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REVIEW

Healthy strategies for successful weight loss and weight maintenance: a systematic review

Stephanie Ramage, Anna Farmer, Karena Apps Eccles, and Linda McCargar

Abstract: The rates of overweight and obesity are rising in Canada and worldwide, and there is a need for effective methods for weight loss and weight maintenance to empower individuals to make changes. The purpose of this systematic review was to examine the evidence available for successful diet strategies for weight loss and weight maintenance among adults. A search was conducted of the following databases: CAB Abstracts, Central Register of Controlled Trials, EMBASE, MEDLINE, Food Science and Technology Abstracts, and Web of Knowledge. The studies investigated had participants who were overweight or obese and between 18 and 65 years of age. A successful study was defined as one that reported an intervention that created ≥5% weight loss from baseline and a maintenance phase during which the ≥5% weight loss was maintained from baseline to 12 months. After exclusions, the search resulted in 67 papers. Overall, for significant safe weight loss, an energy deficit was required, which was commonly achieved by reduced fat intake. Increased dietary fibre was also a component of 21% of successful interventions. Physical activity was included in 88% of successful interventions, and behaviour training such as self-monitoring was part of 92% of successful interventions. The same combination of energy and fat restriction, regular physical activity, and behavioural strategies was also required for successful weight maintenance. This review confirmed previous knowledge about weight loss and weight maintenance in adults. A comprehensive approach, including reduced dietary intake, regular physical activity, and behavioural strategies, is warranted and is supported by the research evidence.

Key words: weight loss, weight maintenance, adults, diets.

Résumé : La proportion de personnes obèses ou présentant un surpoids augmente au Canada et dans le monde entier. Il est important d'identifier des méthodes efficaces de perte de poids et de maintien du poids pour permettre à ces personnes d'effectuer des changements. Le but de cette analyse documentaire systématique est d'examiner les études probantes présentant à l'intention des adultes des régimes efficaces de perte et du maintien du poids. On effectue une recherche dans les bases de données bibliographiques suivantes : « CAB Abstracts », « Central Register of Controlled Trials », « EMBASE », « MEDLINE », « Food Science and Technology Abstracts » et « Web of Knowledge ». Les participants sont des adultes obèses ou présentant un surpoids et âgés de 18 à 65 ans. On définit une étude efficace comme étant celle présentant une intervention suscitant ≥5 % de perte de poids depuis le début du régime et un maintien de ≥5 % du poids perdu durant 12 mois depuis le début du régime. La recherche identifie 67 articles pertinents. Somme toute, pour enregistrer une perte de poids sûre, il faut créer un déficit énergétique et on y parvient généralement par la diminution de l'apport en gras. L'augmentation de l'apport en fibres alimentaires est un facteur dans 21 % des interventions couronnées de succès. Dans 88 % des interventions, on inclut l'activité physique; la sensibilisation comportementale telle que l'autocontrôle est incluse dans 92 % des interventions réussies. La combinaison des mêmes ingrédients (restriction énergétique et en gras, pratique régulière d'activité physique et stratégies comportementales) est également essentielle au maintien du poids. Cette analyse documentaire confirme ce qu'on savait antérieurement au sujet de la perte de poids et de son maintien chez les adultes. Une approche globale comprenant la diminution de l'apport alimentaire, la pratique régulière de l'activité physique et des stratégies comportementales est justifiée et confirmée par des études probantes. [Traduit par la Rédaction]

Mots-clés : perte de poids, maintien du poids, adultes, diètes.

Introduction

It is well known that rates of overweight and obesity have increased worldwide, and this trend is also observed among Canadians (Tjepkema 2006). In 2011, among Canadians 18 years and older, the prevalence of overweight and obesity combined was 60.1% of men and 44.2% of women (Statistics Canada 2011), whereas the prevalence of obesity alone was 19.8% of men and 16.8% of women (Statistics Canada 2011). These rates are of great concern because of the significant association of overweight and obesity with morbidity (Lau et al. 2007; Mitchell et al. 2011), mortality (Lau et al. 2007), and health care costs (Anis et al. 2010; Lau et al. 2007).

To improve health outcomes and decrease social costs, it is imperative that a multipronged approach be taken to reduce the

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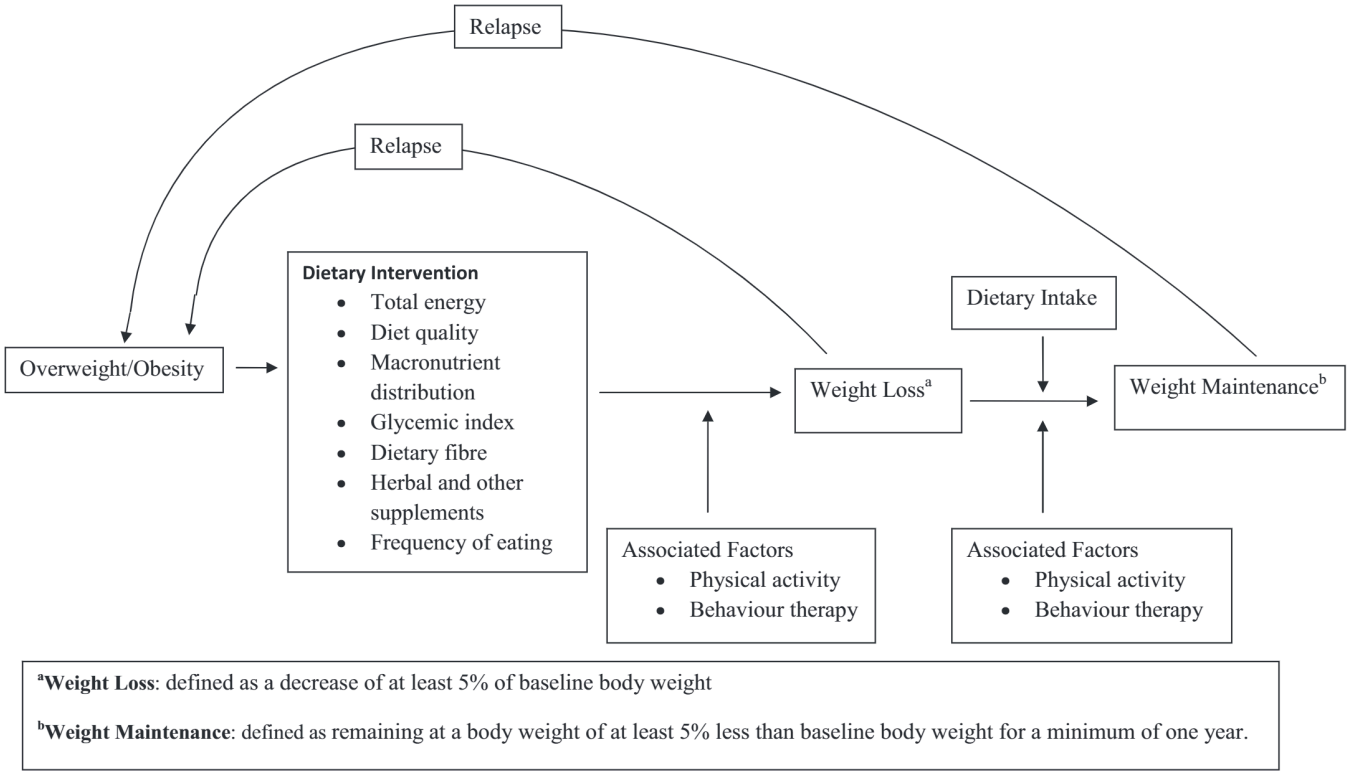
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Fig. 1. Conceptual framework.



prevalence of overweight and obesity, including intervention at the societal, community, family, and individual levels. Although environmental changes at societal and community levels likely have a strong impact, individuals still carry responsibility in terms of their overall health, including maintaining a healthy body weight. Many aspects of the environmental, societal, and community levels are potential areas of intervention, including economic factors (such as taxation and subsidies), food production, food marketing, and the built environment (including schools, worksites, and neighbourhoods) (Mitchell et al. 2011). However, it would likely take decades to determine if interventions in these areas lead to changes in the rates of overweight and obesity (Mitchell et al. 2011). Working at the individual level, education on effective methods for weight loss and weight maintenance can serve to empower individuals to start making changes while action on other levels begins. Actions on both the environmental and the individual level are necessary (Mitchell et al. 2011).

Many studies have been able to induce weight loss among participants; however, maintenance of weight loss has been shown to be much more difficult (Barte et al. 2011; Mitchell et al. 2011). One recent systematic review found that weight-loss interventions, on average, were able to induce a 9.5% weight loss from baseline weight; however, 1 year after the interventions, only 54% of this weight loss was maintained (Barte et al. 2011). As a result, evidence-based recommendations for strategies that can be implemented by individuals for weight loss and maintenance of weight loss are required. Using the concept of energy balance, strategies may focus on energy intake (i.e., diet) or energy expenditure (i.e., physical activity (PA)), or on behaviours that support changes in either energy intake or energy expenditure (i.e., self-monitoring of dietary intake or PA). A conceptual framework was created (Fig. 1) in which factors including dietary intake, PA, and behaviours were examined for their influence on weight loss and weight maintenance. Weight loss and weight maintenance were treated as separate events within the conceptual framework because it was assumed that behaviours related to energy balance may influence weight loss differently from weight maintenance. The framework also illustrates the concept of relapse, which is common in this population and may be related to the identified factors within the framework.

Therefore, the purpose of this paper was to examine the available scientific evidence for successful diet strategies for weight loss and for maintaining weight loss long term among adults at the individual level. This was done by taking a public health perspective, considering only safe and healthy strategies that individuals could do on their own without medical monitoring. As such, very low-calorie diets and pharmacological or surgical strategies that require medical support services were not reviewed.

Research questions

1. What diet strategies are most effective for weight loss and consistent with satisfactory nutritional quality?
2. Are there supporting behaviours (such as physical activity and (or) self-monitoring) that result in safe and successful weight loss?
3. What diet strategies are most effective for weight maintenance and consistent with satisfactory nutritional quality?
4. Are there supporting behaviours (such as physical activity and (or) self-monitoring) that result in safe and successful weight-loss maintenance?

Methods

Study inclusion criteria

This review identified original human research that was quantitative in nature. To be included, studies had to meet the following criteria:

Population of interest

Participants were overweight or obese adults (minimum baseline body mass index (BMI) ≥ 25 kg·m^{-2}) between 18 and 65 years of

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age. Participants were both male and female and represented a range of ethnicities and levels of socioeconomic status. A chronic condition (i.e., type 2 diabetes or hypertension) may or may not have been diagnosed, but studies examining acute clinical illness (i.e., cancer) were not included.

Intervention

A diet intervention to induce weight loss for at least 3 months was required for a study to be included. The minimum follow-up from baseline for maintenance of weight loss was set at 12 months. A minimum energy intake of 1200 kcal for women and 1500 kcal for men was required because it is likely that caloric intakes below that level would not provide sufficient vitamin and mineral intake. Caloric recommendations of 1200–1500 kcal per day are typically recommended for studies with weight-loss interventions (Lau et al. 2007). It is possible that with medical supervision and potential micronutrient supplementation, caloric intake lower than these levels could safely induce weight loss, but this report focused on making recommendations that individuals could implement on their own. Thus, very low-calorie diets were beyond the scope of this review. In addition, interventions that included weight-loss medications or weight-loss surgery were not included because these interventions also require medical intervention and thus were beyond the scope of this review.

Study design

A range of study designs was accepted in this review, including randomized controlled trials (RCTs), intervention studies (with no control), and observational and retrospective studies. RCTs were considered optimal in terms of study design; however, because of the lack of long-term success historically with this study design, some researchers have opted to retrospectively study individuals who have been able to successfully lose and maintain weight loss long term. This type of study provides important evidence and as a result was included in this review. Studies must also have been published within the past 25 years, because this period represents increasing obesity rates and most appropriately represents the cultural and environmental factors currently facing Canadians. A minimum sample size of 25 participants per group was required. Urban or rural environments were acceptable. The study could be based in either a community or an outpatient clinic setting. Studies that were published only in abstract form were not included because they did not provide sufficient evidence regarding the research questions.

Primary outcome

Weight change was the primary outcome, and this variable was required for a study to be included in the review. Successful weight loss was defined as a decrease of at least 5% of baseline body weight. Successful weight maintenance was defined as remaining at a body weight at least 5% lower than baseline body weight for at least 1 year. This level of weight loss (5%) was chosen because it is thought to be significant beyond usual body fluctuations and to have a clinically beneficial impact on comorbidities, including improvements in glycemic control, blood pressure, and lipid levels, as well as in obesity-related complications, including gastroesophageal reflux disease and osteoarthritis (Lau et al. 2007). In addition, maintenance of this relatively modest level of weight loss may help decrease the risk of negative outcomes, including myocardial infarction, stroke, and cardiovascular-related death (Lau et al. 2007). Health care professionals currently recommend 5%–10% weight loss from diet and PA as a realistic and sustainable level (Lau et al. 2007; Mitchell et al. 2011).

Secondary outcomes

Secondary outcomes, such as biochemical outcomes (changes in blood cholesterol levels, triglycerides (TG), insulin, and glucose), physical outcomes (changes in blood pressure and waist circumference (WC)), and demographic variables (sex and country of origin), were also examined.

Search strategy

The CAB Abstracts, Central Register of Controlled Trials, EMBASE, MEDLINE, Food Science and Technology Abstracts, and Web of Knowledge databases were searched with the assistance of a research librarian (LD). The search strategy for the MEDLINE database is included in Appendix A; the search strategies for the other databases were identical except for formatting differences depending on the database. The searches were completed between January and February 2012.

Study selection

Following the search, all references were uploaded into the RefWorks program, which was used to manage citations. Duplicates were then removed from the reference list. Abstracts of the remaining citations were screened by research assistants to determine eligibility for inclusion in the review. Approximately 250 abstracts that were inconclusive were screened in duplicate, and discrepancies were resolved through group discussion.

Once the acceptable abstracts were determined, the full papers were retrieved and reviewed. Each paper was read independently by 2 reviewers. Papers were excluded if information was found (not present in the abstract) that did not fit the inclusion criteria. Any discrepancy between reviewers was resolved through group discussion or discussion among the primary authors. Reasons for exclusion are listed in Fig. 2.

Data collection process

For those studies that met all the inclusion criteria, a quality score was assessed using the Effective Public Health Practice Project (EPHPP) quality assessment tool. A copy of the tool, as well as the manual describing how the tool is to be used, can be found at http://www.ephpp.ca/PDF/Quality%20Assessment%20Tool_2010_2.pdf. This tool has been found to have fair inter-rater agreement for individual domains and excellent agreement for the final grade (Armijo-Olivo et al. 2012). It rates studies on 6 domains (selection bias, study design, confounders, blinding, data collection methods, and withdrawals and (or) dropouts) and provides each domain with a rating of strong, moderate, or weak. In addition, it provides an overall rating of strong, moderate, or weak based on the number of weak ratings received in the individual domains. A study rated overall as “strong” will not have received any weak ratings in any domain, a study rated as “moderate” will have 1 domain with a weak rating, and a study rated as “weak” will have 2 or more domains with weak ratings. Each study was assessed for quality by 2 reviewers, and any discrepancy in the final grade was resolved through group discussion or discussion among the primary authors.

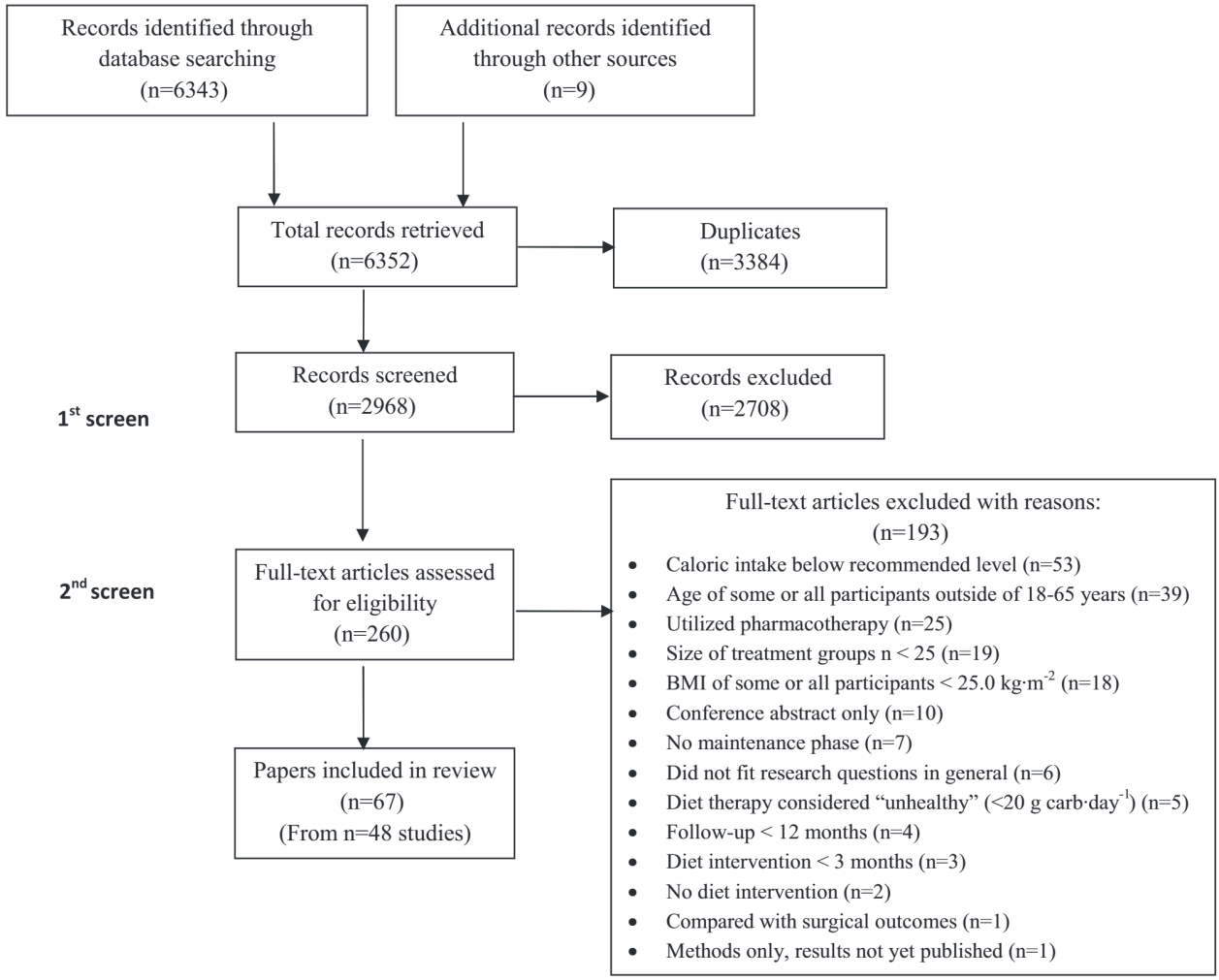
Data were abstracted in duplicate and put into a spreadsheet with predetermined columns (Microsoft Excel). Information on outcome variables were abstracted for 2 time points: the weight-loss phase (WL) and the weight-maintenance phase (WM). The columns included citation, purpose of the study, weight change (%) (WL, WM), total length of study, length of WL, length of WM, biochemical changes (WL, WM), physical changes (WL, WM), diet intervention, PA intervention, behavioural intervention, study design, BMI, % male and female, country of origin, treatment groups, number in each treatment group, method of weight assessment, statistical analysis, trial name, and quality rating. Data are presented in a condensed version in Tables 1, 2, and 3. Data were assumed to be correct as presented, and no study authors were contacted for clarification.

It is common for weight-loss and weight-maintenance research to take the form of large, long-term trials with multiple papers published related to the same study. These papers were identified and listed together so that the same 2 reviewers would review and

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Fig. 2. Study identification flow chart. BMI, body mass index; carb, carbohydrates.



abstract all information for that study (multiple papers). While reviewing some papers, additional references were cited regarding the same study with information that was relevant to the review, but had not been retrieved through the initial search. In these cases (n = 9), the paper was retrieved, read, and abstracted by the reviewer charged with reading the initial paper. This led to a more comprehensive assessment of the large weight-loss and weight-maintenance trials currently available in the literature.

Analysis of information

The aim of this review was to identify studies that not only met all the inclusion criteria but were successful in creating a minimum 5% weight loss from baseline and in which participants were able to maintain that minimum 5% weight loss from baseline for at least 12 months. Once the successful studies were identified, the dietary, PA, and behavioural strategies used in these approaches were summarized, as well as other improvements in secondary outcomes.

Results

Number of papers reviewed and retained

In total, 6352 records were retrieved (Fig. 2). Duplicate references (3384) were identified and removed. Of the remaining 2968 papers, 2708 were excluded during the first screen. As a result, 260 full-text articles were retrieved and read independently by 2 reviewers. After this second screen, 193 papers were excluded. Some papers had multiple reasons for exclusion; the primary reason for exclusion is listed in Fig. 2. This resulted in a final number of 67 papers representing 48 studies.

Description of research papers

All the papers retained for the review are listed in Table 1. Different papers that represent the same study are listed together. Herein, the results will be referred to as "studies" rather than papers or articles, because, for example, 3 papers may have described the same study, providing results on different outcome variables. Thus, overall, 48 studies were retained based on our inclusion–exclusion criteria: 37 studies described weight loss and weight maintenance and 11 studies described weight maintenance only.

Country of origin

Of the retained studies (n = 48), most were from the United States (n = 32), with small numbers from other countries: Finland (n = 3), Japan (n = 3), Australia (n = 2), Germany (n = 2), Denmark (n = 1), Israel (n = 1), New Zealand (n = 1), Portugal (n = 1), Thailand (n = 1), and Sweden (n = 1).

Study design and dates

Of the 48 studies, the majority were RCTs (n = 30). Some studies were single-group intervention trials (n = 7), and some studies were longitudinal surveys that reported on the National Weight

Table 1. Study characteristics included in review.

References*	Country of origin	Baseline *n*	Sex† (%)		Length of intervention	Time from baseline to final assessment	Intervention
			Male	Female			
Weight loss and weight maintenance							
Jeffery et al. 2009 Yatsuya et al. 2011	USA	212	47	53	6 months	30 months	RCT: (*a*) maintenance-tailored treatment; (*b*) standard behaviour treatment
Morgan et al. 2009 Morgan et al. 2011	Australia	65	100	—	3 months	12 months	RCT: (*a*) internet-based weight-control program group; (*b*) control group
Absetz et al. 2007 Absetz et al. 2009	Finland	352	25	75	1 year	3 years	Intervention — Diabetes Prevention Trial
Riebe et al. 2003 Riebe et al. 2005 Blissmer et al. 2006	USA	144‡	22	78	6 months	24 months	RCT: (*a*) extended-care intervention; (*b*) extended-care control
Acharya et al. 2009 Burke et al. 2008	USA	176	13	87	12 months	18 months	RCT (2 × 2 factorial design): (*a*) standard weight-loss diet, Preference = Yes; (*b*) lacto-ovo-vegetarian diet, Preference = Yes; (*c*) standard weight-loss diet, Preference = No; (*d*) lacto-ovo-vegetarian diet, Preference = No
Butryn et al. 2009	USA	238	16	84	3 months	12 months	RCT but results reported as a group: weight-loss intervention using diet counseling and liquid meal replacements
Christiansen et al. 2007	Denmark	249	28	72	21 weeks	2–4 years	Retrospective follow-up of individuals who participated in a weight-loss camp
Cleanthous et al. 2007 Clifton et al. 2008	Australia	119	—	100	12 weeks (intensive), 52 weeks (on diet)	3 years	RCT — isocaloric, low-fat diets: (*a*) high-PRO diet; (*b*) high-CHO diet
Cussler et al. 2008	USA	136	—	100	4 months	16 months	RCT — weight-loss intervention then randomized: (*a*) internet contact maintenance group; (*b*) self-directed maintenance group
Ditschuneit et al. 1999 Flechtner-Mors et al. 2000 Ditschuneit and Flechtner-Mors 2001 Ditschuneit et al. 2002	Germany	100	21	79	3 months	4 years	RCT — diet intervention followed by same diet for all for maintenance: (*a*) conventional foods; (*b*) 2 meals·day^{-1} of liquid meal replacement, 1 meal·day^{-1} of conventional food
Fitzgibbon et al. 2008 Stolley et al. 2009 Fitzgibbon et al. 2010	USA	213	—	100	6 months	18 months	RCT: (*a*) weight loss and maintenance (low-fat, high-fibre diet and PA); (*b*) control
Goodrick et al. 1998	USA	219	—	100	6 months	18 months	RCT for binge-eating women: (*a*) dieting treatment; (*b*) nondieting treatment; (*c*) wait-list control
Itoh et al. 2001	Japan	138	—	100	3 months	24 months	Intervention — weight-loss diet (reduced kcal, low fat)
Karlsson et al. 1994	Sweden	60	—	100	3 months	24 months	RCT for weight loss: (*a*) lacto-vegetarian diet (1300 kcal); (*b*) nonvegetarian diet (1300 kcal)
Keranen et al. 2009 Keranen et al. 2011	Finland	82	28	72	6 months	18 months	RCT for weight loss: (*a*) intensive counseling group; (*b*) short-term counseling

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Table 1 (*continued*).

References*	Country of origin	Baseline *n*	Sex† (%)		Length of intervention	Time from baseline to final assessment	Intervention
			Male	Female			
Layman et al. 2009	USA	130	45	55	4 months	12 months	RCT low-kcal diet intervention: (*a*) moderate-PRO diet; (*b*) high-CHO diet
Leermakers et al. 1999	USA	67	20	80	6 months	18 months	RCT after 6-month treatment phase to maintenance program: (*a*) exercise focused; (*b*) weight focused
Ley et al. 2004	New Zealand	136	74	26	1 year	5 years	RCT: (*a*) reduced-fat ad libitum diet; (*b*) control (usual) diet
Matsuo et al. 2010	Japan	54	—	100	14 weeks	105 weeks	Intervention — weight loss with diet and PA
Matvienko and Hoehns 2009	USA	31	39	61	6 months	12 months	Intervention — modification of the Diabetes Prevention Program
McLaughlin et al. 2008	USA	50§	42	58	18 weeks	12–36 months (mean: 28.8±13.9 months)	RCT but combined as 1 group in analysis: (*a*) 60% CHO, 25% fat, 15% PRO; (*b*) 40% CHO, 45% fat, 15% PRO
Nakade et al. 2012	Japan	236	49	51	12 months	24 months	RCT for weight loss: (*a*) lifestyle intervention group; (*b*) control
Rock et al. 2007	USA	70	—	100	6 months	12 months	RCT for weight loss: (*a*) commercial weight-loss program; (*b*) usual-care control
Rolls et al. 2005	USA	200	23	77	6 months	12 months	RCT examining energy density: (*a*) 1 serving soup·day^{-1}; (*b*) 2 servings soup·day^{-1}; (*c*) 2 servings dry snack·day^{-1}; (*d*) comparison group
Tanumihardjo et al. 2009	USA	60	27	73	3 months	18 months	RCT: (*a*) HiVeg (8 servings vegetables·day^{-1}, 2–3 servings fruit·day^{-1}; (*b*) reduced-kcal diet (–500 kcal from estimated requirement, <25% fat)
Teixeira et al. 2010	Portugal	225	—	100	12 months	24 months	RCT: (*a*) lifestyle intervention; (*b*) control
Thorpe et al. 2008	USA	130	45	55	4 months	12 months	RCT: (*a*) PRO diet (30% PRO, 40% CHO, 30% fat); (*b*) CHO diet (15% PRO, 55% CHO, 30% fat)
Waleekhachonloet et al. 2007	Thailand	132	—	100	3 months	12 months	RCT: (*a*) group behaviour therapy; (*b*) individual behaviour therapy
Westenhoefer et al. 2004	Germany	1247	11	89	1 year	3 years	Intervention — commercial weight-loss program included liquid meal replacement
Wing et al. 2010 West et al. 2011	USA	338	—	100	6 months	18 months	RCT: (*a*) behavioural lifestyle weight-loss program ((*i*) motivation-focused maintenance; (*ii*) skill-based maintenance); (*b*) educational control
Wolfson et al. 2010	Israel	67	27	73	6 months	36 months	Intervention — weight loss and maintenance
Kuller et al. 2006 Kuller et al. 2007 Yankura et al. 2008 Kuller et al. 2012	USA	416	—	100	18 months	48 months	RCT weight loss by diet and PA: (*a*) lifestyle change group; (*b*) health education group
de las Fuentes et al. 2009	USA	60	28	72	6 months	2 years	RCT but analyzed as a single group: (*a*) low-CHO diet; (*b*) low-fat diet
Foreyt et al. 1993	USA	165	52	48	3 months	12 months	RCT: (*a*) exercise only; (*b*) diet only; (*c*) exercise + diet; (*d*) wait-list control

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Table 1 (*concluded*).

References*	Country of origin	Baseline *n*	Sex† (%)		Length of intervention	Time from baseline to final assessment	Intervention
			Male	Female			
Gold et al. 2007	USA	124	19	81	6 months	12 months	RCT between weight-loss programs: (*a*) VTrim; (*b*) eDiets.com
Krukowski et al. 2008	USA	123	17	83	6 months	12 months	Intervention — Web-based weight loss
Laitinen et al. 2010	Finland	74	45	55	6 months	21 months	RCT: (*a*) videoconferencing; (*b*) face to face
Maintenance only							
Cox et al. 2007	USA	89	19	81	NA	Mean: 764 days	Observational study. Follow-up of clients who had completed a weight-management program.
Greene et al. 2006	USA	74	36	64	NA	>1 year	Observational study. Follow-up of clients who had completed a weight-management program.
Phelan et al. 2003	USA	2400	21	79	NA	2 years	NWCR
Phelan et al. 2007	USA	891‡	30	70	NA	3 years	NWCR
Phelan et al. 2006	USA	2708	22	78	NA	1 year	NWCR
Wing et al. 2006 Wing et al. 2007 Wing et al. 2008	USA	314‡	19	81	NA	18 months	RCT maintenance-phase only: (*a*) face-to-face intervention; (*b*) internet intervention; (*c*) control group
Gorin et al. 2004	USA	1429	24	76	NA	1 year	NWCR
Klem et al. 1997	USA	784	20	80	NA	5.5 years (mean)	NWCR
McGuire et al. 1999*a*	USA	238	43	57	NA	1 year	Self-reported behavioural strategies.
McGuire et al. 1999*b*	USA	668	20	80	NA	1 year	NWCR
Phelan et al. 2009	USA	303	WLM = 15; NW = 10	WLM = 85; NW = 90	NA	5 years	Self-reported modified food use among WLM and always NW

Note: RCT, randomized controlled trial; PA, physical activity; CHO, carbohydrate; PRO, protein; NA, not applicable; NWCR, National Weight Control Registry; WLM, weight-loss maintainers; NW, normal weight.
*References listed in the same group represent the same study.
†Percentages were calculated for those studies that reported the actual number of males and females.
‡Only reported baseline information for participants who completed 6-month intervention.
§Only reported baseline demographics for participants who returned for follow-up.

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Table 2. Successful strategies for weight loss and weight maintenance (n = 24).

References*		Diet	PA	Behaviour	Quality†
Jeffery et al. 2009; Yatsuya et al. 2011	Weight loss	SBT: Energy intake goal; record diet daily and calculate energy intake MTT: unit 1 — counting kcal and setting goal; unit 3 — structured meals or meal replacements for 2 meals·day^{-1}; unit 5 — stoplight diet	SBT: specific EE goal; record daily PA and calculate EE MTT: unit 2 — walking with pedometer; unit 4 — aerobic activity of 3000 kcal·week^{-1}	SBT: small group SBT including CBT, stimulus control, relapse prevention MTT: unit 6 — contracting unit, $50 deposit returned if reached weight or behaviour goal	M
	Weight maintenance	SBT: same but ↓ frequency MTT: same, 4-week breaks between units	SBT: same but ↓ frequency MTT: same, 4-week breaks between units	SBT: ↓ frequency, $50 deposit returned at final follow-up visit MTT: 4-week breaks between units	
Morgan et al. 2009; Morgan et al. 2011	Weight loss	Internet: 1 info session, program booklet Control: 1 info session, program booklet	Internet: 1 info session, program booklet Control: 1 info session, program booklet	Internet: self-monitored weight, food, and PA diaries (+ feedback), set goals, online social support Control: no access to Web site	M
	Weight maintenance	Internet: sccess to Web site, no feedback Control: so contact	Internet: access to Web site, no feedback Control: no contact	Internet: access to Web site, no feedback Control: no contact	
Acharya et al. 2009; Burke et al. 2008	Weight loss	Lacto-ovo-vegetarian diet or standard diet; all ↓ kcal (1200–1500 ♀ and 1500–1800 ♂); all ↓ fat to 25% of total kcal	All: **i**nitially 50 min walking·week^{-1}; by week 6, 150 min walking·week^{-1}	All: SBT including goal setting, relapse prevention, and problem solving; **d**aily PA, kcal, and fat diaries (+ feedback)	S
	Weight maintenance	No contact	No contact	No contact	
Butryn et al. 2009	Weight loss	Low-kcal diet consuming 2 liquid meal replacements each day	Not described	Weekly individual contact. Behavioural skills: stimulus control, social support, problem solving	W
	Weight maintenance	(*i*) Standard kcal control; (*ii*) ↓ energy density eating; (*iii*) 1 meal replacement·day^{-1}; (*iv*) ↓ energy density + meal replacements	Not described	20 telephone contacts; emphasized behavioural skills, encouraged adherence	
Christiansen et al. 2007	Weight loss	2190 kcal·day^{-1} (55%–60% CHO, 15% PRO, <30% fat); 3 meals, 2 snacks·day^{-1}	120 min·day^{-1} (0%–60% $\dot{V}O_{2max}$). Group PA: swimming, aerobic exercise, strength training, walking, and cycling	Weekly sessions with a psychologist: cognitive strategies. Education: calculate kcal, portion size, and behavioural strategies for return home	W
	Weight maintenance	No contact	No contact	No contact	
Cussler et al. 2008	Weight loss	All: ↓ by 300–500 kcal·day^{-1}; education provided	All: education provided	All: support groups and wellness skills	M
	Weight maintenance	Internet: electronic food diary 4 days·week^{-1} Self-directed; no contact	Internet: electronic PA diary 3 days·week^{-1} Self-directed; no contact	Internet: daily recorded weight; weekly experiences log and online support group; staff online support Self-directed; no contact but support groups continued to meet on their own	

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Table 2 (*continued*).

References*		Diet	PA	Behaviour	Quality†
Ditschuneit et al. 1999; Flechtner-Mors et al. 2000; Ditschuneit and Flechtner-Mors 2001; Ditschuneit et al. 2002	Weight loss	Group A: ↓ kcal·day^{-1} diet, conventional foods Group B: 2 meal replacements and 3rd meal ↓ fat, ↑ V+F. Snacks = replacement bar All: 1200–1500 kcal·day^{-1} (19%–21% PRO, 48%–54% CHO, 25%–34% fat); 3 meals, 2 snacks	Usual PA	7-day food diary 1·month^{-1} (+ feedback) Behaviour modification training	S
	Weight maintenance	All: 1200–1500 kcal·day^{-1}, 1 meal and 1 snack replacement	Usual PA	7-day food diary 1·month^{-1} (+ feedback)	
Itoh et al. 2001	Weight loss	1400 kcal·day^{-1}, 1.5 g·kg^{-1}·day^{-1} PRO, 30 g fat, 20 g fibre	Walk for 40 min·day^{-1}	Not described	W
	Weight maintenance	Same but no contact	Same but no contact	Not described	
Layman et al. 2009	Weight loss	PRO group: 1.6 g·kg^{-1}·day^{-1} PRO, <170 g·day^{-1} CHO (40% CHO, 30% PRO, 30% fat) CHO group: 0.8 g·kg^{-1}·day^{-1} PRO, >220 g·day^{-1} CHO (55% CHO, 15% PRO, 30% fat) Both: 30% fat, fibre (17 g·4.18 MJ^{-1}) and 1700 kcal·day^{-1} ♀ and 1900 kcal·day^{-1} ♂	Minimum: 30 min walking 5 days·week^{-1}	Weigh food (scales provided) and record 3 days·week^{-1}; weekly group meeting for diet info, Q+A, review diet records	W
	Weight maintenance	Same	Same	Same	
Leermakers et al. 1999	Weight loss	Both groups: 1200 kcal·day^{-1} for ♀, 1500 kcal·day^{-1} for ♂, limit fat to <30% of total energy	Both groups: walk 30 min·day^{-1}, 5 days·week^{-1}	Both groups: group BT	W
	Weight maintenance	Same months 7–12; no contact from months 13–18	Months 7–12: Exercise-focused: biweekly supervised exercise, $ incentives, intergroup competition. Weight-focused: discussion on problems related to PA. Months 1–18: Both groups no contact	Months 7–12: Both groups completed daily food and PA diaries, $1 for session attendance, $1 for self-monitoring. Exercise-focused: relapse-prevention training. Weight-focused: therapist-led group discussions. Months 13–18: Both groups no contact	
Matsuo et al. 2010	Weight loss	1200 kcal·day^{-1}; four-food-group point method	Supervised PA: walking, stretching, calisthenics, and resistance training	Daily food diary, body weight, health, and mental conditions (+ feedback)	M
	Weight maintenance	No contact	No contact	No contact.	
Matvienko and Hoehns 2009	Weight loss	↓ dietary fat intake, weekly fat gram goal	150 min·week^{-1} moderate PA	Met with "health coach" weekly or biweekly, support and problem solving; record PA and fat intake	W
	Weight maintenance	Maintain same	Maintain same	Met with "health coach" 1·month^{-1}	
McLaughlin et al. 2008	Weight loss	750 kcal·day^{-1} deficit based on HBE. Both diets: 15% PRO. Diet 1: 60% CHO, 25% fat. Diet 2: 40% CHO, 45% fat	Maintain usual PA	Food diaries and weekly visits with RD to review diary and be weighed	W
	Weight maintenance	Discharged from program, no diet advice	Discharged from program, no PA advice	Discharged from program	

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Table 2 (*continued*).

References*		Diet	PA	Behaviour	Quality†
Rock et al. 2007	Weight loss	Intervention: Jenny Craig weight-loss program, 1200–2000 kcal·day^{-1}, prepackaged foods, ↑ V+F, ↓ energy density. Control: 500–1000 kcal deficit·day^{-1}, 2 consults with RD	Intervention: 30 min, 5 days·week^{-1} or more. Control: recommended ↑ PA, publicly available PA guidelines	Intervention: CBT. Control: written material for label reading, serving sizes, and eating outside the home provided and discussed	W
	Weight maintenance	Same	Same	Same	
Rolls et al. 2005	Weight loss	Assigned kcal intake with estimated 750 kcal·day^{-1} deficit. Meal plan (55% CHO, 30% fat, 15% PRO) with diet exchanges of 1 soup, 2 soups, 2 snacks, or comparison group	"Increase PA", no details provided	Months 1–3: weekly individual counseling with RD, 3-day diet record every 2 weeks. Months 4–6: counseling every 2 weeks and 3-day diet record monthly	M
	Weight maintenance	Same but with new diet energy level, meal plan, and exchange lists	Same	Met with RD monthly, two 3-day diet records total	
Tanumihardjo et al. 2009	Weight loss	HiVeg: 8 vegetable servings·day^{-1}, 2–3 fruit servings·day^{-1}. Fat reduction: ↓ 500 kcal from estimated requirement, <25% energy from fat. Both: weeks 1–3: food provided 5 days·week^{-1}; weeks 4–12: food provided 5 days·week^{-1} + adhere on weekends	Both: 180 min·week^{-1} aerobic activity and 270 weight resistance reps·week^{-1}; given pedometers	Both: Weeks 1–3: group education sessions 2 days·week^{-1}; individual consults by request. Weeks 4–12: group education sessions 2 days·week^{-1}; individual consults by request	W
	Weight maintenance	Same. Both: month 4: food provided 2 day·week^{-1}; months 5–18: no food provided	Same but independent.	Both: Month 4: individual consults available 2 days·week^{-1}. Months 5–18: individual consults by request	
Teixeira et al. 2010	Weight loss	Intervention: moderate energy-deficit diet	Intervention: increase PA	Intervention: CBT, goal setting, relapse prevention, self-monitoring, and exploring motivation	M
		Control: general health education	Control: general health education	Control: General health education	
	Weight maintenance	No contact	No contact	No contact	
Thorpe et al. 2008	Weight loss	PRO diet: 1.4 g·kg^{-1} PRO, 3 servings dairy·day^{-1} (30% PRO, 40% CHO, 30% fat) CHO diet: 0.8 g·kg^{-1} PRO, 2 servings dairy·day^{-1} (15% PRO, 55% CHO, 30% fat) Both: 1500 kcal·day^{-1} ♀, 1700 kcal·day^{-1} ♂, 57 g fat·day^{-1}, 17 g fibre·day^{-1}	30 min of walking, 5 days·week^{-1}	Met with RD weekly for support, questions, and review of 3-day weighed diet record	W
	Weight maintenance	Same	Same	Same	
Wing et al. 2010; West et al. 2011	Weight loss	BWL: 1200–1800 kcal·day^{-1}, <30% kcal from fat; meal replacements for 2 meals and 1 snack per day; coupons provided Educational control: group education sessions	BWL: graded exercise goal up to ≥200 min·week^{-1} of moderate PA; pedometers used. Educational control: group education sessions	BWL: CBT, stimulus control, problem solving, relapse prevention, and social support Educational control: group education sessions	M
	Weight maintenance	Both: **m**eal replacement coupons provided for 1 meal and 1 snack per day; ↓ kcal until 10% weight loss achieved, then "focused on weight stability"	Both groups: remain at 200 min·week^{-1}	BWL motivation focused: used MI. BWL skill-based: refining behavioural skills	

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Table 2 (*concluded*).

References*		Diet	PA	Behaviour	Quality†
Wolfson et al. 2010	Weight loss	↓ by 500 kcal·day^{-1}; ↓ CHO, ↓ fat, ↓ saturated fat, ↓ cholesterol, ↓ alcohol; ↑ V+F (5–9 servings·day^{-1}), ↑ low-fat dairy (2–4 servings·day^{-1}), ↑ legumes, ↑ whole grains	Weekly group PA class + moderate-intensity PA	Not described	M
	Weight maintenance	No contact	No contact	No contact	
Kuller et al. 2006; Kuller et al. 2007; Yankura et al. 2008; Kuller et al. 2012	Weight loss	LC: 1 — ↓ total, saturated, trans fat, cholesterol; 2 — 1300–1500 kcal·day^{-1}; 3 — ↑ soluble fibre; 4 — promote nutrient density; 5 — ↑ functional food	LC: minimum 150 min·week^{-1} of PA; advance to 180 min·week^{-1} and 240 min·week^{-1}	Both: CBT, self-monitoring, stimulus control, goal setting, problem solving, relapse prevention, social support, and motivation	M
		HE: general education in group sessions	HE: general education in group sessions.	LC: 40 visits·year^{-1} in first year HE: 6 seminars·year^{-1} in first year	
	Weight maintenance	↓ frequency of contact	↓ frequency of contact.	↓ frequency of contact. LC: monthly meetings. HE: seminars several times·year^{-1}	
Foreyt et al. 1993	Weight loss	Diet only and Diet + exercise groups: "Help Your Heart Eating Plan", 30% fat, 50% CHO, 20% PRO; provided kcal-level plans. Exercise only: maintain usual eating habits	Diet + exercise and Exercise-only groups: goal was 3–5 sessions·week^{-1} for ≥45 min. Diet only: maintain usual	Diet only and Diet + exercise groups: daily food diaries (+ feedback weekly). All groups: behavioural strategies (stress management, goal setting, and stimulus control). Exercise-only and Diet + Exercise groups: PA self-monitoring	M
	Weight maintenance	Less frequent contact with staff	Less frequent contact with staff	Less frequent contact with staff	
Gold et al. 2007	Weight loss	VTrim: ↓ energy up to 1000 kcal·day^{-1}; goal of 1200–2200 kcal·day^{-1} eDiets: kcal goal based on HBE, deficit of 1000 kcal·day^{-1}	VTrim: gradually ↑ EE to burn 1000 kcal·week^{-1}, walking encouraged eDiets: encouraged PA	VTrim: therapist led, online; weekly homework + feedback; SBT eDiets: self-reported weight weekly, automated feedback.	W
	Weight maintenance	VTrim: ↓ frequent online contact eDiets: access to Web site	VTrim: ↓ frequent online contact eDiets: access to Web site	VTrim: ↓ frequent online contact eDiets: access to Web site	
Krukowski et al. 2008	Weight loss	1200–2100 kcal·day^{-1} based on body weight	Gradual ↑ to 1000 kcal EE·week^{-1}	Online energy intake and expenditure diary; SBT; weekly chat sessions.	M
	Weight maintenance	Same	Same	Monthly sessions focused on maintaining skills	

Note: A copy of the EPHPP tool, as well as the manual describing how the tool is to be used, can be found at http://www.ephpp.ca/Tools.html. SBT, standard behaviour therapy; EE, energy expenditure; PA, physical activity; CBT, cognitive behaviour therapy; M, moderate; MTT, maintenance tailored therapy; S, strong; W, weak; CHO, carbohydrate; PRO, protein; $\dot{V}O_{2max}$, maximal oxygen consumption; V+F, vegetables and fruit; Q+A, question and answer; BT, behavioural therapy; HBE, Harris Benedict equation; RD, registered dietitian; BWL, behavioural weight loss; MI, motivational interviewing; LC, lifestyle change group; HE, health education group.

*References listed in the same group represent the same study.

†Quality rating was determined using the Effective Public Health Practice Project (EPHPP) quality assessment tool.

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Table 3. Maintenance only: successful strategies (n = 10).

References*	Diet	PA	Behaviour
Cox et al. 2007	Maintainers (vs. gainers): consumed a mean of 384 fewer kcal·day^{-1} and had lower energy density. Total kcal intake was a significant predictor of weight change (↑ 100 kcal·day^{-1} → 0.3 kg weight ↑)	NS between maintainers and gainers	Did not assess
Phelan et al. 2003	NS	NS	Recovery was significantly related to a smaller ↑ in depressive symptoms from baseline to year 1
Phelan et al. 2007	At study entry, low-CHO group: ↑ kcal·day^{-1}. At all time points, low-CHO group: ↑ % kcal from fat, ↑ SFA, ↑ MUFA, and ↑ PUFA intake, ↑ % kcal from PRO and ↓ % kcal from CHO	Low-CHO group: ↓ EE·week^{-1} at all time points, and fewer reported they had ↑ PA	Low-CHO group: ↓ hunger, ↓ dietary restraint, ↓ use of portion sizes, and ↓ counting kcal
Phelan et al. 2006	Later enrollees: ↑ fat intake, ↑ SFA, ↓ % kcal from CHO. Dietary fibre ↑ from beans, vegetables, and fruit; ↓ fibre from grains. ↑ % of participants consuming a low-CHO diet, (<90 g·day^{-1}) in later years (still <17% of participants). Weight regain was significantly related to baseline diet: ↑ kcal, ↑ % kcal from PRO, ↑ fast food, and ↓ frequent breakfast	At 1 year: ↓ in PA were related to weight regain	Not reported here
Wing et al. 2006; Wing et al. 2007; Wing et al. 2008	Weight loss occurred prior to baseline. The 3 most common approaches: commercial weight-loss groups (39.5%), an individual approach with no outside help (22.9%), and exercise (36.6%) with an additional approach usually paired with exercise	Changes in PA were strongly associated with weight change. A ↓ of 500 kcal·week^{-1} in EE was associated with ↑ weight regain of 0.19 kg	Key behavioural strategies: both intervention groups gave ↑ ratings for the importance of self-weighing (vs. control group). The F2F group also gave ↑ ratings than controls for goal setting, kcal counting, and eating and exercise diaries Self-weighing: a smaller % of participants in F2F and internet groups who weighed themselves daily regained ≥ 2.3 kg compared with those who weighed themselves less often
	NS association between kcal consumed or % kcal from fat and weight regain	NS differences in PA between groups	
Gorin et al. 2004	Not reported	Not reported	Participants who maintained a consistent diet were 1.5 times more likely to maintain weight (±2.2 kg) over the year than those who reported being stricter on weekdays
Klem et al. 1997	Top 3 methods to lose weight: limit certain types or classes of foods (87.6%), limit quantities of food (44.2%), and count kcal (43.7%). ~20% used liquid formula for weight loss. Significantly ↑ women than men used a formal program or professional assistance to lose weight. Women were ↑ likely than men to eat all foods but to limit quantity, to count fat grams, and to follow an exchange diabetic diet	Subjects reported expending a mean of 11830 KJ·week^{-1} through PA (walking ~45 km·week^{-1})	77% of subjects (equally males and females) reported either an emotional or a medical trigger that preceded their successful weight-loss attempt. Men were ↑ likely to report a medical trigger. Women were ↑ likely to report an emotional trigger

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Table 3 (*concluded*).

References*	Diet	PA	Behaviour
McGuire et al. 1999*a*	WLM (compared with WLR and controls) used more strategies to lower dietary fat: avoid frying, substitute low fat for high fat, ↓ Total Food Habit Questionnaire score	WLM (compared with WLR and controls): ↑ strenuous activities, ↑ activities that made them sweat, ↑ Total Activity Score	↑ WLR than WLM used a "self-help program" as a weight-loss strategy. ↑ WLM weighed themselves at least 1·week^{-1} (vs. WLR and controls). WLM and WLR had similar restraint but were ↑ vs. control for concern about dieting, weight fluctuation, and total score
McGuire et al. 1999*b*	Baseline predictors of weight regain: Gainers: ↑ use of assistance for weight loss, ↑ use of liquid formula diet. Maintainers: ↓ % of daily kcal from PRO. Change from baseline to 1 year: Gainers: ↑ % energy from fat	Baseline predictors of weight regain: NS between groups. Change from baseline to 1 year: Gainers ↓ EE by 1000 kcal·week^{-1}. Maintainers ↓ EE by 500 kcal·week^{-1}	Baseline predictors of weight regain: Gainers had ↑ disinhibition, ↑ binge eating, and ↑ depressive symptoms. Change from baseline to 1 year: Gainers had ↓ self-monitoring, ↓ restraint, ↑ disinhibition, ↑ hunger, and ↑ binge eating
Phelan et al. 2009	WLM (compared with NW): ↓ energy from fat, ↑ energy from CHO, ↑ energy from PRO, ↑ low-fat diet strategies, ↑ servings·day^{-1} and ↑ portion of artificially sweetened soft drinks, ↓ sugar-sweetened beverages, ↓ servings·day^{-1} and ↓ portion of juice, ↓ servings·day^{-1} and ↓ portion of alcohol, ↑ servings·day^{-1} and ↑ portion of water	NA	WLM (compared with NW): ↑ restraint

Note: All studies were rated as moderate quality. PA, physical activity; NS, not significant; CHO, carbohydrate; SFA, saturated fatty acid; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid; PRO, protein; EE, energy expenditure; F2F, face to face; NW, normal weight; WLM, weight-loss maintainers; WLR, weight-loss regainers; NA, not applicable.
*References listed in the same group represent the same study.

Control Registry (NWCR) in the United States (n = 7). The remaining 4 studies had a retrospective design (Table 1). Because the inclusion criteria specified only studies published in the past 25 years, the retained studies were generally current. The earliest publication date of a specific study was considered as the study date; 8 studies were published between 1990 and 2000, 7 were published between 2001 and 2005, and the majority (32) were published between 2006 and 2010. One study was published in 2012 (Table 1). Also shown in Table 1 are the baseline sample size, percentage of males and females, time of intervention, time of final assessment, and study intervention. Based on these characteristics, there was considerable variation among studies.

Primary outcomes: successful weight loss and weight maintenance

The main purpose of this review was to determine successful strategies for weight loss and weight maintenance. Table 2 includes only studies that demonstrated significant weight loss (>5%) and subsequent maintenance of that weight loss (in at least 1 arm of the study) for at least 1 year. This further exclusion resulted in 34 remaining studies (24 studies described weight loss and weight maintenance and 10 studies described weight maintenance only).

Weight-loss and weight-maintenance combined studies (n = 24)

Twenty-four studies met the criteria for successful weight loss and weight maintenance (Table 2). For 7 of these studies, the percentage of weight loss could not be calculated, but a significant absolute weight loss–weight maintenance was reported (Butryn et al. 2009; Itoh et al. 2001; Jeffery et al. 2009; Kuller et al. 2006, 2007, 2012; Leermakers et al. 1999; Tanumihardjo et al 2009; Wolfson et al. 2010; Yankura et al. 2008; Yatsuya et al. 2011) and thus, these studies were retained. The majority of retained studies (n = 20) reported that participant weight was measured by study staff. Two studies reported that weight was measured at baseline but only a subsample was measured at follow-up, with the remaining participants providing self-reported weight (Christiansen et al. 2007; McLaughlin et al. 2008), and 2 studies did not report whether weight was measured or self-reported (Itoh et al. 2001; Wolfson et al. 2010).

The weight-loss intervention had to take a minimum of 3 months. The lengths of the interventions were found to be variable among studies: 15 weeks (Matsuo et al. 2010), 18 weeks (McLaughlin et al. 2008), 21 weeks (Christiansen et al. 2007), 3 months (Butryn et al. 2009; Ditschuneit and Flechtner-Mors 2001; Ditschuneit et al. 1999, 2002; Flechtner-Mors et al. 2000; Foreyt et al. 1993; Itoh et al. 2001; Morgan et al 2009, 2011; Tanumihardjo et al. 2009), 4 months (Cussler et al. 2008; Layman et al. 2009; Thorpe et al. 2008), 6 months (Gold et al. 2007; Jeffery et al. 2009; Krukowski et al. 2008; Kuller et al. 2006, 2007, 2012; Leermakers et al. 1999; Matvienko and Hoehns 2009; Rock et al. 2007; Rolls et al. 2005; West et al. 2011; Wing et al. 2010; Wolfson et al. 2010; Yankura et al. 2008;Yatsuya et al. 2011), and 12 months (Acharya et al. 2009; Burke et al. 2008; Teixeira et al. 2010). These time periods were considered to reflect the weight-loss phase, because the intervention either ended or was reduced considerably. Mean weight loss (baseline to end of intervention) ranged from ~5% to 15%. There did not appear to be a relationship between the length of the intervention and the percentage weight loss (i.e., longer interventions did not result in more or less weight loss).

The weight-maintenance period had to take a minimum of 1 year from baseline, and the measurement considered for this review was the time point closest to 1 year at which body weight data were reported. This also varied among studies: 12 months (Butryn et al. 2009; Foreyt et al. 1993; Gold et al. 2007; Krukowski et al. 2008; Layman et al. 2009; Matvienko and Hoehns, 2009; Morgan et al. 2009, 2011; Rock et al. 2007; Rolls et al. 2005; Thorpe et al. 2008), 16 months (Cussler et al. 2008), 18 months (Acharya et al. 2009; Burke et al. 2008; Jeffery et al. 2009; Leermakers et al.

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1999; Tanumihardjo et al 2009; West et al. 2011; Wing et al. 2010; Yatsuya et al. 2011), 24 months (Itoh et al. 2001; Teixeira et al. 2010), 105 weeks (Matsuo et al. 2010), 29 months (McLaughlin et al. 2008), 36 months (Wolfson et al. 2010), 2–4 years (Christiansen et al. 2007), and 4 years (Ditschuneit and Flechtner-Mors 2001; Ditschuneit et al. 1999, 2002; Flechtner-Mors et al. 2000; Kuller et al. 2006, 2007, 2012; Yankura et al. 2008). Mean weight loss that was maintained (from baseline to 1 year or more) ranged from 5.3% to 10.5%. In the studies that met the criteria for successful weight loss and maintenance, there did not appear to be a relationship between the length of the maintenance phase and the percentage weight maintenance (i.e., longer maintenance did not result in more or less weight regain).

Weight-maintenance-only studies (n = 10)

Ten studies focused only on the weight maintenance of individuals who had previously had a significant weight loss. These studies were retained because it has been speculated that not only is weight maintenance more difficult to achieve than weight loss, but that the strategies needed to sustain long-term weight loss are different from those for initial weight loss. Six of these studies reported on aspects of the NWCR, an ongoing longitudinal study of persons aged ≥18 years who lost ≥13.6 kg and have kept the weight off for ≥1 year (Gorin et al. 2004; Klem et al. 1997; McGuire et al. 1999*b*; Phelan et al. 2003, 2006, 2007). The remaining 4 studies were follow-ups of people who had participated in other programs (Cox et al. 2007; Wing et al. 2006, 2007, 2008) or who had lost weight on their own (McGuire et al. 1999*a*; Phelan et al. 2009). The majority of these studies included self-reported weight only (Gorin et al. 2004; Klem et al. 1997; McGuire et al. 1999*a*, 1999*b*, Phelan et al. 2003, 2006, 2007, 2009); however, 2 studies did report measured weight (Cox et al. 2007; Wing et al. 2006, 2007, 2008).

Successful strategies: weight loss

The strategies used to achieve the positive results in the 24 studies that demonstrated successful weight loss were evaluated further (Table 2). A "diet" intervention of some type had to be included in each study. There was considerable variation among specific study protocols, but key recurring interventions were observed.

Energy and macronutrients

Only studies in which the diet intervention was considered healthy (capable of meeting nutrient requirements) and to be at a reasonable energy intake level (>1200 kcal) were retained. Of the 24 studies with a significant weight-loss intervention, 22 specified a minimum energy intake or a specific energy reduction from usual intake. Daily energy intake levels (kcal·day^{-1}) were specified as

- 1200 (Matsuo et al. 2010)
- 1200 for women and 1500 for men (Leermakers et al. 1999)
- 1400 (Itoh et al. 2001)
- 1500 for women and 1700 for men (Thorpe et al. 2008)
- 1700 for women and 1900 for men (Layman et al. 2009)
- 2190 (Christiansen et al. 2007)

Alternatively, some studies recommended a range of energy intake (kcal·day^{-1}):

- 1200–1500 (Ditschuneit and Flechtner-Mors 2001; Ditschuneit et al. 1999, 2002; Flechtner-Mors et al. 2000)
- 1200–1500 for women and 1500–1800 for men (Acharya et al. 2009; Burke et al. 2008)
- 1200–1800 (West et al. 2011; Wing et al. 2010)
- 1200–2000 (Rock et al. 2007)
- 1200–2100 (Krukowski et al. 2008)
- 1300–1500 (Kuller et al. 2006, 2007, 2012; Yankura et al. 2008)

Energy deficits (decreased kcal·day^{-1} from usual intake) were also prescribed in some studies:

- 300–500 (Cussler et al. 2008)
- 500 (Tanumihardjo et al 2009; Wolfson et al. 2010)
- 750 (McLaughlin et al. 2008; Rolls et al. 2005)
- Up to 1000 (Gold et al. 2007)

Four studies simply stated the following: "a moderate energy deficit" (Teixeira et al. 2010), "provided calorie-level plans" (Foreyt et al. 1993) "low-calorie diet" (Butryn et al. 2009) and "specific energy intake goals" (Jeffery et al. 2009; Yatsuya et al. 2011).

Studies rated as strong quality suggested the 1200–1500 kcal·day^{-1} range (Acharya et al. 2009; Burke et al. 2008; Ditschuneit and Flechtner-Mors 2001; Ditschuneit et al. 1999, 2002; Flechtner-Mors et al. 2000). Studies rated as moderate quality (Cussler et al. 2008; Foreyt et al. 1993; Jeffery et al. 2009; Krukowski et al. 2008; Kuller et al. 2006, 2007; 2012; Layman et al. 2009; Matsuo et al. 2010; Rolls et al. 2005; Teixeira et al. 2010; West et al. 2011; Wing et al. 2010; Wolfson et al. 2010; Yankura et al. 2008; Yatsuya et al. 2011) all used some form of calorie restriction, except for 1 Internet-based program that focused on self-monitoring, individual feedback, and social support (Morgan et al. 2009, 2011).

A review of the macronutrient prescriptions in the weight-loss interventions indicated that a reduction in fat was often specified (15 of 24 studies) as a percentage of total energy (25% (Acharya et al. 2009; Burke et al. 2008; Tanumihardjo et al 2009), <30% (Christiansen et al. 2007; Leermakers et al. 1999; West et al. 2011; Wing et al. 2010), or 30% (Foreyt et al. 1993; Layman et al. 2009; Rolls et al. 2005; Thorpe et al. 2008)), or as 30 g·day^{-1} (Itoh et al. 2001), or as a general recommendation to decrease fat (Cussler et al. 2008; Ditschuneit and Flechtner-Mors 2001; Ditschuneit et al. 1999, 2002; Flechtner-Mors et al. 2000; Kuller et al. 2006, 2007, 2012; Matvienko and Hoehns 2009; Wolfson et al. 2010; Yankura et al. 2008). One-half of these studies were of moderate to strong quality (n = 8) and about one-half were of weak quality (n = 7).

Three studies compared isocaloric diets of high-carbohydrate (CHO) against high-protein (PRO) (CHO = 55% or 40%; PRO = 15% or 30%) (Layman et al. 2009; Thorpe et al. 2008) or high-CHO against high-fat (CHO = 60% or 40%; high-fat = 25% or 45%) macronutrient distribution (McLaughlin et al. 2008). Weight loss was significant in all 3 studies and there were no differences in weight loss attributable to different macronutrient intakes between groups.

Other diet strategies

Numerous other diet modifications were used in the studies, although much less frequently than were energy and fat reductions. Increased fibre (Cussler et al. 2008; Itoh et al. 2001; Kuller et al. 2006, 2007, 2012; Layman et al. 2009; Thorpe et al. 2008; Yankura et al. 2008) was the next most commonly used strategy. The fibre recommendations among successful studies were varied and included 17 g·day^{-1} (Thorpe et al. 2008), 20 g·day^{-1} (Itoh et al. 2001), 17 g·1000 kcal^{-1} (Layman et al. 2009), and 5–10 g of soluble fibre·day^{-1} (Kuller et al. 2006, 2007, 2012; Yankura et al. 2008), as well as a general recommendation that fibre be increased(Cussler et al. 2008). Other successful adjunct strategies included education programs (Cussler et al. 2008; Morgan et al. 2009, 2011), increased meal frequency (3 meals and 2 snacks) (Christiansen et al. 2007; Cussler et al. 2008; Ditschuneit and Flechtner-Mors 2001; Ditschuneit et al. 1999, 2002; Flechtner-Mors et al. 2000), portion control (Cussler et al. 2008), liquid meal-replacement products (Butryn et al. 2009; Ditschuneit and Flechtner-Mors 2001; Ditschuneit et al. 1999, 2002; Flechtner-Mors et al. 2000; Jeffery et al. 2009; West et al. 2011; Wing et al. 2010; Yatsuya et al. 2011), prepackaged foods and (or) food provision (Rock et al. 2007; Tanumihardjo et al. 2009), food groups and (or) food exchange systems (Jeffery et al. 2009; Matsuo et al. 2010; Rolls et al. 2005; Yatsuya et al. 2011), increased dairy foods (Thorpe et al. 2008; West et al. 2011; Wing et al. 2010), decreased CHO (Wolfson et al. 2010), decreased cholesterol (Kuller et al. 2006, 2007, 2012; Wolfson et al. 2010; Yankura et al. 2008), decreased alcohol (Wolfson et al. 2010),

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increased water (Cussler et al. 2008), increased fruits and vegetables (Kuller et al. 2006, 2007, 2012; Wolfson et al. 2010; Yankura et al. 2008), and increased functional foods (soy, stanols, omega 3 fatty acids) (Kuller et al. 2006, 2007, 2012; Yankura et al. 2008).

Physical activity

Twenty-three of the 24 studies that reported a significant weight-loss intervention also included a PA component, with only 1 study (Butryn et al. 2009) providing no information on activity. Some studies provided general recommendations: 2 studies encouraged participants to maintain usual PA (Ditschuneit and Flechtner-Mors 2001; Ditschuneit et al. 1999, 2002; Flechtner-Mors et al. 2000; McLaughlin et al. 2008), 2 studies recommended increased PA (Rolls et al. 2005; Teixeira et al. 2010), and 2 studies provided PA education (Cussler et al. 2008; Morgan et al 2009, 2011). In most studies, a weekly time goal was prescribed, with a suggested number of sessions per week. These goals included walking up to 150 min·week^{-1} (Acharya et al. 2009; Burke et al. 2008; Layman et al. 2009; Leermakers et al. 1999, Thorpe et al. 2008); moderate PA at 150 min·week^{-1} (Matvienko and Hoehns 2009; Rock et al. 2007) or 200 min·week^{-1} (West et al. 2011; Wing et al. 2010); and aerobic activity of up to 180 (Tanumihardjo et al 2009), 225 (Foreyt et al. 1993), 240 (Kuller et al. 2006, 2007; 2012; Yankura et al. 2008), and 280 (Itoh et al. 2001) min·week^{-1}. Moderate PA was not defined in the research papers (Matvienko and Hoehns 2009; Rock et al. 2007); however, the *Compendium of Physical Activities* describes moderate PA as having an intensity of 3.0–5.9 metabolic equivalents (Ainsworth et al. 2011). Using this definition, walking on a level, firm surface at a speed of 2.5 (slow pace) to 4.0 miles·h^{-1} (brisk pace) would be classified as moderate PA (Ainsworth et al. 2011).

PA was also prescribed by energy expenditure goals of 1000 kcal·week^{-1} (Gold et al. 2007; Krukowski et al. 2008) and 3000 kcal·week^{-1} (Jeffery et al. 2009; Yatsuya et al. 2011). Group sessions were used by some researchers (120 min·day^{-1} at 50%–60% maximal oxygen consumption ($\dot{V}O_{2max}$ test)) (Christiansen et al. 2007), as well as supervised exercise sessions (Matsuo et al. 2010) and group classes once a week (Wolfson et al. 2010). The overall EPHPP quality ratings for the studies that included a PA intervention were weak (n = 9), moderate (n = 11), and strong (n = 1). There was a tendency for the higher-quality studies to have a greater amount of prescribed PA, but this was not consistent among all studies.

Behaviour training

Twenty-two of the 24 studies also included a behaviour training (BT) component, with only 2 studies (Itoh et al. 2001; Wolfson et al. 2010) providing no information on behavioural interventions. BT was described in broad terms as standard behaviour therapy (Acharya et al. 2009; Burke et al. 2008; Jeffery et al. 2009; Yatsuya et al. 2011), cognitive behaviour therapy (Jeffery et al. 2009; Kuller et al. 2006, 2007, 2012; Rock et al. 2007; Teixeira et al. 2010; West et al. 2011; Wing et al. 2010; Yankura et al. 2008; Yatsuya et al. 2011), general education on behavioural strategies (Christiansen et al. 2007; Ditschuneit and Flechtner-Mors 2001; Ditschuneit et al. 1999, 2002; Flechtner-Mors et al. 2000; Leermakers et al. 1999; Tanumihardjo et al. 2009) or wellness (Cussler et al. 2008), stress management (Foreyt et al. 1993), or interactions with health practitioners: a psychologist (Christiansen et al. 2007), a health coach (Matvienko and Hoehns 2009), an on-line therapist (Gold et al. 2007) or a registered dietitian (McLaughlin et al. 2008, Rock et al. 2007; Thorpe et al. 2008). Many studies used specific techniques, with the most frequently reported being keeping diaries of some or all aspects of the program (eating, activity, behaviours, weight) (Acharya et al. 2009; Burke et al. 2008; Ditschuneit and Flechtner-Mors 2001; Ditschuneit et al. 1999, 2002; Flechtner-Mors et al. 2000; Foreyt et al. 1993; Krukowski et al. 2008; Kuller et al. 2006, 2007, 2012; Layman et al. 2009; Matsuo et al. 2010; Matvienko and Hoehns, 2009; McLaughlin et al. 2008; Morgan et al 2009, 2011; Rolls et al. 2005; Teixeira et al. 2010; Thorpe et al. 2008; Yankura et al. 2008). Other techniques included social support (Butryn et al. 2009; Cussler et al. 2008; Jeffery et al. 2009; Krukowski et al. 2008; Kuller et al. 2006, 2007, 2012; Layman et al. 2009; Morgan et al 2009, 2011; West et al. 2011; Wing et al. 2010; Yankura et al. 2008; Yatsuya et al. 2011), goal setting (Acharya et al. 2009; Burke et al. 2008; Foreyt et al. 1993; Jeffery et al. 2009; Krukowski et al. 2008; Kuller et al. 2006, 2007, 2012; Morgan et al 2009, 2011; Teixeira et al. 2010; West et al. 2011; Wing et al. 2010; Yankura et al. 2008; Yatsuya et al. 2011), stimulus control (Butryn et al. 2009; Foreyt et al. 1993; Jeffery et al. 2009; Krukowski et al. 2008; Kuller et al. 2006, 2007, 2012; West et al. 2011; Wing et al. 2010; Yankura et al. 2008; Yatsuya et al. 2011), relapse prevention (Acharya et al. 2009; Burke et al. 2008; Jeffery et al. 2009; Krukowski et al. 2008; Kuller et al. 2006, 2007, 2012; Teixeira et al. 2010; West et al. 2011; Wing et al. 2010; Yankura et al. 2008; Yatsuya et al. 2011), problem solving (Acharya et al. 2009; Burke et al. 2008; Butryn et al. 2009; Krukowski et al. 2008; Kuller et al. 2006, 2007, 2012; West et al. 2011; Wing et al. 2010; Yankura et al. 2008), and motivation techniques (Kuller et al. 2006, 2007, 2012; Teixeira et al. 2010; Yankura et al. 2008) (e.g., promoting the participants' intrinsic motivation for lifestyle change, which is more sustainable than external motivation (Teixeira et al. 2010)). Because almost all studies reported BT, their quality scores ranged from weak to moderate to strong.

Summary: weight loss

Overall, for significant safe weight loss to be achieved, it appears that an energy deficit is required, with a minimum level of 1200 kcal·day^{-1} for women and 1500 kcal·day^{-1} for men. A reduction in fat was commonly used in combination with the energy restriction, with levels of ≤30% of total energy being prudent. Increasing dietary fibre was a key component of 5 of the 24 studies (21%). PA was included as part of the intervention in 21 studies (88%), and BT and (or) behavioural support was included as part of the intervention in 22 studies (92%). Dietary intake and PA, as well as behaviours that support changes in diet and activity, appear to be important factors in any healthy, successful weight-loss program.

Successful strategies: weight maintenance

Two groups of studies are discussed herein. These studies include the weight-maintenance phase of the studies that included a weight-loss intervention (n = 24) and those that focused on weight maintenance only (n = 10).

For the maintenance phase of the weight-loss studies, 4 distinct follow-up strategies emerged: continue the same intervention (Itoh et al. 2001; Krukowski et al. 2008; Layman et al. 2009; Rock et al. 2007; West et al. 2011; Wing et al. 2010); continue the intervention but with fewer components or less personal contact (Cussler et al. 2008; Ditschuneit and Flechtner-Mors 2001; Ditschuneit et al. 1999, 2002; Flechtner-Mors et al. 2000; Foreyt et al. 1993; Gold et al. 2007; Jeffery et al. 2009; Kuller et al. 2006, 2007, 2012; Matvienko and Hoehns 2009; Morgan et al. 2009; Morgan et al. 2011; Rolls et al. 2005; Tanumihardjo et al 2009; Yankura et al. 2008; Yatsuya et al. 2011); re-randomize the groups into different interventions (Butryn et al. 2009; Leermakers et al. 1999); or have no contact during the maintenance phase until final measurements were taken (Acharya et al. 2009; Burke et al. 2008; Christiansen et al. 2007; Matsuo et al. 2010, McLaughlin et al. 2008; Teixeira et al. 2010; Thorpe et al. 2008; Wolfson et al. 2010). No follow-up strategy appeared to have higher weight-maintenance percentages or higher-quality ratings.

All the weight-maintenance-only studies were rated as being moderate quality. The studies reporting on the NWCR used different subsets of the registry to investigate different research questions. In 1 NWCR study, regainers who "recovered" (i.e., were gaining weight over time but then lost the weight again) were compared with regainers who did not lose weight (Phelan et al.

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2003). One difference between the groups was that the recovery group had fewer depressive symptoms. Another NCWR study described the use of a low-CHO diet (Phelan et al. 2007). Compared with other registry participants, the low-CHO group consumed more fat, more PRO, and less CHO; exercised less; used fewer behavioural strategies; and felt less hunger. The authors questioned "the long-term health effects of weight loss associated with a high-fat diet and low activity level" (Phelan et al. 2007). In a comparison of successful NWCR maintainers in 1995 and 2003, it appeared that the latter cohort may have had a somewhat lower-quality diet caused by an increased percentage of calories from fat and saturated fat and a lower percentage of calories from CHO (Phelan et al. 2006). However, this increased percentage of calories from fat in the latter cohort remained well below the national average, and only a small proportion of participants were consuming what would be considered a "low-carb" diet (Phelan et al. 2006). There were also healthful increases in fibre from vegetables and fruit and beans in the latter cohort (Phelan et al. 2006). This evidence supports the idea that as long as calories are maintained at an appropriate level for the individual, weight maintenance is possible with a variety of macronutrient distributions. When both cohorts were pooled, weight maintenance was associated with decreased energy and fat intake, decreased consumption of fast food, and increased activity (Phelan et al. 2006). For NWCR participants, dieting consistency, as opposed to being less strict on weekends or holidays, also predicted weight maintenance (Gorin et al. 2004). In 2 other NWCR follow-up studies, successful maintainers had low energy intakes (~1381 kcal·day^{-1}), low fat intakes (24%), and high activity levels (~2827 kcal·week^{-1} of energy expenditure), and a large proportion of them had regular meal patterns, used portion control, and weighed themselves daily (Klem et al. 1997). Maintainers vs regainers were more likely to have a lower fat intake, higher energy expenditure, higher dietary restraint, less hunger, less dietary disinhibition, and less binge eating (McGuire et al. 1999*b*). The 4 remaining weight-maintenance studies (Cox et al. 2007; McGuire et al. 1999a; Phelan et al 2009; Wing et al. 2006, 2007, 2008) had results similar to those of the NCWR studies. Weight maintenance was associated with the following modifiable behaviours: decreased total energy intake (Cox et al. 2007), decreased energy density (Cox et al. 2007), decreased fat intake (McGuire et al. 1999a; Phelan et al 2009), increased diet strategies (fewer sugar-sweetened beverages, use of sugar-modified and fat-modified foods, decreased alcohol intake, and increased water intake (Phelan et al 2009)), and regular weighing: daily or weekly (McGuire et al. 1999*a*; Wing et al. 2006, 2007, 2008). Weight maintenance was also associated with the following mental health factors: decreased depressive symptoms, disinhibition, and hunger and increased dietary restraint (Wing et al. 2006, 2007, 2008).

Summary: weight maintenance

Overall, for weight maintenance, it appears that the initial weight-loss program should be very comprehensive, and that much of the knowledge and skills carry over into the weight-maintenance phase. Twenty-four different studies demonstrated weight maintenance after weight loss, with a variety of approaches during weight maintenance (including no contact). The common factor was that the majority of these studies included dietary restrictions, PA, and BT in the initial weight-loss phase.

Of the weight-maintenance-only studies, similar results were found regarding what is required to maintain weight loss. Terms such as "continued vigilance" and "long-term lifestyle changes" have been used. Thus, a combination of energy and fat restriction, regular PA, and behavioural strategies is required for long-term weight maintenance.

Secondary outcomes: biochemical and physical

Biochemical

Biochemical changes were measured in 13 of the 24 studies that reported successful weight loss and maintenance (Acharya et al. 2009; Burke et al. 2008; Ditschuneit and Flechtner-Mors 2001; Ditschuneit et al. 1999, 2002; Flechtner-Mors et al. 2000; Itoh et al. 2001; Jeffery et al. 2009; Kuller et al. 2006, 2007, 2012; Layman et al. 2009; Matsuo et al. 2010, Matvienko and Hoehns, 2009; McLaughlin et al. 2008; Rock et al. 2007; Tanumihardjo et al 2009; Thorpe et al. 2008; Wolfson et al. 2010; Yankura et al. 2008; Yatsuya et al. 2011). The 4 biochemical parameters that were reported most commonly as significantly different from baseline were total cholesterol (TC), high-density lipoprotein (HDL), low-density lipoprotein (LDL), and TG. A significant improvement (decrease) in TC was found following the intervention in 5 studies (Ditschuneit and Flechtner-Mors 2001; Ditschuneit et al. 1999, 2002; Flechtner-Mors et al. 2000; Layman et al. 2009; Matsuo et al. 2010, Matvienko and Hoehns, 2009; Tanumihardjo et al 2009) and after maintenance in 2 studies (Matsuo et al. 2010; Wolfson et al. 2010). HDL was variable after the intervention phase, with an improvement (increase) in 1 study (Layman et al. 2009) and a worsening (decrease) in 3 studies (Jeffery et al. 2009; Kuller et al. 2006, 2007, 2012; Matvienko and Hoehns, 2009; Yankura et al. 2008; Yatsuya et al. 2011), whereas it was consistently improved (increase) after maintenance in 7 studies (Acharya et al. 2009; Burke et al. 2008; Jeffery et al. 2009; Layman et al. 2009; Matsuo et al. 2010, McLaughlin et al. 2008; Rock et al. 2007; Wolfson et al. 2010; Yatsuya et al. 2011). LDL was improved (decreased) following the intervention in 6 studies (Acharya et al. 2009; Burke et al. 2008; Kuller et al. 2006, 2007, 2012; Layman et al. 2009; Matsuo et al. 2010, Matvienko and Hoehns, 2009; Tanumihardjo et al 2009; Yankura et al. 2008) and after maintenance in 1 study (Kuller et al. 2006, 2007, 2012; Yankura et al. 2008). TG was also affected, with 7 studies reporting an improvement (decrease) following intervention (Acharya et al. 2009; Burke et al. 2008; Ditschuneit and Flechtner-Mors 2001; Ditschuneit et al. 1999, 2002; Flechtner-Mors et al. 2000; Jeffery et al. 2009; Kuller et al. 2006, 2007, 2012; Layman et al. 2009; Matsuo et al. 2010; Tanumihardjo et al. 2009; Yankura et al. 2008; Yatsuya et al. 2011) and 6 studies reporting an improvement (decrease) after maintenance (Ditschuneit and Flechtner-Mors 2001; Ditschuneit et al. 1999, 2002; Flechtner-Mors et al. 2000; Jeffery et al. 2009; Layman et al. 2009; Matsuo et al. 2010; McLaughlin et al. 2008; Wolfson et al. 2010; Yatsuya et al. 2011). As expected, an improvement in weight status led to an improvement in biochemical parameters, with the exception of HDL, which appeared to react variably to interventions but was consistently improved during maintenance.

Physical

Of the 24 studies that achieved successful weight loss and maintenance, 12 also measured changes in physical outcomes (Ditschuneit and Flechtner-Mors 2001; Ditschuneit et al. 1999, 2002; Flechtner-Mors et al. 2000; Foreyt et al. 1993; Itoh et al. 2001; Jeffery et al. 2009; Kuller et al. 2006, 2007, 2012; Layman et al. 2009; Matsuo et al. 2010; Matvienko and Hoehns, 2009; Morgan et al 2009, 2011; Rock et al. 2007; Tanumihardjo et al 2009; Thorpe et al. 2008; Yankura et al. 2008; Yatsuya et al. 2011). Three commonly reported physical outcomes were WC, systolic blood pressure (SBP), and diastolic blood pressure (DBP). Six studies reported decreased WC following the weight-loss phase (Foreyt et al. 1993; Jeffery et al. 2009; Kuller et al. 2006, 2007, 2012; Matsuo et al. 2010; Matvienko and Hoehns, 2009; Rock et al. 2007; Yankura et al. 2008; Yatsuya et al. 2011) and the weight-maintenance phase (Jeffery et al. 2009; Kuller et al. 2006, 2007, 2012; Matsuo et al. 2010; Matvienko and Hoehns 2009; Morgan et al. 2009, 2011; Rock et al. 2007; Yankura et al. 2008; Yatsuya et al. 2011;). SBP was lowered following weight loss in 4 studies (Ditschuneit and Flechtner-Mors

2001; Ditschuneit et al. 1999, 2002; Flechtner-Mors et al. 2000; Itoh et al. 2001; Kuller et al. 2006, 2007, 2012; Matsuo et al. 2010; Yankura et al. 2008) and after weight maintenance in 2 studies (Ditschuneit and Flechtner-Mors 2001; Ditschuneit et al. 1999, 2002; Flechtner-Mors et al. 2000; Morgan et al. 2009, 2011). DBP was lowered following weight loss in 3 studies (Itoh et al. 2001; Matsuo et al. 2010; Matvienko and Hoehns 2009) and following weight maintenance in 3 studies (Ditschuneit and Flechtner-Mors 2001; Ditschuneit et al. 1999, 2002; Flechtner-Mors et al. 2000; Matvienko and Hoehns 2009; Morgan et al. 2009, 2011). Weight loss and weight maintenance appeared to support improvement in WC, SBP, and DBP.

Other demographic factors

Sex

Of the studies with a weight-loss and weight-maintenance phase that included both men and women (Acharya et al. 2009; Burke et al. 2008; Butryn et al. 2009; Christiansen et al. 2007; Ditschuneit and Flechtner-Mors 2001; Ditschuneit et al. 1999, 2002; Flechtner-Mors et al. 2000; Foreyt et al. 1993; Gold et al. 2007; Jeffery et al. 2009; Krukowski et al. 2008; Layman et al. 2009; Leermakers et al. 1999, Matvienko and Hoehns 2009; McLaughlin et al. 2008; Rolls et al. 2005; Tanumihardjo et al 2009; Thorpe et al. 2008; Wolfson et al. 2010; Yatsuya et al. 2011), weight loss and maintenance were generally not significantly different between the groups (approximately 5%–10%). Only 1 study reported a significant difference between the sexes (Jeffery et al. 2009; Yatsuya et al. 2011) and it related to changes in a biochemical measure, HDL cholesterol. The women in this study had a significant decrease in HDL during weight loss but the men did not; however, there was no difference between the sexes in terms of HDL during the maintenance phase (Jeffery et al. 2009; Yatsuya et al. 2011).

Only 1 study enrolled males only (Morgan et al. 2009, 2011), and the weight loss and maintenance found in this study was very similar to those in studies that enrolled both males and females. Seven studies included female participants only (Cussler et al. 2008; Itoh et al. 2001; Kuller et al. 2006, 2007, 2012; Matsuo et al. 2010; Rock et al. 2007; Teixeira et al. 2010; West et al. 2011; Wing et al. 2010; Yankura et al. 2008). Again, these studies found levels of weight loss and weight maintenance similar to those found in studies with both males and females (5%–10%), with the exception of 1 study (Matsuo et al. 2010) that found ~12% lower weight after the weight-loss phase and ~9% lower weight from baseline at the end of the maintenance phase.

Of the group of studies that focused on weight maintenance only, sex was not found to be a predictor of weight maintenance. The only significant finding related to sex was that the NWCR participants following a low-CHO diet were more likely to be male (Phelan et al. 2007).

From these data, we can conclude that sex does not appear to be a driving factor in the success of weight loss or maintenance.

Country of origin

The majority of those studies with successful weight loss and weight maintenance were from the United States (Acharya et al. 2009; Burke et al. 2008; Butryn et al. 2009; Cussler et al. 2008; Foreyt et al. 1993; Gold et al. 2007; Jeffery et al. 2009; Krukowski et al. 2008; Kuller et al. 2006, 2007, 2012; Layman et al. 2009; Leermakers et al. 1999, Matvienko and Hoehns 2009; McLaughlin et al. 2008; Rock et al. 2007; Rolls et al. 2005; Tanumihardjo et al 2009; Thorpe et al. 2008; West et al. 2011; Wing et al. 2010; Yankura et al. 2008; Yatsuya et al. 2011). However, of the 4 studies that had a more significant weight loss, 2 were not from the United States (they were from Denmark and Japan). There did not appear to be any trends for differences in weight loss or weight maintenance across countries.

Discussion

This review investigated the weight-loss and weight-maintenance literature in adults over the past 25 years, the time period when overweight and obesity rates have increased worldwide. It is known that obesity is influenced by genetic, environmental, physiological, and psychosocial factors and it will not be reversed satisfactorily by changing just 1 of these domains. This review focused on individual-level influences, to determine what strategies could be implemented safely by adults to achieve clinically significant weight loss (≤5%) (Lau et al. 2007) and weight maintenance (≥1 year).

Overall, for significant weight loss of at least 5% from baseline, a sustained reduction in energy intake was necessary. Often, this was facilitated by a reduced fat intake and increased fibre in the diet. In the majority of studies, a variety of other diet strategies was used to support the diet intervention goals, for example, to maintain diet quality or to prevent hunger or improve satiety. Furthermore, some form of PA and BT was a critical component of the interventions in the studies that demonstrated successful weight loss. The importance of these 3 strategies (sustained energy reduction, increased PA, and BT) is underscored by the fact that all of the 5 studies that had the highest level of successful weight loss and weight maintenance (8%–10% weight change) incorporated all 3 strategies into their study protocols (Acharya et al. 2009; Burke et al. 2008; Layman et al. 2009; Matsuo et al. 2010; Rolls et al. 2005; Thorpe et al. 2008). All had a prescribed calorie level, included recommendations for increased PA, and used a method of self-monitoring, although the monitoring was not necessarily daily (Acharya et al. 2009; Burke et al. 2008; Layman et al. 2009; Matsuo et al. 2010; Rolls et al. 2005; Thorpe et al. 2008). Some of these most successful studies used daily food and activity diaries (Acharya et al. 2009; Burke et al. 2008; Matsuo et al. 2010), whereas others used 3-day food records completed on a weekly or monthly basis (Layman et al. 2009; Rolls et al. 2005; Thorpe et al. 2008).

In addition, upon examination of those studies that were not successful in inducing at least 5% weight loss and maintenance, many were found to be lacking at least 1 of the 3 strategies identified. Many of the unsuccessful studies did not report a specific caloric target for participants and employed a less strict approach to dietary changes, including focusing on healthy eating instead of diet restriction (Blissmer et al. 2006; Fitzgibbon et al. 2008, 2010; Laitinen et al. 2010; Ley et al. 2004; Nakade et al. 2012; Riebe et al. 2003, 2005; Stolley et al. 2009). In addition, a lack of a reported PA intervention (Karlsson et al. 1994; Ley et al. 2004; Westenhoefer et al. 2004) or a lack of monitoring whether participants were meeting PA recommendations (de las Fuentes et al. 2009) was also noted among studies that observed weight loss and maintenance of <5%. A lack of reported regular participant self-monitoring (de las Feuntes et al. 2009; Keranen et al. 2009, 2011), or self-monitoring that was encouraged but not required, (Waleekhachonloet et al. 2007) was also noted among the unsuccessful studies. There were other reasons noted as to why some studies may not have been successful in inducing weight loss and maintenance of at least 5%, including difficulty with high dropout rates (Blissmer et al. 2006; Keranen et al. 2009, 2011; Riebe et al. 2003, 2005); poor participant compliance with lifestyle recommendations (Cleanthous et al. 2007; Clifton et al. 2008; Karlsson et al. 1994); a high proportion of participants who were already meeting lifestyle recommendations prior to the study (Absetz et al. 2007, 2009); and identification of mental health issues, including high levels of binge eating behaviours among participants (Goodrick et al. 1998; Keranen et al. 2009, 2011). However, it does appear that the inclusion of a specific calorie goal with decreased dietary fat intake to help meet the calorie goal, increased PA, and self-monitoring behaviours are 3 key strategies

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that may help lead to successful weight loss and weight maintenance in individuals.

A recent systematic review of weight-loss and weight-maintenance studies in men only also found that the effectiveness of the weight-loss trial improved if there was a prescribed energy restriction (Young et al. 2012). An analysis of the Canadian Community Health Survey diet composition data found that increased total kilocalories consumed increased the odds of obesity in both men and women, and that increased fibre intake decreased the odds of obesity (men only) (Langlois et al. 2009). Our results are also in agreement with previous recommendations from the Canadian clinical practice guidelines for the management and prevention of obesity (Lau et al. 2007), which suggest a combination of a high-quality energy-reduced diet, PA, and BT to promote weight loss.

It is often stated that weight maintenance requires a different set of strategies to "keep the weight off"; however, we did not observe this from the studies in this review. It appeared that what facilitated the initial weight loss had to be sustained over the long term to support weight maintenance. Indeed, in the 5 studies that had the highest level of weight-loss maintenance (8%–10%), 2 did not have any participant contact during the maintenance phase (Acharya et al. 2009; Burke et al. 2008; Matsuo et al. 2010), whereas the other 3 maintained the same protocol from the weight-loss phase during the weight-maintenance phase (Layman et al. 2009; Rolls et al. 2005; Thorpe et al. 2008). The benefits of energy restriction, fat restriction, and regular PA were reconfirmed. One observation was that BT appeared to be emphasized more strongly in the weight-maintenance studies, with self-monitoring and cognitive strategies reported frequently. This represents a critical factor in long-term behaviour change.

This review does have limitations. First, although minimum amounts of time for the intervention (3 months) and maintenance (12 months from baseline) were set as part of the inclusion criteria, maximal amounts of time were not specified. As a result, the studies represented a variety of time periods for intervention and maintenance. Although there was no apparent difference in success rates for weight loss and maintenance from the studies with a longer follow-up that were assessed in this review, it is well known that the longer the time period, the more difficult it is to maintain weight loss. Also, the review was limited to English language-only research because of time and resource constraints for translation from other languages. The age of the participants was also not considered in this review, except for the inclusion criteria of 18–65 years. It is possible that studies with participants at the lower end of the age range (i.e., 20–30 years) may have achieved different results in terms of successful weight loss and maintenance than did studies with participants at the higher end of the age range (i.e., 55–65 years). In addition, some studies focused specifically on pre- or postmenopausal women. Although the changes in hormone levels that occur during menopause may affect the success of weight loss and maintenance, the menopausal state of women was not accounted for in this review.

Conclusion

The quest for the "quick fix", the "magic pill", or some "special nutrient combination" drives the public and researchers to find something new or different that will facilitate weight loss. However, the concept of a negative energy balance for weight loss cannot be disputed. Under controlled conditions, lower energy intake facilitates weight loss, but the circumstances often related to a lower energy intake (hunger, fatigue, motivation, sustainability, planning, and finances) make this difficult.

Previous knowledge regarding weight loss and weight maintenance in the adult population was confirmed by this review. A reduction in energy and fat intake, as well as increased dietary fibre, regular PA (at least 150 min aerobic activity·week^{-1}), and self-monitoring and other behavioural techniques, are recommended for healthy weight loss and long-term weight maintenance in adults. A comprehensive approach, including all 3 of these components, is warranted and is supported by the research evidence.

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Appendix A

MEDLINE search

1. Weight Loss/
2. ((lose or loss or lost or reduction or reduce* or decrease*) adj3 (weight or bmi or body mass index)).tw.
3. ((maintain* or maintenance) adj3 (weight or body mass or bmi)).tw.
4. weight-maintenance.tw.
5. (prevent* adj3 (weight adj3 (gain* or increase*))).tw.
6. (weight regain or (weight adj5 rebound)).tw.
7. (1 or 2) and (3 or 4 or 5 or 6)
8. exp Diet Therapy/
9. (atkins or weight watchers or meal replacement* or jenny craig* or slimfast or slim fast or vlcd or mediterranean or south beach or "eat right for your type").tw.
10. (diet or diets or dieting or dieters or diet-induced or dietary intervention* or (calori* adj2 restrict*)).tw.
11. lifestyle.ti.
12. 8 or 9 or 10 or 11
13. 7 and 12
14. limit 13 to english language
15. limit 14 to yr = "1986–2012"
16. limit 15 to animals
17. (rat or rats or mouse or mice or murine).ti.
18. exp *Pregnancy/
19. pregnan*.ti.
20. limit 15 to "all child (0 to 18 years)"
21. ((child* or adolescent* or teen* or juvenile or school*) not adult*).ti.
22. 15 not (16 or 17 or 18 or 19 or 20 or 21)
23. randomized controlled trial.pt.
24. clinical trial.pt.
25. randomi?ed.ti,ab.
26. placebo.ti,ab.
27. dt.fs.
28. randomly.ti,ab.
29. trial.ti,ab.
30. groups.ti,ab.
31. or/23–30
32. 22 and 31
33. 22 not 32

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