

Obesity Treatment/Outcomes

Does severe dietary energy restriction increase binge eating in overweight or obese individuals? A systematic review

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Summary

Severe dietary energy restriction is often used for overweight or obese individuals to achieve rapid weight loss and related health improvements. However, the extent of putative adverse effects on eating behaviour is unknown. We thus systematically searched seven databases for studies that assessed binge eating before and after severe dietary energy restriction (low or very low energy diets) in overweight or obese individuals. Fifteen clinically supervised interventions from 10 publications (nine of which involved only women) were included. Among individuals with clinically relevant pre-treatment binge eating disorder, severe dietary energy restriction significantly decreased binge eating in all four interventions involving this population, at least during the weight loss programme. In contrast, no consistent association between severe dietary energy restriction and the onset of bingeing was found in 11 interventions involving individuals without pre-treatment binge eating disorder, with four such interventions showing significant increases, two showing no change, and five showing significant decreases in binge eating. We conclude that clinically supervised severe dietary energy restriction appears safe and beneficial for overweight or obese individuals with pre-treatment binge eating disorder, and does not necessarily trigger binge eating in those without binge eating disorder.

Key words: Binge eating, eating disorders, obesity, reducing diet.

Abbreviations: BMI, body mass index; CBT, cognitive behavioural therapy; LED, low energy diet; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-analyses; VLED, very low energy diet.

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Introduction

Obesity continues to be an epidemic problem around the world (1,2). In order to treat this condition, health professionals are increasingly prescribing more radical treatments for their patients. One of these treatments involves the prescription of severe dietary energy restriction in the form of low energy diets (LEDs, 3.3–5 MJ d⁻¹) or very low

energy diets (VLEDs, <3.3 MJ d⁻¹), typically achieved using meal replacement formulae with essential micronutrients (3,4).

The use of severe dietary energy restriction has advantages over weight-reducing diets involving less severe energy restriction. These include reduced appetite during adherence to the diet (5), rapid and motivating weight loss leading to reductions in cardiovascular risk, as well as

improvements in fertility and respiratory disorders (6,7). Fast weight loss via VLED predicts significant long-term (3 years) weight loss maintenance (8). In addition, meal replacement formulae are widely available to consumers, and their simplicity of use aids adherence (9–11). However, potential long-term side effects of this dietary intervention are not completely understood (12), notably with respect to disordered eating behaviours such as binge eating.

There are several reasons why clinicians may be concerned about the effect of severe dietary energy restriction on eating behaviour. Dieting often precedes binge eating (13–16). Moreover, the cognitive behavioural formulation of eating disorders suggests that strict dieting associated with changes in mood, combined with over-evaluation of the importance of shape and weight, leads to binge eating (17). Because severe dietary energy restriction is a form of strict dieting, this raises concerns that it may induce eating disorders or exacerbate existing eating disorders. In light of these concerns, some current producers of commercially available meal replacement formulae that are used as LEDs or VLEDs contraindicate their use for individuals with eating disorders (18).

Very little is known about the effect of severe dietary energy restriction on eating behaviour. A review published in 2000 concluded that moderate dietary energy restriction did not cause clinically significant binge eating in overweight individuals, and actually reduced binge eating in those who exhibited binge eating prior to the dietary intervention (19). However, that study was not a systematic review. It focused on diets in general and included only three studies that directly assessed the effects of severe dietary energy restriction on binge eating (20–22). Those three studies showed diverse changes in binge eating (increases and decreases) in response to severe dietary energy restriction. A narrative review published in 2001 covered diverse nutritional, medical and psychological effects of severe dietary energy restriction (23). However, that review included only two empirical papers that assessed the effect of VLED on binge eating, indicating improvements in eating behaviour (20,24). Therefore, considering the lack of a more detailed examination of the effects of severe dietary energy restriction on binge eating, we undertook a systematic review of studies that assessed binge eating before and after weight loss treatment with severe dietary energy restriction in overweight and obese individuals.

Methods

This review was conducted according to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) guidelines (25).

Selection criteria

Included studies were published empirical trials – randomized or non-randomized – that evaluated a regime involving severe dietary energy restriction (<5.0 MJ d⁻¹ for at least 1 week with no interruption) in order to achieve weight loss in overweight or obese participants. To be included in this review, studies had to assess binge eating before and after the dietary intervention. For this systematic review, both LED and VLED interventions were considered as forms of severe dietary energy restriction because they typically restrict energy intake to ~30–50% or less of the energy requirements of overweight or obese individuals. There were no restrictions placed on the date of publication or the age of participants included in the studies. Included publications could involve participants with and without eating disorders.

Studies with the following characteristics were excluded: unpublished studies, literature reviews, studies on intermittent diets, studies that analysed binge eating only as a predictor of treatment outcomes, studies that used a sample from a published study that was included in this review, and studies not written in English.

Search strategy

We searched seven electronic databases, namely PubMed, PsycInfo, Cinahl, Web of Science, PreMedline, Scopus and Cochrane Data Base of Reviews, from inception of each database until May 2014. The search strategy combined two groups of keywords (Interventions and Outcomes) as follows:

Interventions

- Calori* restriction OR low calorie diet OR low energy diet OR very low calorie diet OR very low energy diet OR weight loss OR weight control.

Outcomes

- Binge eating disorder OR eating disorder* OR disordered eating OR purg* OR bulimi* OR binge eating OR bulimia nervosa.

These terms were mapped to subject headings specific to each database, and the subject headings were also used to expand the search. As seen from the Outcomes listed above, search terms related to bulimia nervosa (e.g. purg*, bulimi* and bulimia nervosa) were used, even though assessment of compensatory behaviours was not the primary outcome of interest for this review, because purging behaviour is frequently associated with binge eating.

Screening

Titles and abstracts of the studies identified in the above search were independently screened by two authors (FQL and AAG). The full texts of potentially eligible studies were obtained and were independently screened by the same authors according to the inclusion and exclusion criteria. Discrepancies over which studies to include in the review were resolved by consensus with a third author (AS). Reference lists of the included papers were also screened for potential additional relevant papers. A detailed overview of each stage of the literature search and screening is shown in Fig. 1.

Data extraction and synthesis

One author (FQL) extracted the following data from each study: design, intervention(s) (e.g. type of diet, the use of exercise or additional therapies for weight loss, and a description of control group(s)), baseline sample information (sample size, body mass index [BMI] and pre-treatment symptoms of eating disorders), instrument(s)

used to assess binge eating, and main changes in eating behaviour (Table 1). Information about the dietary interventions was reviewed by an author who is a dietitian (AAG). The focus of the data extraction was on the change in eating behaviour in individuals in response to severe dietary energy restriction. Data on the eating behaviour of individuals who underwent moderate dietary energy restriction or no dieting (control groups) were also assessed in order to compare their outcomes with that of individuals who underwent severe dietary energy restriction.

In order to maximize insights into the possible effect of severe dietary energy restriction on binge eating, studies were classified according to the eating behaviour of research participants prior to the dietary intervention, i.e. those without binge eating, those with subclinical binge eating and those who met clinical criteria for binge eating disorder. Some studies included mixed samples of individuals with and without subclinical binge eating. These classifications are shown in Table 2. Note that some of the 10 publications included in this systematic review imposed dietary interventions on more than one subgroup of

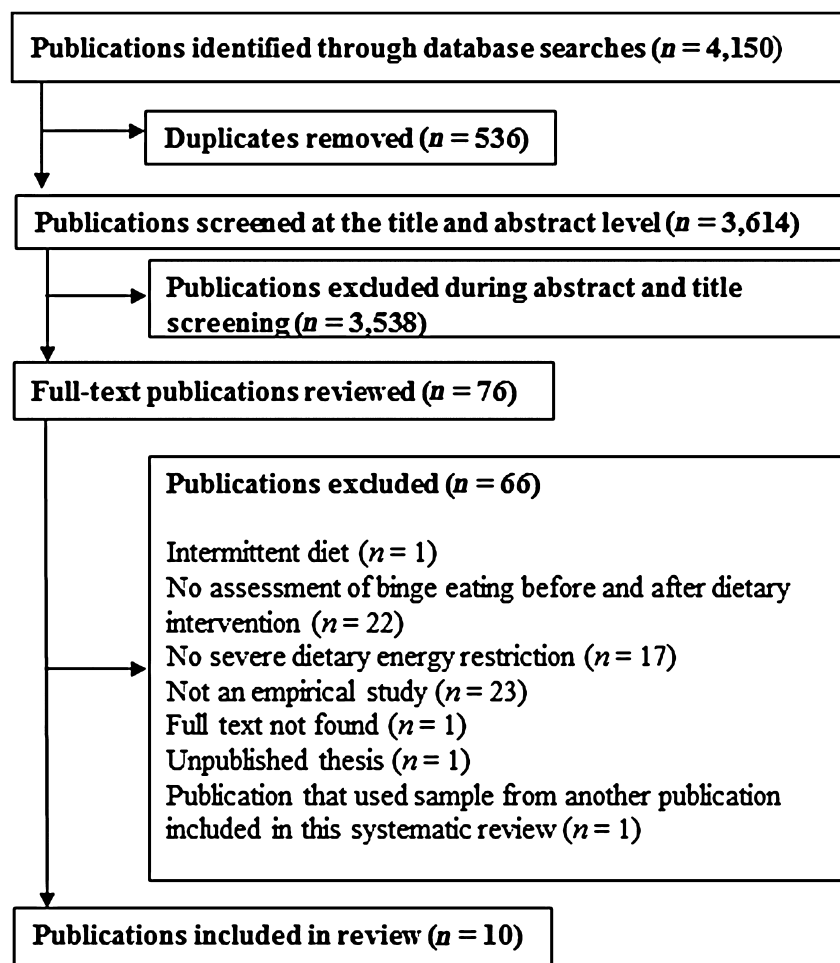


Figure 1 Flow chart of publication selection for the systematic review.

Table 1 Interventions, baseline characteristics of participants, time points of binge eating assessments and main changes in binge eating in the 10 publications included in this systematic review

Publication	Intervention(s)	Baseline		Time points of binge eating assessments relative to the start of the intervention (weeks)	Main changes in binge eating
		Sample size	BMI (kg m ⁻²) (mean ± SD or SEM, or range)		
Anunziato, 2009 (29)	8 weeks of LED (4.6 MJ d ⁻¹) + CBT, followed by random assignment to 14 weeks of weight maintenance: A. Normal food + CBT + meal replacement (split between low and high adherers to meal replacement use for analysis) B. Normal food + CBT (control)	A. 32 B. 28	31.8 ± 2.5 (SD) (overall)* *BMI for each group was not provided	0, 22, 35, 74	<ul style="list-style-type: none"> - Reduction in binge eating occurred during the LED - Relapses of binge eating episodes occurred when measured at week 74, but only for low adherers to the consumption of meal replacements during the maintenance period - A tendency to resume binge eating behaviour was seen in those eating normal food during the weight maintenance phase - Eating Habits Checklist
De Zwaan, 2005 (32)	A. 12 weeks of VLED (3.3 MJ d ⁻¹) followed by 6 weeks of re-feeding, followed by 6 weeks of LED (5.0 MJ d ⁻¹) B. As above, but with CBT starting 2 weeks into re-feeding phase	A. 35 B. 36	A. 35.7 ± 4.2 (SD) B. 36.6 ± 3.2 (SD)	0, 12, 18, 24, 28, 50, 76	<ul style="list-style-type: none"> - At week 76, 56.3% of participants no longer met criteria for binge eating disorder. No significant difference between groups was found in regard to binge eating disorder remission at this time point (54.5% for CBT group and 58.1% for no CBT group). - 33% of participants were completely abstinent from binge eating between assessments at weeks 50 and 76 - Structured Clinical Interview for DSM-III - Binge Eating Scale - Eating Disorder Inventory - Eating Behaviour-IV
Fogelholm, 1999 (30)	1 week of LED, 8 weeks of VLED (60% energy restriction from weight maintenance requirements), 3 weeks of LED, followed by randomization to 28 weeks of: A. Weight maintenance without increase in habitual exercise B. Weight maintenance + exercise (expenditure of 4.2 MJ w ⁻¹) C. Weight maintenance + exercise (expenditure of 8.4 MJ w ⁻¹)	85 (overall)* *Sample size for each group was not stated	34.0 (29–46)* *BMI for each group and SD or SEM were not provided	0, 12, 20, 40	<ul style="list-style-type: none"> - Binge eating decreased in all groups relative to baseline during the weight reduction phase (from week 0 to 12) and maintenance phase (from week 20 to 40); - Bulimic Inventory Test of Edinburgh
Pekkarinen, 1996 (24)	8 weeks of VLED (1.8 MJ d ⁻¹), 1 week of partial meal replacement, 1 week of LED (5.0 MJ d ⁻¹) without meal replacement and 6 weeks of moderate dietary energy restriction (2.1–4.2 MJ d ⁻¹ deficit from weight maintenance requirements)	62	36.4 (31.5–42.0)	0, 17, 52, 104–117	<ul style="list-style-type: none"> - Binge eating symptoms decreased relative to baseline at week 17 for all participants. This reduction was maintained at weeks 52 and 104 for those participants who lost more than 10% of their baseline weight. - Binge eating symptoms returned to pre-treatment level between weeks 104 and 117 for those participants who lost 10% or less body weight or who gained weight compared to baseline measurement - Bulimic Inventory Test of Edinburgh - Binge Eating Scale

Table 1 Continued

Publication	Intervention(s)	Baseline		Time points of binge eating assessments relative to the start of the intervention (weeks)	Main changes in binge eating
		Sample size	BMI (kg m^{-2}) (mean \pm SD or SEM, or range)		
Raymond, 2002 (31)	12 weeks of VLED (3.3 MJ d^{-1}), followed by 6 weeks of re-feeding then 6 weeks of weight stabilization (+psychoeducational/behavioural weight management during the entire 24 weeks). Half of the participants with binge eating disorder received CBT and the other half did not. Because there were no differences in outcomes with or without CBT, all participants were grouped in the same analysis.	154	Participants were at least 22.6 kg above average body weight for their height (based on metropolitan height and weight tables)* *Mean BMI was not provided	0, 24, 28, 50, 76	<ul style="list-style-type: none"> - 57% of participants with binge eating disorder at baseline did not meet criteria for this disorder at week 76 - 25% of participants classified as having subclinical binge eating and 10% of those classified as having no binge eating met full criteria for binge eating disorder at 76 weeks - Structured Clinical Interview for DSM-IV
Telch, 1993 (21)	12 weeks of VLED followed by 39 weeks of gradual re-feeding + behaviour therapy (more specific information was not provided)	115	30-45* *Mean BMI was not provided	0, 4, 13, 26, 39, 52, 65	<ul style="list-style-type: none"> - Post VLED, 30% of subjects identified as non-binge eaters at baseline reported binge eating episodes - At week 52 (end of behaviour therapy after VLED), 62% of non-binge eaters at baseline reported binge eating episodes - At week 65, 15% of the non-binge eaters at baseline met full criteria for binge eating disorder - Binge eating decreased between weeks 52 and 65 for individuals who were classified as non-binge eaters at baseline - Participants with binge eating disorder at baseline reduced binge eating episodes during the VLED but resumed binge eating episodes when eating normal food after the VLED - At week 65, 39% of individuals who were classified as having binge eating disorder at baseline no longer met full criteria for this category
Wadden, 1994 (20)	A. 16 weeks of VLED (1.8 MJ d^{-1}), followed by 36 weeks of LED ($4.2\text{-}5.0 \text{ MJ d}^{-1}$) + behaviour therapy + exercise B. 52 weeks of moderate energy restriction (5.0 MJ d^{-1}) + behaviour therapy + exercise	A. 28 B. 21	A. 40.0 ± 5.7 (SD) B. 38.8 ± 5.4 (SD)	0, 26, 52, 78	<ul style="list-style-type: none"> - Stanford Eating Behaviour Questionnaire - Mean scores on the Binge Eating Scale were of moderate severity at baseline and decreased significantly at weeks 26 and 52 in both groups - Participants under moderate energy restriction exhibited significantly greater reductions in Binge Eating Scale scores than participants on the VLED at week 52, but not at week 26, when both groups showed similar results - Binge Eating Scale - Questionnaire of Eating and Weight Patterns

Table 1 Continued

Publication	Intervention(s)	Baseline		Time points of binge eating assessments relative to the start of the intervention (weeks)	Main changes in binge eating
		Sample size	BMI (kg m ⁻²) (mean ± SD or SEM, or range)		
Wadden, 2004 (28)	A. 39 weeks of moderate energy restriction (5.0–6.3 MJ d ⁻¹) + exercise + CBT	A. 43	A. 36.3 ± 4.9 (SD)	0, 9, 20, 28, 40, 65	Instrument(s) used to measure binge eating – At week 28 (during moderate energy restriction after LED), four participants in the LED group reported having had one binge eating episode and one participant reported having had two binge eating episodes, while those in the other groups reported having had no binge eating episodes – At no time during treatment and follow-up did any participant meet criteria for binge eating disorder – There were no differences between groups in the number of subjective binge eating episodes – At weeks 40 and 65, there were no differences in binge eating between groups – Eating Disorders Examination – Binge eating reduced for all groups at weeks 13 and 24. Improvements were maintained up to week 52. – Small increase in purgative behaviour at week 39 in the LED group, but this had returned to baseline levels at week 52 – Multidimensional Assessment of Eating Disorders Symptoms
	B. 12 weeks of LED (4.2 MJ d ⁻¹), followed by 23 weeks of moderate energy restriction	B. 41	B. 36.0 ± 4.2 (SD)		
	C. No dieting + exercise	C. 39	C. 35.5 ± 4.3 (SD)		
Williamson, 2008 (27)	A. LED (3.7 MJ d ⁻¹) until 15% of body weight was lost (average of 8 weeks), followed by weight maintenance period + CBT	A. 12	A. 27.8 ± 0.5	0, 13, 24, 39, 52	Mixed sample: individuals without binge eating + individuals with subclinical binge eating No information in the paper as to whether data are expressed with SD or SEM
	B. Moderate (25%) dietary energy restriction + CBT	B. 12	B. 27.9 ± 0.4		
	C. Moderate (12.5%) dietary energy restriction + exercise + CBT.	C. 12	C. 27.6 ± 0.5		
	D. Weight maintenance + CBT (control group).	D. 12	D. 27.9 ± 0.6		
Yanovski, 1994 (33)	26 weeks comprising 12 weeks of VLED (3.3 MJ d ⁻¹), followed by 12 weeks of re-feeding + behaviour therapy + exercise, and weight stabilization	38	40.1 ± 1.8 (SEM)	0, 37	Distinct groups: individuals without binge eating, individuals with subclinical binge eating, and individuals with binge eating disorder – At week 37, participants diagnosed with binge eating disorder at baseline showed a significant decrease in Binge Eating Scale scores – The amount of food consumed during binges was reduced, as the percentage of small binges (<2.1 MJ) increased while the percentage of larger binges (>2.1 MJ) decreased – Frequency and severity of binge eating were reduced in participants who met criteria for binge eating disorder at baseline – At week 37, there was no change in the eating behaviour of participants who were classified as having few or no problems with binge eating at baseline – Binge Eating Scale – Questionnaire of Eating and Weight Patterns

BMI, body mass index; CBT, cognitive behavioural therapy; DSM, Diagnostic and Statistical Manual of Mental Disorders; LED, low energy diet; MJ, megajoule; SD, standard deviation; SEM, standard error of the mean; VLED, very low energy diet.

Study samples categorized by pre-treatment eating behaviour	Study	Changes in frequency or intensity of binge eating
Individuals without binge eating	Wadden, 2004* (28)	↑
	Raymond, 2002 (31)	↑
	Telch, 1993 (21)	↑
	Yanovski, 1994 (33)	↔
Mixed samples: individuals without binge eating & individuals with subclinical binge eating [†]	Williamson, 2008* (27)	↓
	Wadden, 1994* (20)	↓
	Annunziato, 2009 (29)	↓
	Fogelholm, 1999 (30)	↓
	Pekkarinen, 1996 (24)	↓
Individuals with subclinical binge eating [†]	Yanovski, 1994 (33)	↔
	Raymond, 2002 (31)	↑
Individuals with binge eating disorder	De Zwaan, 2005 (32)	↓
	Raymond, 2002 (31)	↓
	Yanovski, 1994 (33)	↓
	Telch, 1993 (21)	↓

Table 2 Changes in binge eating in response to severe dietary energy restriction in participants with different pre-treatment binge eating behaviours

*Direct comparison between severe dietary energy restriction with other weight management intervention (control group).

[†]Frequency of binge eating episodes does not meet the clinical criteria for binge eating disorder, as determined by the authors of the publication at the time of the study.

↑, increase; ↓, decrease; ↔, no change. Note that some of the 10 included publications employed interventions with more than one subgroup; therefore, some publications are listed more than once.

participants. It is for this reason that some publications are listed more than once in Table 2.

Quality assessment

Quality of the publications included in this review was assessed by consensus between two authors (FQL and PH) using criteria adapted from a previous publication (26). Publications were assessed on the clarity of information provided about the hypothesis or aim, outcomes, participant characteristics, main findings, attrition rates, method of randomization, allocation concealment, validity and reliability of outcome measures, blinding of participants and assessors, sample power calculation and selective outcome bias (i.e. whether or not researchers appeared to selectively report their findings). Attrition $\leq 30\%$ was considered acceptable. Bias was defined as the practice of reporting completers only for interventions where attrition was $>30\%$. Each publication included in this review was classified under each of these criteria as 'yes', 'no', 'unclear' or 'not applicable' (e.g. measures that were applicable only to randomized controlled trials), as shown in Table 3.

Results

Study selection

Ten publications met the inclusion criteria of this systematic review, as shown in Fig. 1. It was not possible to

perform a meta-analysis of these publications because the designs of the studies were highly diverse. Thus, the publications were reviewed qualitatively.

Characteristics of the studies

The studies used different terminologies to describe dietary energy restriction. The terms used were caloric restriction, low calorie diet, very low calorie diet, meal replacement diet or balanced deficit diet. In order to standardize terminology based on the International System of Units (SI units), the term 'energy' was adopted instead of 'calorie', and all data that were provided in calories were converted to MJ (1 calorie = 0.00418 MJ). Energy intake prescriptions for the severely energy-restricted diets (LED and VLED) ranged from 1.8 to 5.0 MJ d⁻¹, as shown in Table 1.

The diversity of aims and methodological approaches of the studies are briefly described below and detailed in Table 1. There were three studies that directly compared severe dietary energy restriction with other weight loss interventions (20,27,28). In addition, two studies prescribed severe dietary energy restriction to all participants for weight loss, and then randomized participants to different weight maintenance strategies (29,30). Furthermore, two studies investigated the effects of severe dietary energy restriction and cognitive behavioural therapy (CBT) (31,32). The other three studies prescribed severe dietary energy restriction for all participants (21,24,33).

Table 3 Quality appraisal of the 10 publications included in this systematic review based on the following parameters as previously published (26)

Publication	Hypothesis or aim and outcomes clearly described	Participant characteristics and main findings clearly described	Attrition rates (dropouts) reported and acceptable	Method of randomization	Allocation concealment	Outcome measures valid and reliable	Blind participants and assessors	Sample power calculation	Absence of selective outcome bias
Annunziato, 2009 (29)	Yes	Yes	Yes (30%)	Unclear	Unclear	Yes	No	Unclear	No
De Zwaan, 2005 (32)	Yes	Yes	Yes	Unclear	Unclear	Yes	Unclear	Unclear	Yes
Fogelholm, 1999 (30)	Yes	Yes	Yes	Unclear	Unclear	Yes	Unclear	Unclear	Yes
Pekkarinen, 1996 (24)	Yes	Yes	Yes	Not applicable	Not applicable	Yes	Unclear	Unclear	Yes
Raymond, 2002 (31)	Yes	Yes	Yes	Not applicable	Not applicable	Yes	Unclear	Unclear	Yes
Teich, 1993 (21)	Yes	Yes	Unclear	Unclear	Unclear	Yes	Yes	Unclear	Unclear
Wadden, 1994 (20)	Yes	Yes	Yes	Unclear	Unclear	Yes	Unclear	Unclear	Yes
Wadden, 2004 (28)	Yes	Yes	Yes	Unclear	Unclear	Yes	Yes	Unclear	Yes
Williamson, 2008 (27)	Yes	Yes	Yes	Unclear	Unclear	Yes	Unclear	Unclear	Yes
Yanovski, 1994 (33)	Yes	Yes	Yes	Not applicable	Not applicable	Yes	Yes	Unclear	Yes

Participants

Sample sizes in the included studies ranged from 38 to 154 (Table 1). One publication included a sample of men and women (27), and the other nine publications investigated only female participants. Participants' ages ranged from 18 to 62 years. In all studies, participants were overweight or obese ($BMI \geq 25 \text{ kg m}^{-2}$), but showed different patterns of eating behaviour before the treatment (i.e. participants without binge eating, with subclinical binge eating, with binge eating disorder, or mixed samples) (Table 1).

Binge eating assessment

The instruments used to assess binge eating are shown in Table 1. Any reported and statistically significant changes in binge eating were considered relevant.

Quality assessment outcomes

Despite some issues related to clarity of presentation, the 10 included publications met most quality requirements (Table 3). These publications often presented unclear information about methods of randomization, allocation concealment, blinding of participants and assessors, and sample power calculation. On the other hand, they generally presented clear information about hypotheses or aims, participant characteristics and main findings, attrition rates, the validity and reliability of the outcome measures, and selective outcome bias.

Studies with samples of individuals without pre-treatment binge eating

Of the four interventions that included samples of individuals without pre-treatment binge eating, three showed increases in binge eating to varying degrees (21,28,31), and one (33) found no change in binge eating in response to severe dietary energy restriction (Table 2). These studies are described below.

A study in people without pre-treatment binge eating (28) showed a small effect of severe dietary energy restriction on the percentage of people who engaged in binge eating at the end of the study. In that study, 5 individuals from a total of 41 (12%) who used an LED followed by moderate dietary energy restriction exhibited significantly more binge eating episodes at the end of the intervention than individuals who were submitted only to moderate dietary energy restriction or no dietary energy restriction (28). From these five individuals, four had one episode of binge eating and one individual had two episodes of binge eating, while in the other groups, none of the participants had any binge eating episodes. These binge eating episodes

occurred while the participants were following a diet involving moderate energy restriction after they had used the LED. However, in two follow-up assessments made at 40 and 65 weeks after the start of the dietary intervention, these binge eating episodes had spontaneously remitted and there were no longer any apparent differences in binge eating between groups. This study was of particularly high quality (see Tables 1 and 3) because it was the only study that directly compared severe dietary energy restriction with other dietary regimes in individuals without pre-treatment symptoms of eating disorders. In summary, this high-quality study showed a small and transient increase in binge eating in a small number of participants in response to severe dietary energy restriction.

In contrast to the above study, two other studies (21,31) showed more harmful effects of severe dietary energy restriction on the eating behaviour of participants who did not exhibit pre-treatment binge eating. In one study, 3 of 29 (~10%) of the participants who did not present any symptoms of eating disorders before the use of a 12-week VLED met the clinical criteria for binge eating disorder when assessed at 52 weeks (31). In the other intervention involving participants who did not exhibit pre-treatment binge eating (21), 30% of participants who followed 13 weeks of severe dietary energy restriction reported the occurrence of binge eating episodes when measured immediately after a VLED. This percentage rose to 63% of participants when measured at 52 weeks after the start of the intervention, albeit symptoms were not strong enough to reach the criteria for binge eating disorder. In that study, 15% of participants without pre-treatment binge eating met full criteria for binge eating disorder when measured at 65 weeks after the start of the intervention (21).

In summary, of the four studies that examined individuals without pre-treatment binge eating, three interventions indicated the onset of binge eating ranging from 1–2 isolated binges to ~10–15% of individuals developing binge eating disorder in response to severe dietary energy restriction, and one study showed no effect (Table 2).

Studies with mixed samples: individuals without pre-treatment binge eating plus individuals with pre-treatment subclinical binge eating

While the above-mentioned studies mostly suggest that severe dietary energy restriction was associated with the onset of binge eating in people without binge eating at baseline, other studies indicated the opposite. In all of the five studies involving 'mixed samples' (i.e. studies in which individuals without binge eating and individuals with subclinical binge eating at baseline were analysed together), beneficial effects of severe dietary energy restriction to

reduce binge eating were ubiquitously found (Table 2). Brief descriptions of the most relevant findings in this regard are presented below.

Of these studies with 'mixed samples', two high-quality studies are particularly noteworthy as they involve direct comparison of severe dietary energy restriction with other weight loss interventions (20,27). In one such study (27), LED as well as three dietary interventions of 24 weeks in duration that did not involve severe dietary energy restriction were employed in order to test the hypothesis that dietary weight loss interventions increase symptoms of binge eating disorder. However, average scores for binge eating were decreased in all dietary intervention arms, including the LED, without significant differences between groups when measured at 13 and 24 weeks. Moreover, these decreases in binge eating were maintained in all dietary intervention groups when assessed at 52 weeks after the start of the interventions. A small increase in subclinical purgative behaviour was found specifically in participants in the LED group when measured at 39 weeks after the start of the intervention, but this had returned to baseline levels when measured at 52 weeks. Another high-quality study (20) compared individuals submitted to 52 weeks of severe or moderate dietary energy restriction, with participants in both groups exhibiting reductions in average scores for binge eating when measured at the end of the interventions, albeit the reduction was significantly less pronounced in those on the severely energy-restricted diet. In conclusion, both of these high-quality studies revealed significant reductions in average binge eating scores after severe dietary energy restriction in groups of individuals with no or subclinical binge eating.

Among the five studies that examined mixed samples, severe dietary energy restriction was always associated with reductions in binge eating (Table 2). There were two studies (29,30) that compared different weight maintenance interventions instead of different weight loss interventions. In one such study (29), all participants were treated with LED for 8 weeks and were then randomized to one of two different weight maintenance interventions; one involving normal food supplemented with meal replacement formulae, and the other involving normal food. In that study, significant reductions in average group scores for binge eating were measured during the severe dietary energy restriction, but the results at 74 weeks after the start of treatment varied depending on whether participants were classified as low or high adherers to the consumption of meal replacements during the weight maintenance phase. Those who were low adherers, using meal replacements on 9–55% of days during the weight maintenance phase, exhibited a return to baseline levels of binge eating at 74 weeks. Similar results were observed in those eating normal food during the weight maintenance phase; these participants exhibited a tendency to resume binge eating.

However, those participants who were high adherers to the consumption of meal replacements, consuming them on 74–80% of days during weight maintenance, exhibited a sustained reduction in binge eating when measured at 74 weeks. In another study (30), participants were submitted to 12 weeks of severe dietary energy restriction before being randomized to one of three different weight maintenance interventions of 28-week durations. In that study, average scores for binge eating were significantly reduced in all groups when measured during weight loss and weight maintenance, without any significant differences between groups. Taken together, these studies support the hypothesis that severe dietary energy restriction is associated with neutral or beneficial effects on binge eating behaviour in mixed samples of people without binge eating or with subclinical binge eating at baseline, mainly during the period when participants are on the severely energy-restricted diet.

In addition to benefits observed during the diet, there is also some evidence that severe dietary energy restriction can lead to long-term improvements in binge eating, at least in those who lose clinically significant amounts of weight on the diet. In the fifth study from this category (see Table 2) (24), all participants were submitted to 10 weeks of severe dietary energy restriction without any comparison intervention. In that study, significant reductions in average binge eating scores relative to baseline were measured at 17 weeks after the start of treatment, and these reduced average binge eating scores were maintained when measured at 52 and between 104 and 117 weeks after the start of the treatment, but only in those participants who lost greater than 10% of their initial weight. In contrast, participants who lost 10% or less of their initial weight or who gained weight during the prescribed severe dietary energy restriction also exhibited significant reductions in binge eating at week 17, but binge eating had returned to baseline levels when assessed between weeks 104 and 117.

These ubiquitous findings of reductions in average binge eating scores seen in all of the five studies in this category of mixed samples, especially the high-quality randomized controlled clinical trials that directly compared LED or VLED with other interventions (20,27), indicate that severe dietary energy restriction had beneficial effects for those with subclinical binge eating. While these five studies investigated the eating behaviour of mixed samples of participants without pre-treatment binge eating and participants with pre-treatment subclinical binge eating, the findings also imply that severe dietary energy restriction was not associated with the development of binge eating for those without pre-treatment binge eating. This finding contrasts with the outcomes from the studies mentioned in the previous section (studies with samples of only individuals without pre-treatment binge eating).

Studies with samples of individuals with pre-treatment subclinical binge eating

Broadly consistent with the above conclusions from studies with mixed samples, a study involving only individuals with subclinical binge eating prior to intervention (33) showed no effect of 26 weeks on a VLED programme (including a 12-week re-feeding phase) on binge eating when measured at 13 weeks after completion of the whole programme. In that study, other eating disorder symptoms such as purging, frequent fasting and compensatory exercise were also assessed; however, no onset of any of these symptoms was found. In contrast, another study with a pure sample of individuals with subclinical binge eating at baseline (31) showed that severe dietary energy restriction was associated with worsening of binge eating. In that study, participants were submitted to 12 weeks on a VLED, followed by a 6-week re-feeding phase and a 6-week weight stabilization phase. The authors found that 25% of participants met full clinical criteria for binge eating disorder at the 76-week time point (52 weeks after completion of the weight stabilization phase) (31). Although this outcome is consistent with the finding that severe dietary energy restriction appears to increase binge eating in those without pre-treatment binge eating (Table 2, top 4 rows), it contrasts with the six other studies showing beneficial or neutral effects of severe dietary energy restriction on binge eating in mixed or pure samples of individuals with subclinical binge eating at baseline (Table 2, middle 6 rows). In addition, the lack of a control group in that study (31) compromises its capacity to determine any causality between severe dietary energy restriction and worsening of binge eating.

Studies with samples of individuals with pre-treatment binge eating disorder

There were four studies that examined the effects of severe dietary energy restriction on the eating behaviour of individuals who met the clinical criteria for binge eating disorder at the baseline assessment (Table 2). In all of these studies, significant reductions in average binge eating scores were observed during and after the dietary intervention. In one such study (32), all participants were subjected to severe dietary energy restriction and were then randomized to receive either additional CBT for binge eating disorder or no additional treatment. In that study, significant reductions (by 56%) in average group binge eating scores were observed, and abstinence from binge eating occurred in 33% of participants, regardless of whether or not they received CBT. In another study (31), 63 individuals with binge eating disorder were submitted to severe dietary energy restriction for 12 weeks, followed by a 6-week food reintroduction phase then a 6-week weight stabilization

phase. At the 76-week time point (52 weeks after completion of the entire programme), 36 of the 63 participants (57%) no longer met the clinical criteria for binge eating disorder. Thus, both of these studies indicated associations between severe dietary energy restriction and reductions in binge eating in individuals who meet criteria for binge eating disorder prior to treatment.

Findings from another study (21) provide important insights regarding improvements and relapses in binge eating. In that study, participants with binge eating disorder exhibited significant group average reductions in binge eating when measured after 4 and 13 weeks on a 13-week VLED, but group average binge eating scores were similar to baseline levels at all subsequent time points (i.e. at 26, 39, 52 and 65 weeks after the start of the intervention), at which times normal foods had been reintroduced into the diet. Therefore, it is possible that for some individuals with binge eating disorder, reductions in binge eating can be temporary, occurring only while under severe dietary energy restriction. On the other hand, in that study, 39% of participants who were classified as having binge eating disorder at baseline no longer met the criteria for this categorization when measured at 65 weeks after the start of the treatment.

Besides reductions in the overall level of binge eating, severe dietary energy restriction in participants with binge eating disorder appears to reduce the amount eaten at each binge eating episode (33).

Taken together, the four interventions mentioned above showed an association between severe dietary energy restriction and significant reductions in binge eating for individuals with pre-treatment binge eating disorder. These benefits have been measured both during as well as up to 65 weeks after commencement of the severe dietary energy restriction, but there is some evidence that relapses in binge eating occurred for some individuals when food was reintroduced.

Discussion

The aim of this systematic review was to determine the effects of severe dietary energy restriction on binge eating in overweight or obese individuals seeking weight loss. Inconsistent associations between severe dietary energy restriction and the onset of binge eating were found in individuals without pre-treatment binge eating. Of nine studies involving this population, three showed increases in binge eating (21,28,31), one found no effect (33), and five involving mixed samples including individuals without previous binge eating showed reductions in binge eating (20,24,27,29,30). Therefore, it is not possible to assert that the use of LEDs or VLEDs triggers binge eating among all overweight or obese patients who do not exhibit pre-treatment binge eating. In contrast, for participants who exhibited subclinical binge eating or binge eating disorder

prior to the dietary intervention, the majority of interventions involving this population (9 of 11) showed that the use of LED or VLED reduced binge eating, at least during the severe dietary energy restriction (20,21,24,27,29–33), with the other two studies showing no change (33) or an increase (31). It is noteworthy, however, that those improvements in eating behaviour may be temporary, as relapses in binge eating were reported in three studies (21,24,29). Thus, while severe dietary energy restriction seems safe and beneficial for those with pre-treatment subclinical binge eating or binge eating disorder, it may induce binge eating in some (but not all) individuals without any pre-treatment binge eating.

The findings from this review support the safety and benefits of severe dietary energy restriction, achieved via clinically supervised LED or VLED, in overweight or obese people with subclinical binge eating or binge eating disorder, at least in the time frame investigated in the studies included in this systematic review (maximum of 104–117 weeks after commencement of the intervention). These findings extend previous research showing that people with binge eating can achieve similar weight loss via severe dietary energy restriction in comparison to people without binge eating (34,35). Other studies have also found that the presence of eating disorders does not influence short- or long-term weight loss achieved via VLED meal replacement programmes (36). Thus, clinically supervised LEDs and VLEDs can be used as an effective weight loss treatment for overweight or obese individuals with subclinical binge eating or binge eating disorder, and may have the additional benefit of reducing binge eating.

There are several reasons why severe dietary energy restriction via LED or VLED programmes may have reduced binge eating in those with pre-treatment binge eating. One possibility is that individuals submitted to this treatment have been shown to exhibit mood improvements in association with weight loss (28), and this may enable participants to stop using food as a mood regulator, as is known to occur during binge eating episodes (17). A second possible explanation is that appetite is known to be significantly suppressed during VLED (5), and this may reduce the drive to eat. A third potential explanation is that the highly structured and clinically supervised programmes through which the diets were administered may have contributed to improved eating behaviour.

Our finding that severe dietary energy restriction does not exacerbate – and may even reduce – pre-existing binge eating is opposite to the hypothesis that dieting causes binge eating. However, it is important to be specific about what is meant by the term ‘dieting’. In this review, the specific type of dieting under investigation was severe dietary energy restriction achieved via LED or VLED meal replacement programmes, conducted in overweight or obese individuals under medical supervision, within the

context of a clinical trial. This is very different from the unsupervised, self-imposed dietary restriction or starvation typically seen in patients with eating disorders that is frequently a trigger for binge eating episodes (17). It is also different from the semi-starvation state that was induced in normal weight individuals and shown to lead to psychological and social effects closely related to eating disorders, as in the landmark study by Keys and colleagues (37). Thus, it is important to be clear about the form of the dietary restriction that is being used when investigating potential effects of 'dieting' on the symptoms of eating disorders (14).

While this review showed that clinically supervised severe dietary energy restriction had overall neutral or beneficial effects on binge eating behaviour in those with pre-existing binge eating, the safety of such dietary interventions for individuals who did not have pre-existing symptoms of eating disorders is less clear. In the four studies involving only participants who had no pre-treatment binge eating symptoms, three (21,28,31) showed that severe dietary energy restriction was associated with increases in binge eating, while one (22) showed no effect. The most critical period for the onset of binge eating episodes appeared to be after the severe dietary energy restriction, when individuals had transferred to a diet involving moderate or no energy restriction and had been reintroduced to conventional food. In contrast, in all of the five studies involving mixed samples of participants with and without symptoms of subclinical binge eating at baseline, severe dietary energy restriction was associated with decreases in binge eating. As those studies involved mixed samples, however, it is not possible to know what effect severe dietary energy restriction was having specifically on those individuals who did not have any binge eating behaviour at baseline. Thus, the evidence shows that strict dieting is not always a trigger for binge eating, as some clinicians have interpreted from the cognitive behavioural formulation of eating disorders (17).

This systematic review has several strengths and limitations. It was conducted according to the PRISMA guidelines (25). As such, it included a systematic search of seven databases with no limit on the earliest publication date, clearly defined inclusion and exclusion criteria, at least two authors were involved in screening against the inclusion and exclusion criteria and data extraction (FQL, AAG, AS), as well as in critical quality appraisal of publications (FQL, PH), and presented a flow chart of the process of publication selection. The review was limited, however, in that it did not seek 'grey' or unpublished literature. Additionally, the included studies had diverse experimental designs, wherein 7 of the 10 included publications did not directly compare the effect of severe dietary energy restriction with that of other dietary interventions or no intervention (control groups). In addition, different instruments were

used to assess eating behaviour, and the longest follow-up assessment was 104–117 weeks after the start of the treatment in only one study (24), with all other studies using a follow-up period of 78 weeks or less (20,21,27–33). Finally, all but one (24) of the studies in this systematic review investigated only female participants, so the findings may not apply to men. Despite these limitations, this systematic review has revealed the influence of severe dietary energy restriction on binge eating among overweight or obese participants according to their pre-treatment eating behaviour. Indeed, this review revealed reductions in binge eating for those with pre-treatment subclinical binge eating or binge eating disorder, and revealed increases in binge eating in some but not all individuals without binge eating prior to treatment.

Our current findings enable us to make recommendations for future research. Firstly, this field would benefit from randomized controlled trials with extended follow-up assessments directly comparing the effect of severe dietary energy restriction with moderate or no dietary energy restriction. Secondly, such trials would benefit from regular assessments of binge eating during and after the dietary interventions in order to identify critical periods when binges are more likely to occur. Thirdly, studies in this field need to characterize the eating behaviour of participants prior to intervention (i.e. those with no binge eating, subclinical binge eating or binge eating disorder), and present the results separately for each subcategory of participants, because the effects of energy restriction on eating behaviour are likely to depend upon whether or not an individual engages in binge eating at baseline. Fourthly, future studies involving male participants are needed because binge eating disorder affects significant numbers of men (38), and because VLED programmes may be particularly beneficial for men (39). Finally, this field would benefit from a standardized assessment of eating disorders to provide more comparable data. To this end, we recommend the Eating Disorders Examination (17), or the self-reported version of this instrument, the Eating Disorders Examination Questionnaire (40); in addition to information about the frequency of binges, these instruments assess cognitive aspects related to eating disorders (e.g. eating, shape and weight concerns). We are addressing some of these limitations in a current clinical trial (41).

Obesity is a major health concern that requires treatment to prevent or attenuate associated health issues and diseases. Severe dietary energy restriction via supervised meal replacement programmes is the single most effective non-pharmaceutical, non-surgical obesity treatment (42), but many clinicians are hesitant to prescribe such programmes for fear of inducing or exacerbating eating disorders. This review shows that clinically supervised severe dietary energy restriction can be used for the treatment of obesity without exacerbating existing binge eating (subclinical or

clinical). Such diets can also be used in obese people who do not have pre-existing binge eating, but clinicians should note that some susceptible individuals may develop binge eating behaviour, particularly upon completion of the diet. Thus, eating behaviour should be monitored during and after the diet, and referral to psychological services for additional therapy may be necessary in some cases.

Conflict of interest statement

AS has received payment from Eli Lilly, the Pharmacy Guild of Australia, Novo Nordisk and the Dietitians Association of Australia for seminar presentation at conferences. She is also the author of *The Don't Go Hungry Diet* (Bantam, Australia and New Zealand, 2007) and *Don't Go Hungry For Life* (Bantam, Australia and New Zealand, 2011). SWT receives royalties from Hogrefe and Huber and McGraw-Hill Publishers, and has also been the recipient of an honorarium from Shire Pharmaceuticals. PH receives royalties from Hogrefe and Huber and McGraw-Hill Publishers.

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