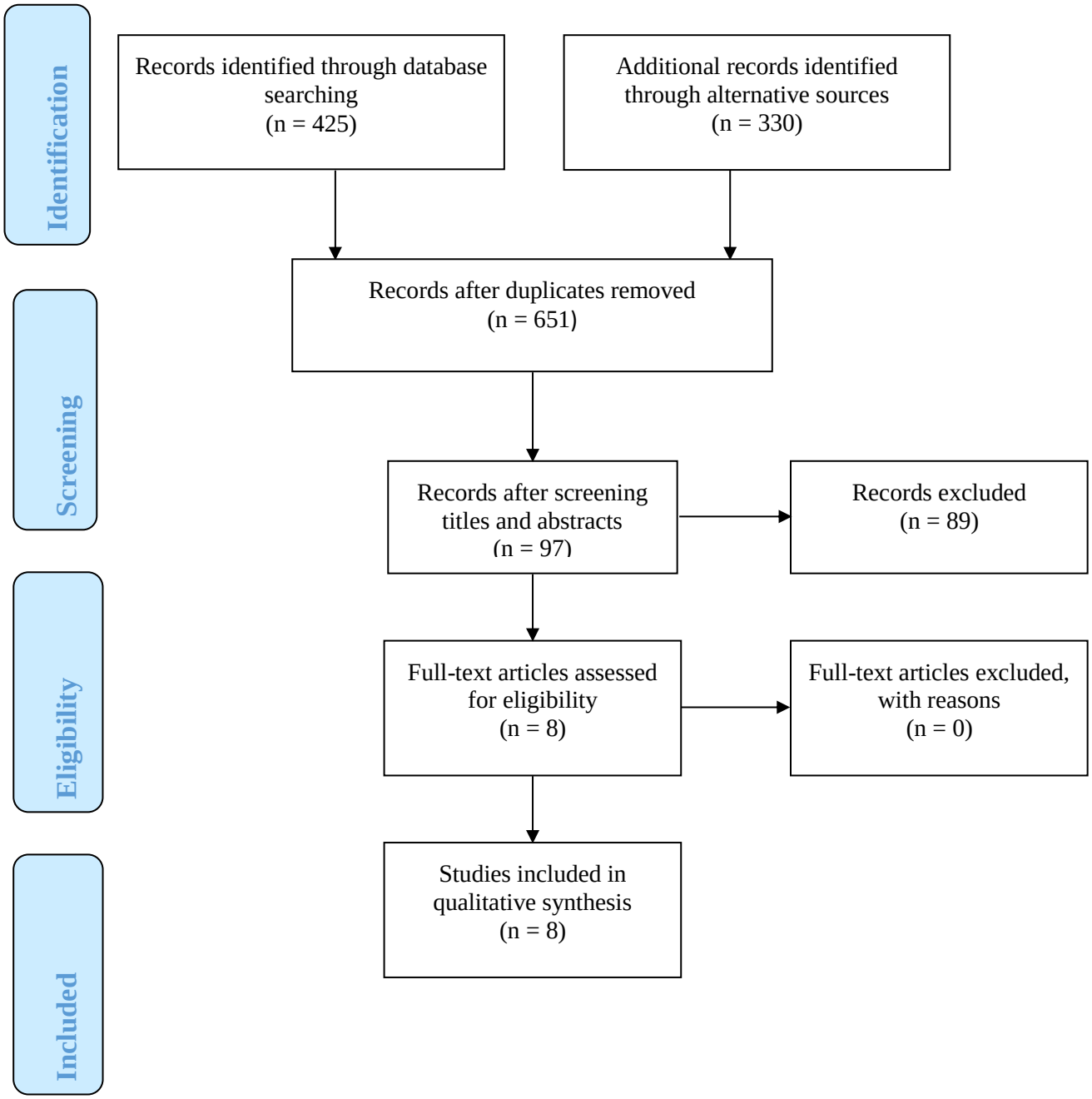

Figure 1. The Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) flow diagram for study inclusion.

Characteristics of identified RCTs

The eight trials (total n =862 participants) consisted of, on average, 80% females with age and BMI ranging from 36 to 47 years and 37.4 to 59.0 kg/m^2 respectively. Two of the selected RCTs were abstracts presented at conferences (43,44) and one was a brief report (45). Five of the trials were conducted in Europe (43–47), two in North America (48,49) and one in South America (50). Five trials reported attrition rates ranging from 6.7 to 27%. The study settings included hospitals (43–45), specialised clinics (47–50) and a university (46). The characteristics of the RCTs are summarised in Table 1.

Diet interventions

Fifty percent of the RCTs used Very Low Calorie Diets (VLCD) consisting of 647 to 800kcal (2707-3347kJ) per day (44,45,47,50) (Table 2) and the other half adopted Low Calorie Diets (LCD) with energy content ranging from 1030 to 1600kcal (4310-6694kJ) per day (43,46,48,49) (Table 3). The diet duration ranged from 10 days to six months with two weeks being the most common duration (N=6 diets). (43,45,50).

The majority of the RCTs compared groups that were both energy-restricted and 16 distinct types of diets were identified (Table 2 & 3). It is unclear whether energy intake was restricted for the control group in one of the trials (44).

Only one RCT used an energy-restricted diet based solely on liquid food products (50). Three trials did not indicate the diet consistency (43–45) and the rest used a diet which incorporated both liquid and solid food products.

Weight loss outcomes

As outlined in Table 4, five diets achieved at least 5%TWL (44,46,48,49) and 11 did not achieve this target (Table 4). Two VLCD diets just failed to achieve the 5% weight loss target (4.8%) (47).

Secondary outcomes

There is a high degree of heterogeneity in the secondary outcomes described and corresponding measurement methods as well as reporting units (Table 5).

Two RCTs reported reductions in liver size after 3-5%TWL (43,44). Only one trial reported significant visceral fat changes after 3.5%TWL (50). The same trial found an inverse relationship between surgery time and visceral fat in the liquid VLCD group (P=0.0014). Another trial observed that the duration of surgery for the group following a VLCD diet was 10 minutes shorter than the control group that was on a "normal" diet (P=0.16) (44).

Four RCTs observed improvements in biochemical risk factors following energy-restriction and varying degrees of success in weight loss (45,46,49,50). One trial reported a positive shift in clinical risk factors which included a decrease in blood pressure after a LCD for seven weeks (46). There was no significant difference between groups for perioperative complications (44,47,50).

Discussion

A striking feature about the literature in this area is an increase in the number of publications of RCTs since 2014, probably due to the growing recognition that preoperative weight loss may optimise some perioperative outcomes (30,32,33,51).

The %TWL was not reported by three RCTs (43,44,49) and the values were estimated via inference from reported data (Table 4). Overall, the five diets (44,46,48,49) that successfully achieved at least 5%TWL exhibited considerable heterogeneity in terms of energy intake and duration.

Regarding energy intake, the four VLCD trials (35,44,47,50) prescribed 647-800 kcal (2707-3347 kJ) which is in line with the accepted definition of a diet providing less than 800 kcal per day (3347 kJ) (8,52,53). The remaining four LCD trials (43,46,48,49) prescribed 1030-1600 kcal (4310-6694 kJ) as per its standard definition of a diet restricted to 1200-1600 kcal per day (5021-6694 kJ) (54). However, compliance with the prescribed intake of energy is debatable for the majority of the trials. Three did not report a method for assessing compliance with the prescribed diet (44,48,49) and four relied on self-reported methods (35,43,46,47) which are notoriously prone to under-reporting of "socially undesired" food and beverages by obese individuals (55,56). In order to overcome this, future trials should attempt to supplement the self-reported measures with weight loss biomarkers (57) or conduct the dietary intervention in a controlled environment with convert supervision. This may also provide insight into the acceptability and willingness of patients to adhere to energy-restricted diets.

In terms of diet duration, all the diets of a two weeks duration (35,43,50) and some diets of a longer duration of 12-24 weeks (48,49) failed to achieve 5%TWL. Interestingly, other diets with the same duration of 12-24 weeks (48,49) successfully

achieved 5%TWL. However, the weight loss achieved by the longer-term diets was comparable to the short duration diets of 4-11 weeks (44,46). This could be attributed to the well-recognised and expected slowing down of weight loss after an active weight reduction phase (8). Hence, it is realistic to assume that 5%TWL can be achieved in a shorter duration.

In fact, two diets (47) achieved 4.8%TWL in less than two weeks. These were the only diets that prescribed a very low carbohydrate, high protein and low/moderate fat diet that is defined as providing less than 20g of carbohydrate per day (58,59) and at least 20% of protein (60) and less than 35% of fat (61) (low fat) from total energy intake. The very low carbohydrate diet could have encouraged mild ketosis and suppressed hunger levels which aided the rapid weight loss observed (53,62). However, apart from the fact that a low carbohydrate diet is a topic of controversy (63), it is not ideal for a patient to be in a catabolic state during surgery as it may increase the risk of poor recovery postoperatively and even morbidity (18,33,64). Nevertheless, the catabolic extent of a short-term, low carbohydrate VLCD diet is unclear and requires further robust research as it may be an option to achieve a larger preoperative weight loss within a shorter span of time.

Six diets did not report the macronutrient composition (44,48,49) and the remaining interventions (n=8) (35,43,45–47) prescribed a moderate carbohydrate (>20g of carbohydrate per day but <50% of total energy intake from carbohydrates) (65) , high protein (>20% of energy from protein) (60), and low/moderate fat diet (<35% of energy from dietary fat) (61). By inference, these diet prescriptions resulted in longer duration of at least three weeks to achieve 5%TWL (Table 4). Therefore, this finding suggests that the macronutrient mix of the diet plays a role in determining the duration taken to achieve 5%TWL.

This review is unable to determine whether an energy restricted diet consisting of liquid foods is more superior in promoting weight loss as only one diet explored this and failed to achieve 5%TWL at two weeks (37). Nevertheless, despite not achieving the target weight loss, the trial demonstrated that the liquid VLCD group achieved significantly more reduction in visceral fat thickness (20.6%) compared to the VLCD group that incorporated both solid and liquid foods (0.28%). This is encouraging as it may minimise the risk of converting a laparoscopic procedure to an open bariatric surgery since the reduction in visceral adiposity allows more space for pneumoperitoneum, which is a practice required during laparoscopic surgery (23). Further research is merited to confirm, or otherwise, whether energy-restricted diets incorporating liquid food products induce greater visceral fat loss and improve subsequent surgery duration or complication rates.

Similarly, two trials observed that just 2 -3.5%TWL optimises blood glucose levels and lipid profile (49,50) that could consecutively minimise perioperative risks (27,28). Another trial demonstrated that less than 5%TWL results in liver shrinkage (43) that reduces the risk associated with the laparoscopic procedure (16–18). Hence, it may be worthwhile to encourage preoperative weight loss in obese individuals regardless of the degree of weight loss achieved.

Quality of evidence

RCTs are considered to be the highest evidence level according to the CRDG's hierarchy of evidence level (40). However, the majority of studies were assessed as weak methodological quality (Table 1). The abstracts used in this review represent grey literature and were included to minimise location bias (66) but inevitably they were limited in detail. Although the authors were contacted (43,44), no further information was available.

The results from this review are mainly applicable to Western adult females who are in the obesity class three category and motivated to lose weight. Caution should be used when translating these results to other populations such as Asians who have a different body composition (67). It is also uncertain how generalizable these findings are to adults older than 60 years old.

Precautions should be taken in individuals with disease status that may be affected by energy-restriction – for instance, porphyria, renal and/or liver failure, diabetes being treated with sulphonylureas (68). This is important information for bariatric guidelines to consider including, in future publications.

Quality of the systematic review

The limitations associated with this review are acknowledged. Firstly, the findings should be interpreted with caution as it is based on a relatively small number of "poor" to "fair" quality RCTs. The reviewer was not blinded to the literature sources and authors of the trials and there is also language bias as studies with negative outcomes tend to being published mostly in non-English journals (36). It was also beyond the scope of this research to thoroughly examine the safety and impact of preoperative weight loss on nutritional status prior to bariatric surgery.

Notwithstanding the above limitations, this is the first systematic review that exclusively examined RCTs that investigated the effects of energy-restricted diets on preoperative weight loss. Its validation was strengthened by using the PRISMA for protocol guidance, PICO formula to guide the review question, standardised extraction forms and supplementing the comprehensive electronic search with grey literature; so as to minimise location bias (69). Furthermore, all the trials identified were retrieved despite some of them being unavailable from the primary database.

Implications for future research

The uncertainty and bias in the existing evidence base calls for improvement in the execution and monitoring of dietary interventions as well as in the measurement and reporting of weight loss outcomes. Future studies in this area should:

- Express mean weight loss in kilograms and %TWL as a minimum.
- Specify the energy and macronutrient composition of prescribed and self-reported diet.
- Highlight any concurrent interventions.
- List any adverse effects associated with the diet.
- Specify the weight and height measuring instruments used and precautions taken to ensure measurement accuracy i.e. calibration.
- Consider objective method to monitor dietary intake (e.g. controlled environment).
- Conduct a rigorous RCT that is double-blinded with proper allocation concealment and an intention-to-treat analysis.
- Report percentage reduction in liver volume and indicate measurement method.

Conclusion

In conclusion, this systematic review has highlighted that intentional preoperative weight loss should be encouraged as it aids in ameliorating some risk factors that may potentially contribute to perioperative complications. Importantly, energy-restricted diets serve as a feasible and non-invasive method to achieve preoperative weight loss. The findings are also of clinical significance to medical teams overseeing surgical emergencies in obese individuals.

It is difficult to make any definitive evidence-based conclusions based on the limited number of trials as well as missing information. However, based on the current evidence, it is hypothesized that a diet consisting of 700 to 1050 kcal (2929-4393kJ) with moderate carbohydrate, high protein and low/moderate fat may induce 5%TWL over three weeks. Although a low carbohydrate (<20g/day) diet may achieve this target within a shorter duration of less than two weeks, its safety for bariatric candidates remains ambiguous. Further research through well-designed RCTs is needed to address these gaps in knowledge and to confirm the validity of the above conclusion.

Blinded conflict of interest disclosure statement

Author 1: No conflict of interest

Author 2: No conflict of interest

Author 3: No conflict of interest

Author 4: No conflict of interest

Author 5: No conflict of interest

Author 6: No conflict of interest

Statement regarding ethics

This article does not contain any studies with human participants or animals performed by any authors.

Consent statement

This article does not contain any studies with human participants or animals performed by any authors.

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Table 1 Characteristics of included randomised controlled trials.

Author, year, country	% Female	Age (Years)	Baseline BMI (kg/m^2)	Subjects enrolled (n)	Subjects analysed (n)	Attrition rates (%)	Study quality^	Inclusion/exclusion criteria specified
Chakravartty¶ 2014 UK (44)	95	**IG:**43.5 (NA)†† **CG:**38.5 (NA)††	**IG:**53.4 (NA)†† **CG:**52.75 (NA)††	**IG**:10 **CG**:10	**IG:**NA **CG:**NA	NA	Poor¶	NA¶
Heinberg 2014 USA (49)	71	**IG1**:47.79±47.79† **IG2**:46.95±10.86	**IG1**:49.45±10.63 **IG2**:49.75±8.61	**IG1**:33 **IG2**:40	**IG1:**28 **IG2:**38	**IG1:** 15% **IG2**: 5 % Total:9.6%	Poor	**IC:** ≥18y, BMI ≥40/ ≥35 kg/m^2 with medical comorbidities, fluent in English. **EC:** Nil
Schütz¶ 2014 Germany (43)	67	**IG1**:47.2 (NA)# **IG2:**46.3 (NA)#	**IG1**:47.5 (NA)# **IG2**:47.5 (NA)#	**IG1**:34 **IG2**:36	**IG1**:NA I**G2**:NA	NA	Poor¶	NA¶
Faria 2015 Brazil (50)	81.7	**IG1:** 37.14±10.29 **IG2:** 36.43±10.01	**IG1:**42.40±4.83 **IG2:**39.65±3.54	**IG1:** 71 **IG2:** 71	**IG1:**57 **IG2**:47	**IG1**: 19.7% **IG2:**33.8% Total:27%	Fair	**IC:** Patients preparing for Roux-en-y gastric bypass surgery. **EC:** Nil
Kalarchian 2016 USA (31)	90.2	**IG1**: 43.9±10.3 **IG2:** 45.9±11.6	**IG1**: 47.5±6.4 **IG2:** 47.4±6.2	**IG1:**121 **IG2**:119	**IG1:**103 **IG2:**81	**IG1:**14.9% § **IG2:**31.9% § Total:23% §	Fair	**IC:**≥18y. **EC:** Intellectual disability, genetic obesity syndrome; weight loss 6 months prior, uncontrolled psychiatric issues, pregnant/ lactating, medication affecting weight, previous bariatric surgery, condition requiring a special preoperative care, BMI≥70 kg/m^2 requiring LCD, conflicting research involvement.
Nielsen 2016 Denmark (46)	73	**IG1&2:** 38·8 ±10·4	**IG1&2:** 46·0±4·4	**IG1:**30 **IG2**:15	**IG1:**30 **IG2:**15	Total:6.7%	Fair	**IC:** 18–65y, BMI ≥ 40/ ≥ 35 kg/m^2 with obstructive sleep apnoea/hypertension. **EC:** Diabetes mellitus, thyroid dysfunction, hypothalamic/genetic aetiology of obesity, diverticulitis, arrhythmias, renal dysfunction, elevated liver enzymes, lactose intolerance, porphyria/ phenylketonuria, gout, lactating, use of monoamine oxidase inhibitors or non-potassium-sparing diuretics, inability to comply with LCD.
Schouten 2016 Netherlands (47)	78.8	**IG1**:40.2 (NA)# **IG2:**41.7 (NA)#	**IG1**:42.8 (NA)# **IG2:**43.1 (NA)#	**IG1**:105 **IG2**:107	**IG1:**105 **IG2:**107	NA	Fair	**IC:** BMI >40/>35 kg/m^2 with at least two obesity-related comorbidities. **EC:** Untreated psychiatric disorders, cardiopulmonary disease, previous bariatric and/or gastric surgery,<18 or >60 years.
Baldry 2017 UK (45)	81.5	**IG1**:47 (40)†† **IG2**:42(35)††	**IG1**:51.1(25.4)†† **IG2**:50.1(21.4)††	**IG1**:30 **IG2**:30	**IG1:**26 **IG2**:28	**IG1:** 13% **IG2:** 7% Total: 10%	Fair	**IC:** BMI >40 kg/m^2. **EC:** <18, 2^o NAFLD; diabetes treated by medication other than biguanides, excess alcohol intake, pregnancy, inability to comply with energy restriction.

BMI Body mass index, *CG* Control group, *EC* Exclusion criteria, *IC* Inclusion criteria, *IG* Intervention group, *LCD* Low calorie diet, *NA* Not available, Age and BMI presented as mean (SD) or †† median (range) or #unclear, **§** Preoperative phase, †As reported in paper, ^ Overall score based on Downs and Black's checklist, ¶ Conference abstracts with limited information.

Table 2 Summary of Very Low Calorie Diet (VLCD) interventions.

Author, year	Duration (weeks)	Prescribed & self-reported energy intake (kcal)	Diet details including diet texture (liquid/solid foods or mixed foods)	Macronutrient composition	Concurrent interventions	Compliance data	Reported side effects
Chakravarrty 2014 (43)	4	**IG:** 800† NA†† **CG:** NA† & ††	**IG:** VLCD, unknown consistency: no details. **CG:** Regular diet, mixed: no details.	**IG & CG:** NA	**IG & CG:** NA	NA	NA
Faria 2015 (50)	2	**IG1:** 734-786† 862-1054†† **IG2:** 731-777† 716-924††	**IG1:** VLCD, liquid: yogurt, soup, skim milk, coconut water 20g whey protein **IG2:** VLCD, mixed, regular diet, 10g whey protein. **Both**:1 vitamin and mineral supplement, detailed menus	**IG1&2:** 70g CHO, 76g Pro, 19g Fat †	**IG1&2:** Dietitian X3 visits	24-hr dietary recall & Ketonuria detection (urinalysis)	**IG1:** Week 0 vs. 7 & Week 0 vs. 14: No significant difference in degree of hunger. **IG2:** Week 0 vs. 7 & Week 0 vs. 14: Significant decrease in degree of hunger. Week 7 & 14: **IG1** had significantly higher degree of hunger than **1G2** (P<0.05) Intolerance (n=2) ?Group
Schouten 2016 (47)	10 days	**IG1:** 650† NA†† **IG2:** 647-657† NA††	**IG1:** VLCD, mixed, Promided protein sachets: 1 breakfast sachet, 1 lunch sachet with veg, fish/meat with veg, 1snack sachet. **IG2:** VLCD, mixed, dairy product, meat with veg, fish with veg & salad. **Both:** >1.5L of clear fluids ,3 multivitamin tablets	**IG1:**12g CHO, 101g Pro, 16g Fat† **IG2:** 20g CHO, 81-86g Pro, 21-25g Fat†	**IG1&2:**NA	Daily diet book.	Mean scores **IG1:** Nausea: 3/10, Tolerance: 7/10, Hunger: 6/10. **IG2:** Nausea: 3/10,Tolerance:8/10, Hunger:5/10
Baldry 2017 (45)	2	**IG1:** 800† 715 (558) †† **IG2:** 800† 715 (275) ††	**IG1:** VLCD, unknown consistency, standard prebariatric diet **IG2:** VLCD, unknown consistency: Lighterlife MR diet	**IG1**:93g CHO, 54g Pro, 15g Fat†† **IG2:** 68g CHO, 66g Pro, 20g Fat††	**IG1&2:**NA	Self-reported evaluation	Always feeling hungry **IG1:** 19%, **IG2:** 15%

CG Control group, *CHO* Carbohydrate, *IG* Intervention group, *MR* Meal replacement, *NA* Not available, *Pro* Protein, *VLCD* Very Low Calorie Diet

† Prescribed amount

†† Self-reported amount

Table 3 Summary of Low Calorie Diet (LCD) interventions.

Author, year	Duration (weeks)	Prescribed & self-reported energy intake (kcal)	Diet details including diet texture (liquid/solid foods or mixed foods)	Macronutrient composition	Concurrent interventions	Compliance data	Reported side effects
Heinberg 2014 (48)	12	**IG1:** 1300-1600† NA†† **IG2:** No caloric goal	**IG1:** LCD, mixed: portion-controlled low-glycemic Nutrisystem 3 meals, 1-2 snacks, fruits & vegetable, low-fat diary. **IG2:** No specific caloric goal, mixed: 1 protein liquid MR/day,3 meals/day, reduce fats and salt, 1.8L calorie-free fluids	**IG1&2:** NA	**IG1:** 24 hours support **IG1&2:** Exercise X5/week, dietitian X3 visits	NA	**IG1**:Intolerance but no details **IG2:** NA
Schutz 2014 (43)	2	**IG1:** NA† 753-1049†† **IG2:** NA† 752-992††	**IG1:** LCD, unknown consistency: "high protein, low carbohydrate" product. IG2: LCD, unknown consistency, "high carbohydrate" product **Both:**200g vegetables daily	**IG1:**80g CHO, 75g Pro, 28g Fat† **IG2:** 111gCHO, 58g Pro, 19g Fat†	**IG1&2:** NA	Nutrition diary	NA
Kalarchian 2016 (31)	24	**IG1:** 1200-1400† NA†† **IG2:** NA † NA††	**IG1:** LCD, mixed, "behavioural intervention", balanced diet consistent with bariatric nutritional guidelines. **IG2:** "Usual care", mixed, physician-supervised diet program	**IG1 & IG2:**NA	**IG1:** Exercise program & behaviour change technique expert **IG2:** Physician supervised activity program	NA	NA
Nielsen 2016 (46)	7 vs. 11 weeks	**IG1&2:** 1030† NA†† (7 weeks vs. 11 weeks)	**IG1&IG2:** LCD, mixed, 4 Cambridge liquid meals,1L skim milk, 295g vegetables, 100g low-fat yoghurt (7 weeks vs. 11 weeks)	**IG1&2:**122g CHO, 100g Pro, 14g Fat†	**IG1&IG2:** Weekly dietitian visits	Five-point scale self-evaluation.	Headache (57%), fatigue (50%), constipation (43%), dizziness (33%) and upper respiratory infections (30%) Others: cold intolerance, hunger, abdominal pain, irritability, dry skin, diarrhoea, flatulence, bad breath

CG Control group, *CHO* Carbohydrate, *IG* Intervention group, *LCD* Low Calorie Diet, *MR* Meal replacement, *NA* Not available, *Pro* Protein, † Prescribed amount, †† Self-reported amount

Table 4 Weight loss outcomes.

Author, year	Total weight loss (kg)	Total weight loss (%)	Excess weight loss (%) ^	Change in BMI (kg/m^2)	Instrument to measure height	Instrument to measure weight	Precautions taken when measuring
Chakravartty 2014 (43)	**IG:**-6.5±2.0 **CG:** -0.3±1.6 P<0.001	**IG:** >5¥ **CG:** <2¥	**IG&CG:**NA	NA	NA	NA	NA
Heinberg 2014 (48)	**IG1&2:** NA	**IG1:**2.3¥ **IG2:** 5¥	**IG1&2:** NA	**IG1**:-1.08# **IG2:** -2.48# P=0.003 β, P=0.28∞	NA	NA	NA
Schütz, 2014 (43)	**IG1&2:** NA	**IG1:** 3.4-4.25¥ **IG2:** 3.16-3.95¥	**IG1:** -8.5% ± 3.3 **IG2:** -7.9% ± 3.6 P=NA	NA	NA	NA	NA
Faria 2015 (50)	**7 days:** **IG1:** -2.6±0.2 **IG2:** -2.2±0.2 P=0.5180∞ **2 weeks:** **IG1:** -3.8±0.2 Ω **IG2:** -3.0±0.2 Ω P=0.140∞	**7 days:** NA **2 weeks:** **IG1:**-3.5 (NA) **IG2:**-2.6 (NA) P=NA	**7 days:** NA **2 weeks:** **IG1:** -7.0±0.3 **IG2:** -6.5±0.3 P=0.3123∞	NA	Digital stadiometer	Digital scale/ multifrequency bioimpedance analysis (Inbody® 720, Biospace)	NA
Kalarchian 2016 (31)	**IG1:** 8.3 ± 7.8§ **IG2:** 3.3 ± 5.5§ P<0.0001∞	**IG1:** 6.3% ± 5.8§ **IG2:** 2.5% ± 4.0§ P<0.0001∞	**IG1 & IG2:**NA	NA	Mounted stadiometer	ScaleTronix 5002	Street clothes without shoes
Nielsen 2016 (46)	**IG1:** 12·7 (SEM 0·8) P<0.01 from week 0 to 7 **IG2:** NA	**IG1:** 9·3 (SEM 0·5) **IG2:** 13.2 (SEM 0·5) P=<0.01 for both from baseline to 7 or 14 days	**IG1&2:** NA	**IG1:**-4.2 (SEM0.8) **IG2**: NA P<0.01β	Wall-mounted digital stadiometer	NA	Lightweight clothing, no shoes, emptied bladder and fasted
Schouten 2016 (47)	**IG1:** -5.9 (NA) # **IG2:** -6.0 (NA) # P=0.78∞	**IG1:** 4.8¶ **IG2:** 4.8¶	**IG1&2:** NA	**IG1:**-2.6 (NA) # **IG2:**-2.0 (NA) # P=0.43∞	NA	"Standard scale"	NA
Baldry 2017 (45)	**IG1&2:**NA	**IG1:** -3.6(3.0)¥ **IG2:** -3.4(3.7)¥ P = 0.993∞	**IG1&2:**NA	NA	NA	NA	NA

BMI Body Mass Index, *CG* Control group, *IG* Intervention group, *NA* Not available. Outcome presented as mean (SD), ¥median (range) or #unclear, ^ Ideal body weight calculated as equivalent to a BMI of 25 kg/m^2, **§** Preoperative phase, Ω Weight data taken from table due to discrepancies , ∞ Statistical significance between diets, β Statistical significance from pre- to post-intervention, ¶Estimated from data provided in paper. ¥ Estimated via inference from available data.

Table 5 Secondary outcomes following preoperative weight loss.

Author, year.	Change in liver volume %	Other liver changes	Surgery duration	Operating difficulty	Perioperative complications	Changes in biochemical risk factors	Changes in clinical risk factors
Chakravartty 2014 (43)	**IG:**23% **CG:**2% P<0.03∞ (Ultrasound)	Fibrosis. Not reported. (ARFI)	IG:129min ¥ CG:139min ¥ P=0.16∞	NA	"No median difference between groups"	NA	NA
Heinberg 2014 (48)	NA	NA	NA	NA	NA	**IG1&2:** TG -10, +7, Chol -3.2,-0.94, LDL -4.8,-0.72, Glu -7.63,+26.1, All not significant∞	NA
Schütz, 2014 (43)	**IG1:** –471 ± 358 ml **IG2:** –340 ± 258 ml P>0.05∞ (MRI)	NA	NA	NA	NA	NA	NA
Faria 2015 (50)	"No difference" P=0.788∞ (Ultrasound)	Steatosis at 2 weeks: **IG1:** -0.4# **IG2:** No change# P=0.1142∞ (Ultrasound)	"No difference" P=0.4455∞.Inverse relationship between surgery time and visceral fat for **IG1** P=0.0014.	NA	"No difference between groups"	**IG1&2:** Glu, CRP, Chol, HDL, VLDL, TG, basal insulin, HOMA decreased at 14 days. "No statistical difference between groups & time".	"No difference" for BP. P=1.000∞
Kalarchian 2016 (31)	NA	NA	NA	NA	**IG1:** 1 patient reoperated ?Reason	NA	NA
Nielsen 2016 (46)	NA	NA	NA	NA	NA	Week 0-7(%): Fasting Glu -8·2 (SEM 1·8), insulin -28·6 (SEM 6·4), C-peptide-15·4 (SEM 4·5, P < 0·0 β1 β. TG -9·7 (SEM 4·7), Chol -21·7 (SEM 2·0), LDL-23·1 (SEM 2·2), P < 0·05 β. Week 7-11:No further decrease.	Week 0-7: Heart rate -4·9 (SEM 1·3) beats/min, systolic -7·1 (SEM 2·3), diastolic BP -7·3 (SEM 1·8) mmHg, all P < 0·01 β.Week 7-11: No further decrease
Schouten 2016 (47)	NA	NA	**IG1:** 44 mins **IG2:** 43 mins P=0.65 ∞	VAS score **IG1:** 31 **IG2:** 36 P=0.25∞	**IG1:** 5.7% (n=6) **IG2:** 4.8% (n=5) P=0.76∞	NA	NA
Baldry 2017 (45)	NA	**IG1&2:** "No sig difference in steatosis, liver injury, portal and lobular inflammation &fibrosis" (Biopsy)	NA	Increasing perceived difficulty associated with higher steatosis % (Biopsy)	NA	**IG1&2:** CRP and fetuin-A reduced significantly	NA

ARFI Acoustic Radiation Force Impulse, *BP* Blood pressure, *Chol* Total cholesterol, *CG* Control group, *CRP* C-reactive protein, *GB* Gastric banding, *Glu* Glucose, *HDL* High density lipoprotein, HOMA Homeostatic model assessment, *IG* Intervention group, *Lap* Laparoscopic, *LDL* Low-density lipoprotein, *NA* Not available, *TG* Triglyceride, *VAS* Visual analogue score, Outcome presented as mean (SD), ¥median (range) or #unclear, ∞ Statistical significance between diets, β Statistical significance from pre- to post-intervention